

Article

3-30-300 Benchmark: An Evaluation of Tree Visibility, Canopy Cover, and Green Space Access in Nagpur, India

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Abstract: Urban green spaces (UGSs) are vital in enhancing environmental quality, social well-being, and climate resilience, yet their distribution and accessibility remain uneven in many rapidly urbanizing cities. The 3–30–300 rule offers a structured guideline with which to assess urban greenness, emphasizing tree visibility, canopy cover, and green space proximity. However, its applicability in dense and resource-constrained urban environments has not been sufficiently examined. This study evaluates the feasibility of the 3–30–300 rule in Nagpur, India, using survey-based visibility assessments, NDVI-derived vegetation cover analysis, and QGIS-based accessibility evaluation. The study also introduces the Urban Greenness Exposure Index (UGEI), a composite metric that refines greenness assessment by capturing intra-zone variations beyond broad classifications. The findings reveal significant variations in urban greenness exposure across Nagpur’s ten municipal zones. Low-greenness zones report the highest tree visibility deprivation (below two trees), limited canopy cover (~7%), and restricted green space access (over 80% of residents lacking access within 300 m). The correlation analysis shows that higher canopy cover does not necessarily correspond to better visibility or accessibility, highlighting the need for integrated planning strategies. The study concludes that applying the 3–30–300 rule in high-density Indian cities requires localized adaptations, such as incentivizing street tree planting, integrating vertical greenery, and repurposing vacant lots for public parks. The UGEI framework offers a practical tool for identifying priority zones and guiding equitable greening interventions, based on insights drawn from the Nagpur case study.

Keywords: 3–30–300 rule; SDG11; urban environment; Global South; Indian cities; urban greening



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1. Introduction

Worldwide, the percentage of people living in urban areas is projected to reach nearly 70% by 2050 [1], with cities in India and China at the forefront of this urban shift [2]. Rapid urbanization, especially in the Global South, increases pressure on urban environments, resulting in the fragmentation and decline of urban green spaces (UGSs) [3]. This trend is particularly evident in Asian cities [3,4], but also observed in Europe and North America [5]. Case studies from cities such as Hanoi, Vietnam [6], Mashhad, Iran [7], Dehradun, India [8], and Karachi, Pakistan [9], show the significant degradation of green cover. Additionally, inner-city areas in places like Hong Kong, China [10], and Dhaka, Bangladesh [11], have witnessed rapid declines in green spaces due to dense urban development.

UGSs are increasingly recognized as essential for promoting public health and well-being benefits [12–14], offering ecosystem services such as air purification, heat regulation, and climate mitigation [4,15–18]. Beyond their ecological benefits, UGSs support biodiversity, enhance aesthetic and cultural value, and contribute to urban livability [16,19–21]. These contributions are acknowledged in global policy frameworks such as the United Nations Sustainable Development Goal 11, notably Target 11.7, which emphasizes inclusive access to safe, green public spaces by 2030.

Despite these benefits, green space provision remains unequal and insufficient in many rapidly urbanizing regions. Challenges include the competing demands of grey infrastructure, spatial constraints, and social inequalities [4,5,21–23]. While several greening standards exist, most focus on individual parameters such as per capita green space or distance, without capturing the multi-dimensional nature of urban green exposure [23–25]. To address this gap, the 3–30–300 rule was introduced as a holistic framework that captures the visibility, availability, and accessibility of greenery. However, its practical application in resource-constrained, high-density urban contexts—particularly in the Global South—remains underexplored.

This study aims to evaluate the applicability of the 3–30–300 rule in the context of a high-density, resource-constrained Indian city, with the broader goal of supporting equitable and data-driven urban greening strategies. To achieve this, the study pursues the following objectives:

1. To assess how the three components of the 3–30–300 rule—tree visibility from home, neighborhood-level canopy cover, and proximity to a green space within 300 m—can be measured and analyzed in the urban setting of Nagpur, India.
2. To examine the interrelationships between these three components.
3. To develop the Urban Greenness Exposure Index (UGEI) as a composite metric that identifies intra-zone disparities in greenness exposure and supports targeted intervention beyond broad greenness classifications.

2. Literature Review and Conceptual Framework

2.1. The 3–30–300 Rule as a Framework

Urban planners and policymakers increasingly seek evidence-based frameworks to enhance the quality, availability, and accessibility of UGSs. Various organizations such as the WHO [26], the European Union (EU), the Greater London Authority [27], and researchers working on UGS benchmarking have developed various standards and recommendations [21,26–31]. However, existing measures often focus on individual aspects, such as accessibility or availability, rather than providing a comprehensive approach that considers visible, living, accessible, and usable green spaces while recognizing the critical role of trees and canopy cover [32,33].

To address these limitations, Konijnendijk et al. (2021) introduced the 3–30–300 rule, a holistic guideline designed to assess urban greenness through three integrated criteria: (1) Every resident should be able to see at least three trees from their home (visibility); (2) Their neighborhood should have at least 30% tree canopy cover (density); (3) A public green space should be within 300 m of every home (accessibility) [33]. This rule is praised for its simplicity and adaptability, offering measurable, people-centered targets. Nevertheless, its successful implementation demands local contextualization, especially in resource-constrained, high-density urban environments, where physical, socioeconomic, and institutional barriers limit equitable green space access.

2.2. Empirical Applications and Gaps in Global and Indian Contexts

Initial applications of the 3–30–300 rule have shown mixed outcomes. A study in Xiamen City, China, found that only 3.55% of residents fully met all three criteria. However, those living in neighborhoods with at least 30% vegetation coverage reported improved physical and social health outcomes [14]. Similarly, a study across five Polish municipalities identified structural challenges in fulfilling the visibility component due to their dense urban form and built infrastructure [34].

Despite these insights, a paucity of research on the implementation and effects of the 3–30–300 rule in the Global South remains. India, for example, presents several contextual challenges regarding greening policies. Urban expansion has intensified land-use competition, driven grey infrastructure prioritization, and exacerbated spatial disparities in UGS distribution [35–38]. Although the country has adopted numerous urban greening frameworks—including the Urban Greening Guidelines, the National Mission for a Green India, the National Clean Air Programme (NCAP), and the Climate Smart Cities Assessment Framework (CSCAF)—implementation remains weak due to fragmented governance, limited inter-agency coordination, and data accessibility issues [39,40].

Furthermore, the per capita availability of green space remains alarmingly low in most Indian cities. For instance, cities like Jaipur (2.3 m²), Pune (1.4 m²), Surat (2.7 m²), and Nagpur (3.65 m²) have minimal green cover, while others like Ludhiana and Kanpur report even lower figures [36,39,41–43]. The World Health Organization (WHO) recommends a minimum of 0.5–1 hectare of public green space within 300 m of urban residents' homes [27]; yet, most Indian cities fall significantly short of this benchmark [39]. The situation is particularly concerning in high-density cities like Chennai (0.81 m²) and Pune (1.4 m²), where green space remains meager; in contrast, planned cities such as Gandhinagar (160 m²) and Chandigarh (55 m²) provide significantly higher green space per capita [44]. These disparities reinforce the relevance of the 3–30–300 rule as a practical and measurable tool, especially in high-density contexts like Nagpur, where spatial inequalities are most pronounced.

3. Materials and Methods

This study adopts a case study approach, focusing on Nagpur, India, as a representative high-density urban environment in the Global South. The case study method enables an in-depth examination of localized green space dynamics using multiple data collection techniques. These include a structured face-to-face questionnaire survey, remote sensing analysis for canopy cover estimation, and GIS-based spatial analysis for green space accessibility. This mixed-methods strategy ensures the triangulation and robustness of findings.

3.1. Study Area

Nagpur (Figure 1), a tier II city, spans approximately 218 square kilometers and has a population of 2.4 million [45]. The city is divided into ten administrative zones managed by the Nagpur Municipal Corporation (NMC). Known for its greenery, Nagpur has seen significant reductions in its natural green spaces, reflecting urban landscape changes [46,47]. The city's green and blue infrastructure includes lakes, river basins, urban forests, green spaces connected to institutions, parks and gardens, playgrounds, and plantations along roadways. However, disparities exist in the distribution and availability of public UGSs [37]. The city-wide per capita public UGS is 3.65 square meters, below the WHO standards, with significant variation among the ten zones [30]. There are also notable differences in UGS proximity and service area coverage within these zones [30,38]. For this study, Nagpur was categorized into three groups based on UGS availability using predictive modeling, as

derived from previous studies [34] and validated by more recent research [39]. No official data exist at this level of detail, as shown in Figure 2. UGS availability was categorized as high, moderate, and low (Figure 2). This categorization was based on the per capita UGS availability in each administrative zone, as detailed in a previous study by Lahoti et al. [30].

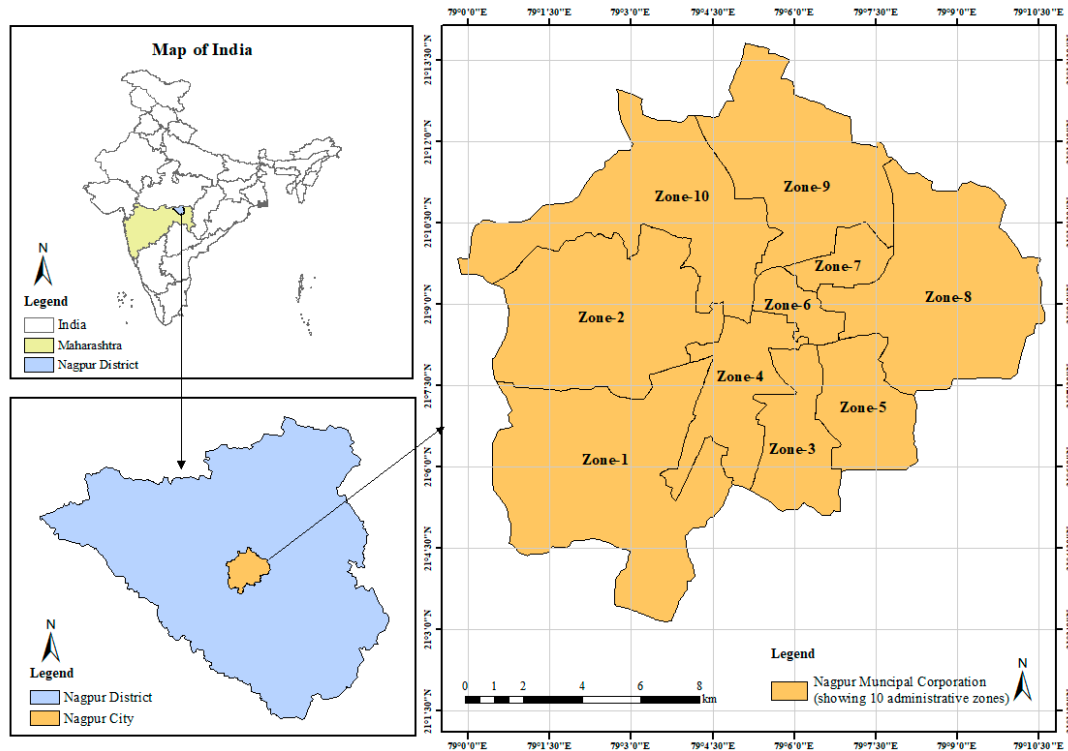


Figure 1. Map of the study area, Nagpur, Maharashtra, India.

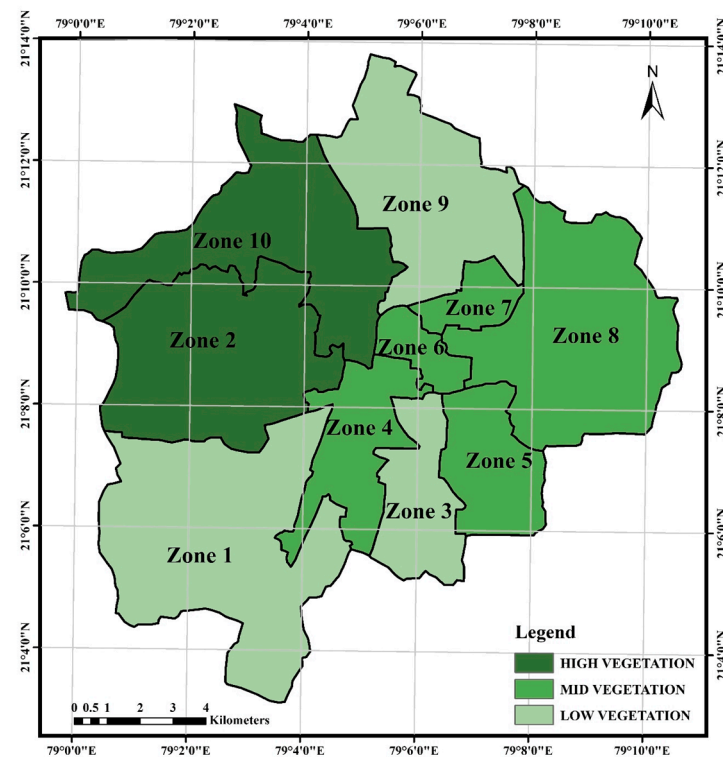


Figure 2. Greenness levels across the 10 Zones of the city, used as the baseline variable for 3–30–300 component analysis.

3.2. Evaluation of Urban Green Space (UGS) Exposure

This study uses a mixed-methods approach to evaluate UGS exposure, incorporating qualitative and quantitative assessments based on the 3–30–300 rule (as in Table 1). Survey data, remote sensing, and spatial analysis were used to measure the three components: tree visibility from home, tree canopy cover, and the accessibility of public UGSs. To ensure consistency across these components, the city was divided into three Greenness Levels—High, Mid, and Low—based on the UGS availability per capita, as shown in Figure 2 [30]. Unlike previous studies that rely solely on UGS per capita as an indicator of green exposure, this research takes a more holistic approach by analyzing how visibility, canopy cover, and accessibility interact.

Table 1. Data sources, analysis methods, and UGS typology considered for the 3–30–300 components.

Component	Data Type	UGS Considered	Analysis Method	Data Source
Visibility of Trees from Home (3-Component)	Face-to-face questionnaire survey data	No direct UGS type considered (focuses on individual tree visibility)	Chi-square test for variability by greenness level	Questionnaire survey data (author)
Canopy Cover Assessment (30-Component)	NDVI and FVC based remote sensing data	Overall vegetation cover (not limited to public UGSs)	ANOVA test for differences across greenness levels	Cloud-free Landsat 9 satellite imagery (acquired on 5 May 2024 from USGS Earth Explorer)
Accessibility to Green Spaces (300-Component)	QGIS-based Euclidean distance buffer analysis (QGIS 3.4)	Only publicly accessible UGSs	Chi-square test for accessibility disparities	Thematic Map * [37]

While prior classifications based on the UGS per capita indicate disparities in urban greenery distribution, this study examines whether these differences manifest uniformly across all three components. The correlation analysis investigates mismatches, such as cases where tree visibility is high despite low UGS accessibility, suggesting a strong presence of street trees or private greenery that does not provide public access. Additionally, it explores whether high canopy cover translates into better accessibility or visibility, or if trees are predominantly concentrated in institutional or restricted areas. This analysis contributes to understanding whether the 3–30–300 framework effectively captures urban greening in this setting or requires adaptation for high-density cities in the Global South. This multi-dimensional approach allows for a comparative assessment of the alignment and divergence among these components.

For data collection, we conducted a face-to-face questionnaire survey with urban dwellers using Google Forms. The digital questionnaire collected information on the frequency with which respondents visited UGSs, their preferred activities, the visibility of trees from their window, and their access to UGS. Additionally, demographic details such as age, gender, household income, and educational background were recorded. However, for the tree visibility (3-component) analysis, we specifically relied on a single question related to the number of trees visible from the respondent’s window.

To ensure diversity and avoid the spatial clustering of responses, respondents were selected such that no two individuals were interviewed from the same street, minimizing redundancies and enhancing spatial representativeness. Furthermore, interviews were conducted in person at respondents’ homes, allowing surveyors to verify responses directly and reduce potential misreporting bias. The survey was conducted in January 2024 by four trained research assistants using an electronic form to enhance efficiency. The target population for the survey was individuals aged 18 and above. Verbal consent was obtained from

the participants before initiating the survey, as no personal information was collected; thus, written consent was not required. Ethical approval was not sought since the questionnaire was anonymous, and the author's institution does not have an ethical board. However, internal approval was obtained from the project team members.

3.2.1. Visibility of Trees from Home (3-Component)

A qualitative assessment was conducted to evaluate the visibility of green elements from participants' homes. This was measured through a structured survey question: "How many trees can be seen outside your window in your house?", with response options 0, 1, 2, 3, 3+, and others. For the analysis, responses were categorized into groups less than 2, 3, 3+, and 10+, based on observed patterns in the data. The visibility was further stratified based on the level of surrounding greenness—High, Mid, and Low—to examine variations in tree visibility across different urban settings. The visibility data were further stratified by the surrounding greenness level (High, Mid, and Low) and analyzed using descriptive statistics, visualization, and a chi-square test to determine whether tree visibility significantly varied according to the greenness level.

3.2.2. Canopy Cover Assessment (30-Component)

Following the 3–30–300 rule, achieving 30% tree canopy cover is often challenging in dense urban areas. Therefore, vegetation coverage can serve as a proxy for tree canopy in such contexts [33]. Urban tree canopy cover is defined as the percentage of area covered by tree leaves, branches, and stems when viewed from above [14,32]. We used the Normalized Difference Vegetation Index (NDVI) and Fractional Vegetation Cover (FVC) as a substitute for direct tree canopy cover, following previous studies [14,48,49]. Cloud-free Landsat 9 satellite imagery (acquired on 4 October 2024) with a 30 m resolution, WRS Path 14, WRS Row 045 and cloud coverage value of 0.62 was obtained from USGS Earth Explorer. The selection of this time frame was based on seasonal vegetation dynamics, as post-monsoon vegetation is at its peak, ensuring a clear distinction between tree cover and other land types. The images were processed in ArcGIS 10.8, to remove negative pixels caused by water bodies and atmospheric attenuation [8]. The NDVI was calculated using the standard equation, where NIR represents the Near-Infrared band, and Red represents the visible red band of the satellite imagery. The NDVI values range from −1 to +1, with positive values indicating vegetated areas and negative values representing non-vegetated surfaces [50].

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

To further refine the assessment, Fractional Vegetation Cover (FVC) was computed using NDVI values. FVC provides a more accurate representation of vegetation density by differentiating between vegetation and bare land areas. It was calculated using the following equation:

$$FVC = \frac{(NDVI - NDVI_{soil})}{(NDVI_{veg} + NDVI_{soil})}$$

NDVI_{veg} represents the NDVI value of fully vegetated areas, and NDVI_{soil} represents the NDVI of bare soil or non-vegetated areas. Following Gutman and Ignatov [51], NDVI_{soil} is defined as the NDVI value corresponding to the cumulative 5% ratio, while NDVI_{veg} corresponds to the 95% cumulative ratio [51]. NDVI and FVC analyses were conducted at city and zone-specific levels to assess the vegetation distribution. Zones were categorized into High, Mid, and Low vegetation levels based on compliance with the 30% vegetation cover threshold. A one-way ANOVA test was performed to determine whether canopy cover significantly varied across these classifications.

3.2.3. Accessibility to Green Spaces (300 Component)

The 300 m accessibility criterion was assessed using QGIS-based spatial analysis. While the NDVI is commonly used to characterize vegetation, it does not account for UGS typologies based on ownership and accessibility [30,35]. To address this limitation, thematic maps were used to identify publicly accessible UGSs [30]. The typology included four recreational classes—parks and gardens, playgrounds, lakes, and forests—ensuring a focus on publicly accessible green spaces with recreational functions.

For accessibility analysis, Euclidean distance was applied to classify UGSs as accessible (≤ 300 m) or inaccessible (> 300 m). A 300 m buffer was created around each UGS larger than 1 hectare using QGIS tools. The population within this buffer was assumed to have access to UGSs, while those outside were categorized as without access. The accessibility data were further stratified by greenness level (High, Mid, Low), and statistical analysis was conducted to assess disparities.

3.3. Correlation Analysis of 3–30–300 Components and Urban Greenness Exposure Index (UGEI)

A Pearson correlation analysis was conducted to explore the relationships between tree visibility (3-component), vegetation cover (30-component), and UGS accessibility (300-component). While each component provides valuable insights individually, their combined analysis helps uncover potential mismatches and spatial inequities. A correlation matrix and heatmap visualization illustrated the strength, direction, and mismatches of the three components.

To further refine the assessment, we developed the UGEI as a composite metric at the zone level. Principal Component Analysis (PCA) was applied to integrate the three components—tree visibility, canopy cover (via NDVI/FVC), and accessibility—into a single index. The PCA approach was chosen due to its ability to reduce dimensionality while preserving variance across correlated variables. Each component was normalized prior to PCA to ensure comparability. The first principal component (PC1), which accounted for the highest variance, was used to derive UGEI scores for each zone. Thus, UGEI reflects the cumulative influence of visibility, vegetation density, and accessibility, offering a nuanced, data-driven metric for identifying intra-zone disparities.

4. Results

4.1. Analysis of the 3–30–300 Components

The results indicate significant differences in tree visibility, canopy cover, and accessibility to UGSs across the predefined greenness levels (High, Mid, and Low). These findings provide insights into how tree exposure varies spatially and whether the 3–30–300 framework effectively captures urban greening realities in the study area.

4.1.1. Tree Visibility (3-Component)

The analysis revealed a significant relationship between the visibility of trees from homes and the surrounding greenness levels ($\chi^2 = 18.87$, $p = 0.0044$). As shown in Figure 3, the majority of respondents in mid- and high-greenness areas (over 70%) reported seeing at least three trees from their windows, whereas low-greenness areas had the highest proportion of respondents in the ‘below two trees’ category (around 25%). Additionally, the percentage of respondents reporting visibility of 10+ trees was notably lower in low-greenness areas compared to those in mid- and high-greenness areas. The chi-square test confirms that tree visibility is not randomly distributed but varies systematically with urban greenness, highlighting potential inequities in tree cover distribution.

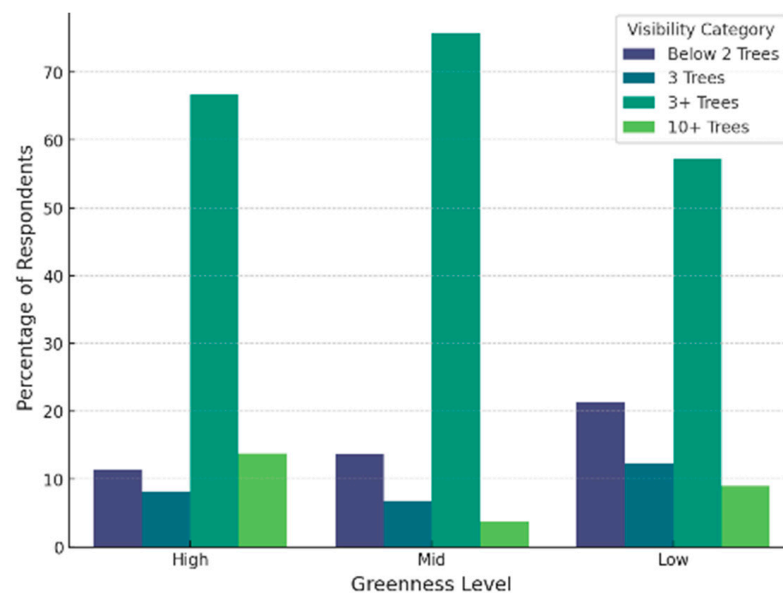


Figure 3. Tree visibility in high, mid, and low-greenness-level zones of the city—3 tree component.

4.1.2. Canopy Cover Gaps (30-Component)

The ANOVA test confirmed a statistically significant difference in canopy cover across greenness levels ($F = 4.75$, $p = 0.0498$). High-greenness areas had the greatest canopy cover (~26%), followed by mid-greenness areas (~13%) and low-greenness areas (~7%). The bar chart (Figure 4a) illustrates this pattern, confirming a declining trend in canopy cover from high to low-greenness zones.

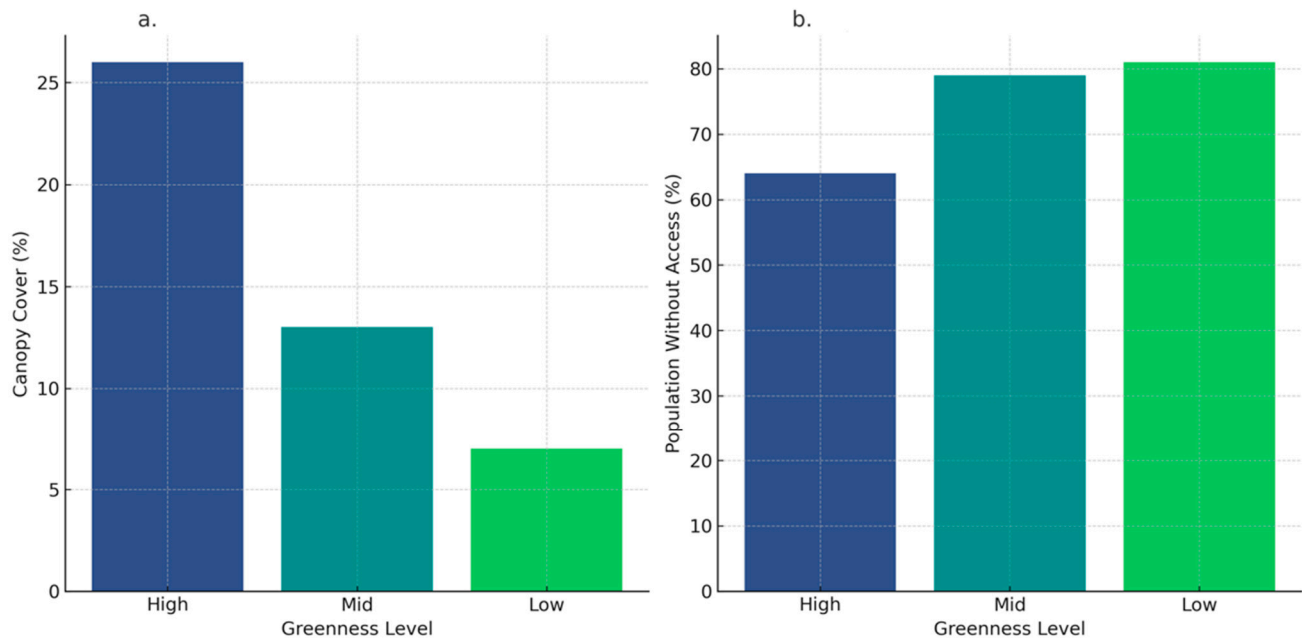


Figure 4. (a) Average canopy cover in high, mid, and low-greenness-level zones of the city—30 component. (b) Proportion of population without access to UGS—300 component.

Despite this overall trend, notable intra-category variations were observed. Certain mid-greenness zones demonstrated relatively high vegetation cover but lower-than-expected tree visibility. This indicates that greenery may be concentrated in non-residential areas, such as institutional or privately managed spaces. Similarly, some low-greenness zones exhibited minimal vegetation, reinforcing the need for targeted urban greening

efforts in these areas. Citywide, the combined NDVI and FVC assessments indicate an overall vegetation coverage of approximately 15.9% (Figure 5), falling significantly below the 30% threshold set by the 3–30–300 rule. While high-greenness zones approached this benchmark, the mid- and low-greenness zones remained well below.

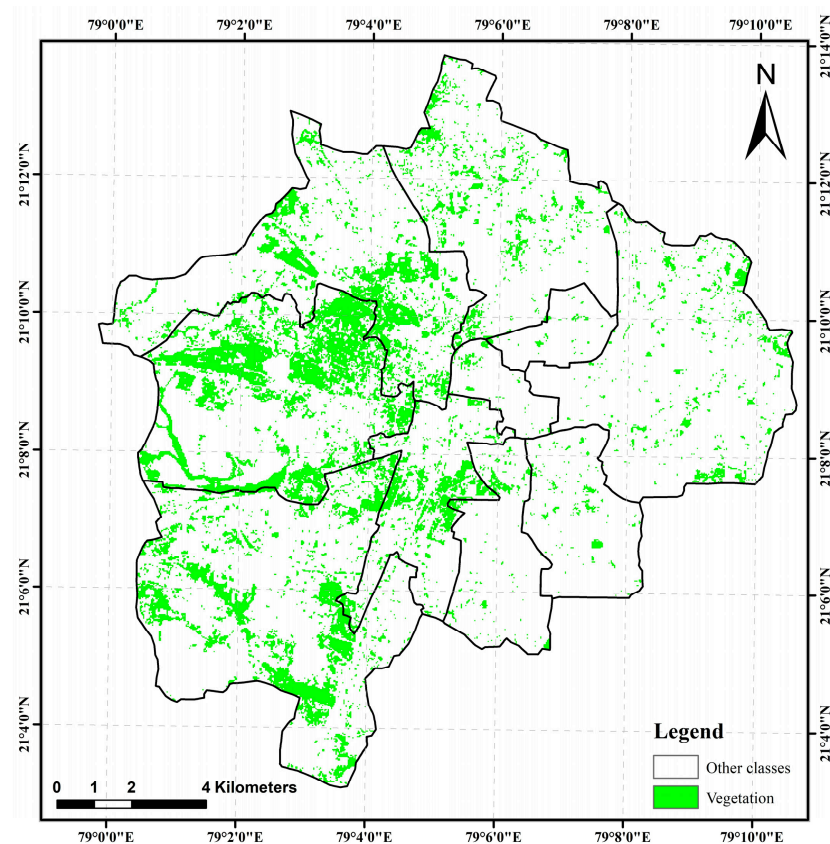


Figure 5. Map showing vegetation cover in high, mid, and low-greenness-level zones of the city—30% canopy cover component.

4.1.3. Accessibility to UGSs (300-Component)

The accessibility analysis revealed significant disparities in access to UGSs across greenness levels ($\chi^2 = 8792.52$, $p < 0.0001$). The proportion of residents without UGS access increased as greenness levels declined, with 64% in high-greenness areas, 79% in mid-greenness areas, and 81% in low-greenness areas. The bar chart (Figure 4b) illustrates these disparities, highlighting the challenges associated with the equitable distribution of public UGS (shown in Figure 6).

The chi-square test confirms that UGS access is not randomly distributed but significantly associated with surrounding greenness levels, reinforcing the need for targeted urban greening interventions. Despite the expected pattern of declining accessibility with decreasing greenness levels, there were notable inconsistencies. Some mid-greenness zones exhibited lower accessibility than anticipated based on their canopy cover, suggesting that while tree cover exists, it does not necessarily translate into publicly accessible UGS. Additionally, in certain low-greenness zones, accessibility rates were particularly poor. These results indicate that tree visibility and canopy cover do not necessarily correspond to physical access to UGSs, underscoring the importance of considering multiple dimensions of green exposure in urban planning.

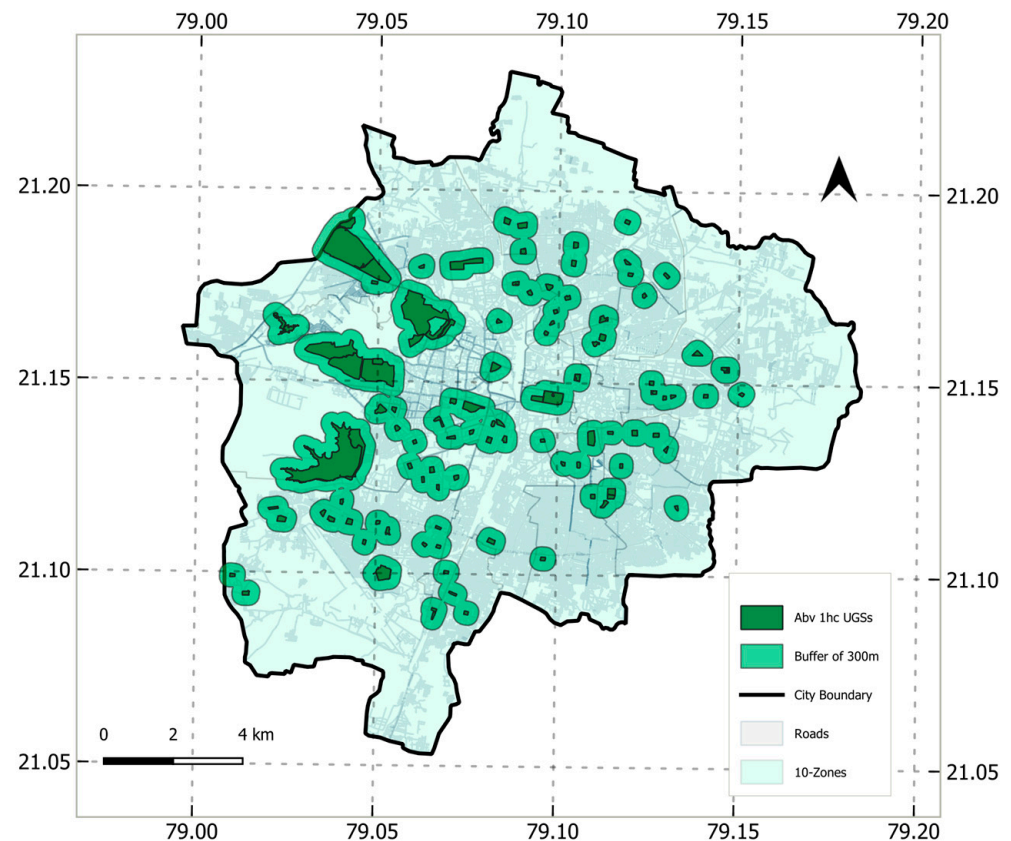


Figure 6. Map depicting 300-m buffers around UGS (≥ 1 Hectare) in QGIS, representing areas with green space access.

4.2. The Correlation Between the 3–30–300 Components

The correlation analysis revealed a strong negative relationship between canopy cover and the proportion of the population without UGS access ($r = -0.98$), indicating that higher canopy areas tend to have better public green space accessibility. A moderate positive correlation ($r = 0.32$) was observed between canopy cover and tree visibility (3+ trees seen from home), suggesting that tree density contributes to visibility but is not the sole determinant. Interestingly, tree visibility and UGS accessibility showed a weak negative correlation ($r = -0.12$), implying that visibility alone does not guarantee physical access to green spaces. The correlation heatmap (Figure 7) illustrates these relationships, highlighting that while higher canopy cover supports visibility and accessibility, urban planning strategies must address these components separately.

This finding demonstrates that while higher canopy cover supports both visibility and accessibility, these factors do not always align perfectly. The weak correlation between visibility and accessibility indicates that tree placement and land-use policies are crucial in shaping green exposure. For instance, areas with many street trees may provide visual exposure to greenery but do not necessarily enhance public access to recreational green spaces. Conversely, some areas with substantial UGS may have lower visibility due to the spatial arrangement of trees and built structures.



Figure 7. Correlation matrix of 3–30–300 components.

4.3. The Urban Greenness Exposure Index (UGEI)

While the High, Mid, and Low Greenness Levels broadly categorize urban greenery, they do not fully capture the variations within each category. To address this limitation, the UGEI was developed as a zone-level composite metric, offering a more detailed assessment of green exposure. Principal Component Analysis (PCA) was conducted and applied to three key indicators—Vegetation Cover (%), Population Without UGS Access, and Population Density—to reduce dimensionality and identify underlying patterns in urban greenness exposure. The first principal component (PC1) accounted for 80.98% of the variance, primarily capturing the trade-off between vegetation cover and accessibility constraints. The second component (PC2) explained 18.25% of the variance, reflecting differences in canopy density across zones. Since PC1 represents a comprehensive measure of greenness accessibility trade-offs, it was used to derive the UGEI. Higher values represent better greenness exposure in this normalized 0–1 scale indicator.

The results highlight substantial intra-category disparities, reinforcing that zones with the same greenness classification may still experience different levels of tree visibility, canopy cover, and accessibility (as in Table 2). Zone 2, classified as a High-Greenness zone, recorded the highest UGEI score (1.000), indicating optimal urban greenness exposure. In contrast, Zone 4, a low-greenness zone, had one of the lowest UGEI scores (0.191), confirming significant deficits in canopy cover and UGS accessibility. Additionally, some mid-greenness zones exhibited lower UGEI values than expected, suggesting that accessibility challenges persist even in areas with moderate vegetation coverage.

Figure 8 presents the UGEI distribution across all 10 zones, highlighting intra-zone disparities. The PCA scatter plot (Figure 8) further illustrates variations in urban greenness exposure, showing how zones with similar greenness levels can exhibit distinct patterns. The clustering of low-greenness zones in the lower range of PC1 indicates severe deficits, while the spread of high-greenness zones along PC1 suggests differences in tree visibility and accessibility despite higher vegetation cover. These findings emphasize the need for targeted, zone-specific greening strategies, as broad classifications may overlook critical

disparities. The UGEI provides a data-driven framework for prioritizing urban greening interventions, ensuring that policies effectively address accessibility and exposure gaps.

Table 2. Urban Greenness Exposure Index (UGEI) scores across each zone.

Zone	Greenness Level	UGEI Score (0–1)
Zone 1	Mid	0.712
Zone 2	High	1.000
Zone 3	Mid	0.645
Zone 5	Mid	0.502
Zone 4	Low	0.191
Zone 6	Low	0.228
Zone 7	Low	0.275
Zone 8	Low	0.381
Zone 9	Low	0.420
Zone 10	High	0.864

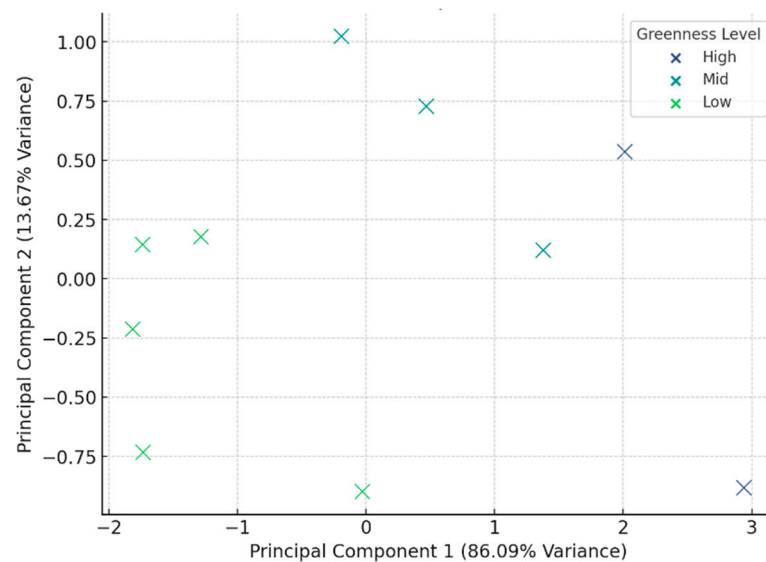


Figure 8. PCA scatter plot and UGEI distribution highlighting zone-specific variations.

5. Discussion

This study provides empirical evidence on how the rule functions in such settings, with findings emphasizing the need for a context-specific adaptation of the rule to address spatial inequalities in tree distribution, canopy cover, and green space accessibility. A correlation analysis highlighted that higher canopy cover does not always translate into improved accessibility or visibility, reinforcing the need for integrated urban planning that balances greening efforts with equitable distribution. The UGEI was introduced to refine this understanding, offering a granular assessment beyond the broad High, Mid, and Low greenness categories. The UGEI helped identify intra-category variations, revealing zones where urban greenness exposure remains critically low and requiring targeted interventions.

To our knowledge, this is the first study to systematically evaluate the 3–30–300 rule in an Indian city, assessing its feasibility, effectiveness, and necessary adaptations in a rapidly urbanizing context. While the rule has been widely applied in European and North American cities, its relevance in high-density, land-constrained environments like India remains largely unexplored. This study provides empirical insights into how the 3–30–300 rule can be adapted for cities in the Global South.

5.1. Context-Specific Adaptation of the 3–30–300 Rule

Tree visibility from homes is crucial for psychological well-being and environmental perception [32]. However, uneven tree distribution—particularly in low-income, high-density areas—limits these benefits. Our findings show that low-greenness zones had the highest proportion of respondents reporting little to no tree visibility. This highlights the need for targeted tree-planting initiatives, particularly in built-up urban areas with scarce vegetation [4]. Similar disparities in tree distribution have been reported in other Global South cities such as Dhaka, Chennai, and Pune, where rapid urbanization, socio-economic inequalities, and compact urban forms constrain equitable green space provision [35,36]. Our findings reinforce these patterns, confirming that the spatial inequalities in tree visibility and accessibility observed in Nagpur reflect broader systemic challenges faced by many high-density developing cities. Incentivizing residential tree planting, integrating greenery into private developments, and expanding street tree programs can help enhance visibility, particularly in underserved neighborhoods.

Interestingly, some mid-greenness areas exhibited higher-than-expected visibility levels, indicating that factors beyond public UGS availability influence tree exposure. Street trees, private gardens, and informal green spaces likely contribute to visibility in these areas, despite lower per capita UGS availability. Conversely, certain low-greenness zones showed moderate tree visibility despite poor overall UGS access, likely due to institutional or restricted-access green spaces. These findings emphasize that tree visibility alone does not necessarily equate to accessibility, as residents may see greenery without having direct access to public UGSs.

Achieving 30% canopy cover is particularly challenging in compact cities where land availability is limited. Urban canopy cover is strongly linked to socioeconomic disparities, with lower-income neighborhoods often having less vegetation [52]. While global studies suggest that a 30% vegetation cover supports physical and social health [53,54], the spatial distribution and vegetation type must also be considered [55]. Our findings confirm these challenges, with high-greenness zones maintaining the highest canopy density (~26%) and low-greenness zones averaging only ~7%, reinforcing that a uniform 30% target may not be feasible across all urban areas. Instead, alternative greening solutions, such as pocket parks, rooftop greenery, and green infrastructure integration, can enhance overall canopy coverage while accommodating density constraints [56].

When recognizing land-use constraints in compact Indian cities, an adjusted interpretation of the 3-tree visibility component may be warranted. Incorporating street trees, vertical gardens, and private residential greenery into visibility assessments could provide a more realistic and inclusive benchmark for high-density environments. Similarly, rather than strictly adhering to the 30% canopy cover target, cities may adopt a composite vegetation coverage approach—combining rooftop gardens, pocket parks, green facades, and informal green spaces—to fulfill the ecological and social functions intended by the rule. Such contextual adaptations ensure that greening strategies remain feasible while addressing local socio-economic and spatial realities.

Proximity to green spaces (within 300 m) is critical for physical activity, social cohesion, and mental well-being. However, mere proximity does not always translate into meaningful usage [38,57]. Over 80% of residents in low-greenness zones lacked access to a green space within 300 m, but this does not necessarily reflect actual usage patterns. Research suggests that the quality and functionality of green spaces play a more decisive role in encouraging public engagement than proximity alone [58,59]. While cities in the Global North have addressed these challenges through rooftop green spaces, vertical gardens, and the conversion of underutilized spaces [56,60], cities in the Global South require more context-specific adaptations. Strategies such as green corridors, neighborhood-scale green-

ing, and the transformation of vacant lots into community parks can improve accessibility and ensure a more equitable distribution of urban greenery, even in high-density settings.

5.2. Strengthening the 3–30–300 Rule Through UGEI

While the 3–30–300 rule provides a useful benchmark, it does not fully account for spatial inequities within broadly classified greenness categories. This study introduces the UGEI as a refined, data-driven metric to capture the zone-level variations overlooked by the broader High, Mid, and Low classifications. The analysis revealed that some mid-greenness zones exhibited lower UGEI scores than expected, suggesting that moderate canopy cover alone does not guarantee improved tree visibility or accessibility to green spaces. Similarly, low-greenness zones with slightly higher canopy cover still suffered from poor access to UGS, reinforcing that tree planting alone is insufficient without improved connectivity and equitable spatial distribution. These findings align with prior research, emphasizing that urban greening must be integrated with strategic spatial planning rather than simply achieving numerical canopy or proximity targets [4].

By incorporating UGEI into urban planning, policymakers can prioritize low-exposure zones for targeted interventions, ensuring that urban greening strategies are equitable and evidence-based. Instead of applying a one-size-fits-all approach, the UGEI framework allows cities to efficiently allocate resources, address localized disparities, and ensure that greening initiatives maximize their impact where they are most needed.

This study also advances methodological approaches for assessing urban greenness. By integrating NDVI-based canopy assessment, correlation analysis, and a composite urban greenness metric, the study enhances the applicability of the 3–30–300 rule within a data-driven, context-specific framework. These methodological refinements strengthen urban greening strategies by providing more accurate, actionable insights for planners and policymakers.

5.3. Methodological Contributions

This study advances the application of the 3–30–300 rule by integrating multiple analytical approaches to assess urban greenness exposure in an Indian city. Unlike previous studies that evaluate components of this rule in isolation, this research adopts a holistic, data-driven methodology, combining survey-based visibility assessments, NDVI and FVC-derived canopy cover analysis, GIS-based accessibility evaluations, and correlation analysis to examine the interrelationships between these components.

A key methodological adaptation was using NDVI and FVC as a proxy for tree canopy cover, addressing India's limited availability of high-resolution tree cover datasets. While NDVI has limitations in distinguishing between different vegetation types, it provides a consistent, scalable measure of overall vegetation density, aligning with prior research suggesting that 30% vegetation cover can serve as a substitute for 30% tree canopy cover in compact urban settings [33]. Future studies can refine this approach by incorporating high-resolution LiDAR data, deep learning-based street-view image analysis or machine learning to improve tree canopy estimations and validate findings across diverse urban landscapes [61].

Beyond individual components, this study introduces the UGEI as a refined, zone-level metric that captures spatial variations in greenness exposure beyond the broad High, Mid, and Low classifications. By incorporating UGEI into urban greening assessments, policymakers can prioritize intervention areas, ensuring resources are allocated to zones where greenness disparities are most pronounced rather than applying uniform citywide targets.

Furthermore, the correlation analysis challenges the assumption that higher canopy cover alone improves visibility or accessibility, underscoring the need for integrated planning strategies that emphasize spatial connectivity and the functional usability of green spaces. These methodological advancements enhance the applicability of the 3–30–300 rule in high-density, rapidly urbanizing cities. Future research should focus on the longitudinal tracking of greenness exposure, integrating behavioral data on UGS usage, and validating the UGEI framework across multiple urban contexts to support scalable and equity-focused greening strategies.

5.4. Policy Recommendations for Strengthening the 3–30–300 Rule

The findings of this study highlight the importance of adapting the 3–30–300 rule to local urban contexts, taking into account spatial constraints, land-use priorities, and socioeconomic disparities. While the rule provides a valuable framework for urban greening, its implementation necessitates strategic modifications that optimize available urban space while ensuring the equitable distribution of green spaces.

One key intervention is targeted tree-planting and canopy expansion programs in low-visibility neighborhoods where tree cover is severely lacking. Enhancing tree visibility in dense urban areas requires integrating greenery into private developments, expanding street tree planting initiatives, and encouraging community-led greening projects. Since visual exposure to greenery has been linked to improved mental health, cognitive function, and overall well-being, ensuring that all residents—regardless of their socio-economic status—have visual access to trees should be a priority in equitable urban planning.

In addition to enhancing visibility, expanding access to green spaces through innovative planning is crucial. Many cities in the Global North have addressed space constraints by leveraging underutilized urban areas, integrating rooftop gardens, and developing green corridors along transportation networks [56,60]. For high-density cities in the Global South, where large-scale park development is often unfeasible, pocket parks, linear greenways, and repurposing vacant lots for urban greenery present viable solutions. Recognizing the role of smaller-scale green infrastructure in fulfilling the 300 m accessibility criterion could enable cities to enhance urban greening despite space limitations.

A data-driven approach must also guide future urban greening policies. Integrating UGEI into municipal planning frameworks can ensure need-based, equity-driven greening interventions rather than generic city-wide tree-planting initiatives. By leveraging UGEI-based spatial assessments, policymakers can pinpoint priority zones for greening initiatives, reducing disparities and ensuring urban greening efforts are targeted where they are most needed. Embedding UGEI insights into long-term urban development strategies will enable cities to transition from ad hoc greening projects to systematic, evidence-based urban forestry policies that maximize environmental and social benefits.

5.5. Strengths and Limitations

This study is the first to evaluate the 3–30–300 rule in an Indian city, integrating multiple analytical approaches to assess UGS exposure. Incorporating correlation analysis, spatial clustering, and the UGEI extends previous applications of the rule, offering a more refined, data-driven approach to understanding disparities in urban greenness. The introduction of UGEI as a composite metric enables granular assessments beyond broad greenness classifications, capturing intra-zone variations that are often overlooked in conventional categorizations.

Despite these strengths, certain methodological limitations must be acknowledged. The 3–30–300 rule serves as a guideline rather than a rigid framework, and its interpretation may vary across studies [62]. The visibility component (3-component) remains particularly

challenging to define, as individual perceptions of visibility can be influenced by window orientation, building height, and urban morphology. Future studies could integrate GIS-based spatial modeling to complement self-reported tree visibility data, providing a more objective measure of urban green exposure.

Additionally, the NDVI was used as a proxy for tree canopy cover due to the lack of high-resolution tree cover datasets. While the NDVI is widely used for vegetation assessments, it does not differentiate between grasslands, shrubs, and tree canopies, limiting its precision in evaluating the 30% canopy cover criterion. Similar challenges have been reported in Barcelona, where the absence of high-resolution tree canopy datasets hindered the accurate application of the rule [63]. Future studies should explore the use of LiDAR data or a deep learning-based analysis of street-view imagery to improve tree canopy estimates and differentiate vegetation types more precisely.

Furthermore, this study found no direct correlation between green space proximity (300 m) and tree visibility, suggesting that mere spatial proximity does not guarantee meaningful green exposure. Prior research indicates that green space access is only relevant if visits occur [58], highlighting the need to incorporate behavioral data on green space usage, mobility patterns, and visitation rates. Additionally, this study is cross-sectional, providing a snapshot of urban greenness exposure in Nagpur at a specific point in time. Longitudinal tracking is crucial for monitoring changes over time and evaluating the impact of evolving urban greening policies and interventions. Finally, while this study focuses on Nagpur, we recognize the value of comparative studies across other Indian cities and Global South contexts to strengthen the generalizability of our findings. We recommend that future research conducts cross-city comparisons to assess the broader applicability and adaptability of the 3–30–300 rule. Despite these limitations, this study makes important contributions to urban greening and environmental equity, offering a robust framework for refining the 3–30–300 rule and enhancing its applicability across diverse urban contexts.

6. Conclusions

This study evaluates the 3–30–300 rule in an Indian city, highlighting significant disparities in tree visibility, canopy cover, and access to UGSs. While the 3–30–300 rule provides a structured benchmark, the results indicate that low-greenness zones face the most severe deprivation, with limited tree visibility, low canopy cover (~7%), and restricted green space access (80% of residents lacking a nearby UGS). Correlation analysis further demonstrates that higher canopy cover does not necessarily improve visibility or accessibility, challenging the assumption that increasing tree density alone is sufficient for enhancing exposure to urban greenness. Instead, a more integrated approach is needed, balancing spatial equity, connectivity, and the functional usability of green spaces.

To refine greenness assessments, this study introduces the UGEI, a composite metric that captures intra-zone variations beyond broad greenness classifications. UGEI offers a data-driven framework for identifying areas in greatest need of intervention, ensuring that urban greening efforts are prioritized based on localized disparities rather than uniform, citywide targets. Adapting the 3–30–300 rule to high-density cities demands innovative urban planning strategies, such as enhancing tree visibility through street tree programs and green facades, expanding accessibility via rooftop gardens, pocket parks, and green corridors, and integrating UGEI insights into municipal policies.

Furthermore, this study underscores the broader social and economic significance of urban tree canopy cover. Prior research has established that increased tree canopy contributes to improved air quality, reduced urban heat islands, and enhanced mental and physical well-being, particularly in socio-economically disadvantaged communities [53,54]. Urban greening has also been linked to broader socio-economic benefits, such as improved

community cohesion, enhanced neighborhood livability, and potential economic advantages. These benefits highlight the critical importance of incorporating greening strategies into wider urban social development agendas.

These findings align with national and international urban greening agendas, including India's Urban Greening Guidelines, the National Mission for Green India (GIM), the National Clean Air Programme (NCAP), and the Climate Smart Cities Assessment Framework (CSCAF), reinforcing the importance of data-driven urban planning. Additionally, this research contributes to global sustainability goals (SDG 11) and the Paris Agreement by advocating for nature-based solutions. While this study provides valuable insights, further research should focus on longitudinal assessments to track changes in urban green exposure, integrate behavioral data on UGS usage, and refine methodologies using high-resolution canopy cover datasets. Addressing these gaps will enable cities to develop inclusive, data-driven urban greening strategies prioritizing environmental equity, public well-being, and long-term resilience.

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