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Urban Green Spaces and Parks Contribution to Improving Livability: A Ward-Level Assessment Study of Dehradun, India

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Abstract
Urban green spaces (UGS), which support better air quality, climate regulation, recreation, and well-being, are generally recognised as essential elements of sustainable, livable cities. Dehradun's historic parks and tree cover are in danger due to the city's fast urbanisation (Uttarakhand, India). A mixed-methods, ward-level evaluation of UGS in five representative Dehradun wards is presented in this study. Green space area, accessibility, and per-capita availability were measured in each ward using field surveys, resident questionnaires, and GIS mapping. The results were compared to the national guideline of 9-12 m^2/person. The results show serious deficiencies and disparities: all five wards are significantly below the suggested 9 m^2/person, and the most crowded wards (such as Ward 22-Tilak Road, at about 0.51 m^2/person) have the least access. Field observations and questionnaire data highlight Poor Park maintenance, a lack of amenities and connectivity (particularly in Wards 18 and 22), and a strong desire for additional green spaces. Some of the main policy recommendations are creating ward-level green space plans (including GIS inventories and micro-park targets), giving underprivileged wards priority, and encouraging community stewardship. The urgent need for decentralised green infrastructure planning in Dehradun to enhance social justice, environmental health, and urban liveability is highlighted by these initial ward-scale findings.
Keywords: Urban green spaces/parks; Livability; Sustainable urban planning; Green infrastructure; Health issues; Dehradun region

Key Highlights of Research:
1. **Significant Green Space Deficit:** Dehradun's wards only offer 0.5 to 1.5 m^2 of green space per person, which is significantly less than the required 9 m^2/person.
2. **Inequitable Distribution:** The greatest deficiency of green spaces is experienced by vulnerable populations, such as low-income citizens, the elderly, and children.
3. **Impact on Health and the Environment:** Inadequate green cover is associated with increased pollution, heat, and illnesses like asthma and cancer.
4. **Governance & Planning Failures:** The development of green infrastructure is hampered by uncontrolled construction, land-use violations, and lax enforcement.

INTRODUCTION

Urban green spaces (UGS)- parks, street trees, gardens and other vegetated areas- play a critical role in enhancing city livability by improving air quality, mitigating heat, and supporting mental and physical health (Ghale et al., 2023; Wu et al., 2024). Yet, many rapidly growing Indian cities are experiencing a steep decline in green cover due to unchecked development and weak planning frameworks (Menon & Sharma, 2021; Ramaiah & Avtar, 2019). Dehradun, the capital of Uttarakhand, exemplifies this challenge. Once celebrated for its forest-lined valleys and expansive gardens, Dehradun has seen its tree cover shrink under population pressure and real estate growth. Intra-city disparities are stark: affluent wards retain private gardens and well-maintained parks, whereas dense inner-city neighborhoods suffer acute shortages of open space (Lahoti et al., 2019; Saba & Yadav, 2021; Singh, 2017).

This study addresses a recognized research gap by taking a **ward-level perspective** on UGS in a Tier-2 Indian city. By focusing on selected wards (e.g. Ward 13- D.L. Road; Ward 17- Chukhuwala; Ward 18- Indra Colony; Ward 22- Tilak Road; Ward 23- Khurbura) (Nawani & Kaur, 2021; Ramaiah & Avtar, 2019; Sathyakumar et al., 2020), our analysis reveals fine-scale patterns that citywide studies may miss.

We quantify per-capita green area, assess compliance with national UGS norms (9 m^2/person), and examine residents' access and perceptions of parks. The findings aim to inform planners and policymakers about targeted interventions, such as pocket parks and tree corridors, to restore green space and enhance Dehradun's livability equitably (Ghale et al., 2023).

Figure 1: MDDA Park in Dehradun, Uttarakhand (India)

Figure 2: Paid children's park at Gandhi Park, Dehradun

MDDA Park in Dehradun, Uttarakhand (India) exemplifies the city's remaining green space and hilly backdrop (Kaur et al., 2021; Liu & Wang, 2021). Dehradun is nestled in the Doon Valley with forested hills on its flanks, but growing built-up areas (Fig. 1) have supplanted many urban open spaces. The spatial distribution of UGS is uneven: older, high-density wards typically have only sporadic roadside trees and tiny pocket parks, whereas newer peripheral wards often incorporate larger green areas.

Rapid urbanisation has drastically altered the city's physical and ecological fabric. Between 2001 and 2021, Dehradun's population increased by over 100%, putting immense pressure on its infrastructure and green areas (Sen & Guchhait, 2021). According to the Uttarakhand Pollution Control Board, air pollution levels have more than doubled over the last 5 to 7 years, with PM2.5 levels consistently exceeding permissible limits, particularly in congested city cores like ISBT, Clock Tower, and Saharanpur Chowk. Unregulated and large-scale construction, much of it in violation of environmental and building bylaws, is further degrading the city's ecology. A 2023 survey by the Forest Survey of India (FSI) revealed that Dehradun lost over 170 hectares of tree cover between 2015 and 2022, largely due to construction activities and changes in land use. Eco-sensitive and hilly zones such as Mussoorie fringe areas, Sahastradhara, and Rajpur Road hills have seen rampant deforestation and slope cutting to accommodate real estate development.

This study critically examines the availability, accessibility, and quality of green spaces at the ward level in Dehradun. Compounding the issue, corruption and poor enforcement of planning regulations have led to unauthorized changes in land use maps, turning previously designated green areas and forests into commercial or high-density residential zones. These actions not only violate planning norms but also endanger the ecological sustainability of the region (Sen & Guchhait, 2021).

The uncontrolled expansion of Dehradun has disrupted natural drainage patterns and increased the risk of urban flooding.

LITERATURE REVIEW

Urban green spaces (UGS) are increasingly recognized globally for their multifaceted contributions to environmental sustainability and human well-being. Cities worldwide acknowledge that UGS offer vital **ecosystem services**, regulating microclimates, filtering pollutants, absorbing carbon emissions, supporting biodiversity, and mitigating urban heat islands (Ghale et al., 2023). Empirical studies have further established strong correlations between greater green space in residential environments and **improved general health outcomes**, including reduced stress levels and enhanced psychological well-being (Nazish et al., 2024; Zhang & Qian, 2024). Parks and open spaces also foster **community cohesion**, encourage **physical activity**, and provide critical **recreational opportunities**, especially in densely populated urban settings (Lahoti et al., 2019; Liu & Wang, 2021; Verma, 2016).

As international reviews point out, the **distribution of UGS benefits is often uneven**, with **socially vulnerable populations** in many global cities facing **limited access to quality green spaces** (Bressane et al., 2024; Yan et al., 2024; Zhang & Qian, 2024). This spatial inequity raises important concerns about environmental justice and inclusive urban planning. Research in cities like Berlin, Amsterdam, and Melbourne has emphasized the need for **granular, neighborhood-level analysis** to assess both the quantity and quality of green infrastructure and its accessibility (Anguelovski et al., 2022; Yan et al., 2024).

Despite these insights, **micro-scale studies mapping UGS at the ward level in smaller Indian cities remain limited**. This gap is particularly significant in Tier-2 cities like **Dehradun**, where rapid urbanisation intersects with ecological sensitivity. Our study addresses this void by presenting **ward-level data on green space provision**, using the 2011 population data as a base to assess current disparities. For example, as indicated in Table 1, wards such as **Tilak Road (~0.51 m²/person)** and **Indra Colony (~0.74 m²/person)** fall drastically below the prescribed standard, underlining the urgent need for decentralized planning and corrective policy measures (Banerji, 2024; Dhankar et al., 2024; Ghosh et al., 2023).

Air pollution levels, measured by PM2.5 and PM10, have **doubled over the past 5-7 years**, frequently breaching **National Ambient Air Quality Standards (NAAQS)** (Gemmell et al., 2023). Sound pollution levels have also exceeded safe thresholds, with residential zones often recording **70 dB or more**, against the prescribed **55 dB daytime limit** by the **Central Pollution Control Board (CPCB)** (Kansal et al., 2023).Adding to the complexity are issues of **corruption, poor enforcement**, and **manipulation of land use maps** to convert designated green or forest land into commercial zones. Eco-sensitive zones such as **Sahastradhara, Mussoorie foothills, and Rajpur Road** have been particularly affected, leading to illegal slope-cutting, deforestation, and construction in prohibited areas, direct violations of environmental and municipal bylaws.In light of these challenges, this study contributes original, ward-level insights from Dehradun and underscores the importance of localized planning for equitable green space provision (Ramaiah & Avtar, 2019; Sathyakumar et al., 2020). It emphasizes the need for governance reform, better data transparency, and a participatory approach to urban greening, especially in ecologically vulnerable cities yet undergoing rapid spatial transformation (Anguelovski et al., 2023). Multiple empirical studies (Kc, 2021; Lau et al., 2021; Seyler et al., 2023), have linked reduced exposure to greenery with a rise in chronic respiratory illnesses, cardiovascular diseases, immune disorders, and even certain types of cancer, particularly lung and skin cancer, owing to heightened pollutant exposure and lack of shade. Additionally, a growing body of evidence suggests that long-term deprivation of green spaces contributes to increased incidence of developmental disorders in children, neurodegenerative conditions in the elderly, and exacerbation of mental health disorders, including anxiety, depression, and cognitive decline.From a socio-economic perspective, this urban ecological disparity translates into structural inequity. Dehradun's lower-income neighborhoods, already constrained by limited infrastructure, experience more severe environmental burdens due to the absence of parks, tree-lined streets, and open recreational spaces. These conditions restrict opportunities for outdoor physical activity, informal social interaction, and safe play environments for children, thereby impacting social well-being, academic performance, and occupational productivity. The economic burden of healthcare for chronic illnesses disproportionately affects economically weaker sections, leading to a vicious cycle of poverty and ill-health (Ghosh et al., 2023).

Environmentally, Dehradun's transformation is equally concerning. The city, once admired for its lush landscape and salubrious climate, is now facing rapid ecological degradation. According to the Forest Survey of India (2023), over 170 hectares of urban tree cover have been lost in just seven years (2015-2022). Additionally, PM2.5 concentrations have doubled, frequently exceeding the National Ambient Air Quality Standards (NAAQS) (Dhankar et al., 2024). The lack of vegetative cover impairs air quality regulation, intensifies surface temperatures, and increases stormwater runoff, all of which compound the city's vulnerability to environmental hazards. The destruction of eco-sensitive areas such as the Mussoorie foothills, Rajpur Road slopes, and Sahastradhara basin for unregulated construction is resulting in land instability, slope failure, and significant biodiversity loss (Joshi et al., 2022).Addressing these critical issues retroactively through urban green infrastructure retrofitting requires massive capital expenditure. Land scarcity in core areas, the high cost of land acquisition, and entrenched institutional inefficiencies make such interventions economically unsustainable and logistically complex. As urban sprawl accelerates, without adequate regulatory enforcement, the city risks being locked into an unsustainable growth trajectory. Dehradun's trajectory is thus emblematic of a deeper governance crisis, where short-term

economic gains and real estate interests are prioritized over long-term ecological resilience and public health (Browning et al., 2021; Joshi, 2021).

Figure 3: Biodiversity Park, Dehradun City

Figure 4: Dehradun with Hue Traffic at the clock tower area

In this context, Dehradun stands at a precarious juncture. Once considered a green sanctuary and educational hub in Uttarakhand, the city is rapidly evolving into one of the most environmentally and socio-economically challenged urban centres in the region (Dhankar et al., 2024). If these trajectories continue unchecked, the city will face compounded risks of urban heat stress, rising disease burden, climate-induced disasters, and social exclusion. Therefore, the need for granular, ward-level data-driven planning, integrated environmental governance, and inclusive green infrastructure is more urgent than ever.

METHODOLOGY

This research adopted a mixed-methods approach combining spatial analysis with community surveys. We selected five municipal wards to represent diverse areas of Dehradun. Geographic Information System tools were employed to map and quantify existing green spaces within each ward. Satellite imagery and municipal records facilitated the estimation of total vegetated area per ward. Green space per capita was calculated by dividing the ward's green area by its resident population, and these results were subsequently compared against the established standard of 9 m^2/person.

Concurrently, primary data collection was undertaken through fieldwork. On-site field surveys meticulously documented park conditions, available facilities, and maintenance standards. A structured questionnaire was administered to 250 residents, utilizing stratified random sampling across various socioeconomic strata. The questionnaire addressed park utilization, perceived advantages of green spaces, distance to the nearest park, and recommendations for enhancements. Secondary data sources encompassed municipal green space plans, development regulations, and pertinent policy documents. The analysis integrated quantitative GIS metrics with qualitative survey responses to furnish a comprehensive depiction of Urban Green Space provision and perception within each ward.

STUDY AREA

Dehradun is a mid-sized city with an approximate population of 0.6-0.7 million residents, distributed across 60 municipal wards. It is situated in a valley delineated by the Shivalik foothills and the Rispana and Bindal Rivers. Historically, the city's climate and fertile soils have been conducive to the development of parks, orchards, and a substantial tree canopy. The advent of statehood and the subsequent influx of population have precipitated accelerated urban expansion. Over the past two decades, numerous private and governmental land parcels have been redeveloped, frequently with limited provision for open space. Municipal authorities and the Forest Department bear nominal responsibility for urban greening initiatives, but inter-agency coordination is notably deficient. The wards under consideration in this study encompass the commercial D.L. Road, the densely populated residential areas of Chukkuwala and Indra Colony, and more recent peripheral zones such as Tilak Road and Khurbura. Collectively, these wards exemplify the spectrum of land-use and development patterns observable in Dehradun.

DATA COLLECTION AND ANALYSIS

Ward boundaries and green space features were digitized using GIS. Park boundaries were delineated from satellite imagery and municipal GIS layers, while tree canopy cover was estimated using high-resolution images. These data allowed us to calculate each ward's green area and compute per-capita values. Accessibility was evaluated by mapping walking-distance buffers around parks.

Concurrently, survey data were coded and statistically summarized to derive key indicators, including residents' self-reported travel time to the nearest park, frequency of visits, satisfaction with park amenities, and perceived importance of UGS for livability. These qualitative findings were then triangulated with observational checklists from field visits.

All quantitative results were tabulated and compared, and Table 1 highlights the green space per capita in each case-study ward for clarity. Figures and maps were also generated to visualize the spatial distribution of parks and gaps.

Table 1: Ward-level green space provision in Dehradun (2011 population data). All values are far below the 9 m^2/person norm (Browning et al., 2021; Ghale et al., 2023; Kaur et al., 2021).

S. No.	Ward (Name)	Plan of the ward	Green Space (approx. m^2 per person)	Total residents /Green Area	Inferences
1	Gandhi Park Ward 20		~3.7	-6827 residents, 25,260 m^2	**Green Cover**: Dense tree cover within Gandhi Park, some roadside trees. **Public Parks**: Gandhi Park- a major green space in the city core. **Tree Density**: Relatively high within park premises. **Natural Features**: Located in dense urban area; no major natural features nearby. **Encroachment**: Low within the park, but high pressure around due to traffic and commercial activity. **Accessibility**: Good- centrally located and publicly accessible. **Ranking**: Upper tier (~top 10%) in citywide green space provision.
2	Ward 13 (D.L. Road)		~1.27	~10,200 residents, 13,000 m^2	**Green Cover**: Roadside trees, institutional lawns, and private gardens. **Public Parks**: One small park near D.L. Road market. **Tree Density**: Moderate; mainly along roads and within compounds. **Natural Features**: Near seasonal stream by Survey Chowk. **Encroachment**: Moderate due to inner-city real estate pressure. **Accessibility**: Limited and unevenly distributed. **Ranking**: Mid to lower tier (~25-30 out of 60 wards).
3	Ward 17 (Chukkuwala)		~1.36	~11,000 residents, ~15,000 m^2	**Green Cover**: Institutional compounds and private gardens. **Public Parks**: One medium-sized park near Chukkuwala temple. **Tree Density**: Moderate; along roads and within compounds. **Natural Features**: Near Bindal Rao seasonal stream.

					Encroachment: Moderate due to densification and parking. **Accessibility**: Fair; better than city average. **Ranking**: Mid-tier (top 30-40% citywide).
4	Ward 18 (Indra Colony)		~0.74	**~9,500 residents, 7,000 m²**	**Green Cover**: Small parks, roadside trees, and private gardens. **Public Parks**: None of significant size. **Tree Density**: Sparse; mostly scattered patches. **Natural Features**: No major nearby features. **Encroachment**: High due to densification and lack of open space. **Accessibility**: Poor; limited to informal green spots. **Ranking**: Likely in bottom 20% citywide.
5	Ward 22 (Tilak Road)		~0.51	**9,800 residents, ~5,000 m²)**	**Green Cover**: Mostly scattered trees, roadside vegetation, and private lawns. **Public Parks**: None of significant size. **Tree Density**: Low canopy cover. **Natural Features**: Predominantly urban built-up areas. **Encroachment**: High due to traffic and commercial growth. **Accessibility**: Very poor; no community park. **Ranking**: Among bottom 10% citywide.
6	Ward 23 (Khurbura)		~1.48	**~11,500 residents, ~17,000 m²**	-All wards fall below the 9 m²/person green space norm. -Highest: Gandhi Park (~3.7), Lowest: Tilak Road (~0.51). -Urgent need for equitable green infrastructure.
7	Ward 21, Vasant Vihar		~2.78	**~6511.00 residents, 18,100 m²**	-**Green Cover**: Predominantly private gardens, institutional compounds, and avenue trees. -**Public Parks**: Few small to medium neighborhood parks. -**Tree Density**: Moderate; evenly spread in residential layouts. -**Natural Features**: No significant natural features nearby. -**Encroachment**: Low to moderate; controlled residential development. -**Accessibility**: Fair- green spaces are within walking distance in many areas. -**Ranking**: Upper-mid tier (~top 20-25%) in citywide green space provision

The provision of green space in the selected wards of Dehradun is critically below the urban planning norm of 9 m² per person. Data from our case-study wards reveals:

- Tilak Road suffers the most severe deficit, with a mere 0.51 m² of green space per resident.
- Even Khurbura, the "greenest" of the five, provides only ~1.48 m²/person.

- Alarmingly, all surveyed wards offer less than 20% of the recommended green space, exposing a profound deficiency in accessible green areas essential for residents' well-being.

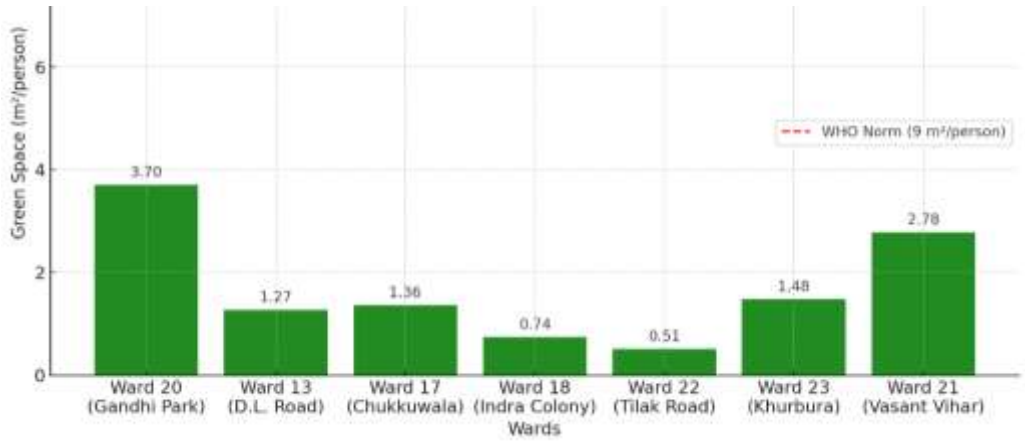

Figure 5: Analysis of ward-wise green space Provision in Dehradun.

The data indicates a significant lack of green space across all surveyed wards in Dehradun, with none meeting the WHO standard of 9 m^2/person. Gandhi Park Ward has the highest provision, at approximately 3.7 m^2/person, while Tilak Road has the lowest, at approximately 0.51 m^2/person. This highlights a critical need for equitable green infrastructure planning, especially in densely populated and underserved areas.

FINDINGS/ RESULTS

The data analysis substantiates the presence of markedly deficient green space ratios across all surveyed wards. In no instance does the available green space approach the recommended 9 m^2/person. Ward 22 exhibits the most pronounced deficiency, with approximately 0.51 m^2/person, followed by Ward 18 at approximately 0.74 m^2. Even Khurbura, the ward with the highest green space ratio within the study, provides only approximately 1.48 m^2 per resident. These findings are indicative of the reduction in expansive parklands and the restricted presence of street vegetation within inner-city locales.

Spatial mapping procedures revealed distributions characterized by clustering, wherein the presence of larger parks and institutional grounds within a given ward correlates positively with an increase in its overall green area. As an example, the Khurbura ward benefits from the presence of several medium-sized parks situated near the Race Course area, whereas the vegetation observed in Chukkuwala predominantly consists of privately maintained gardens. It is important to note that the distribution of green space within wards is frequently uneven, with field observations indicating that the green area within each ward is often concentrated in a singular area, thus placing a substantial proportion of residents beyond a reasonable ambulation distance. Accessibility analysis indicated that in Wards 18 and 22, in excess of 60% of residents reside at a distance greater than 400 m from the nearest park, with physical impediments further complicating access.Survey responses served to underscore the implications of this deficiency. Over 80% of respondents across all wards concurred that green spaces are of substantial importance to the quality of life in Dehradun. Over half of the respondents indicated that they typically travel in excess of 10 minutes to access a park. Commonly cited concerns included inadequate maintenance, insufficient illumination, and a lack of essential amenities in existing parks. A representative respondent from Ward 18 stated, “Our neighborhood lacks a suitable park. We are reliant on a limited number of roadside tree groupings, which are poorly maintained and unsafe during nocturnal hours.” These issues were found to be more pronounced in densely populated commercial areas and informal settlements, as evidenced by diminished satisfaction scores.

The study’s key results can be summarized as follows:

- **Critical Green Space Deficit:** Every assessed ward has UGS well below norms, highlighting an acute citywide deficit that fails to meet basic public health recommendations.
- **Socio-spatial Inequity:** Older, congested wards fare worst; newer or peripheral wards have modestly better green cover, exacerbating environmental injustice. For instance, Ward 13 has only ~1.27 m^2/person, whereas some newer wards approach 3-4 m^2.

- **Maintenance and Quality Gaps:** Many parks suffer from neglect, reducing their usability and negating the potential benefits of existing green spaces. Stakeholders noted that park budgets are minimal, reflecting a lack of prioritization.
- **High Awareness, Low Engagement:** While nearly all respondents recognized UGS benefits, organized community efforts are rare, indicating a disconnect between awareness and action. There are no formal mechanisms for citizen input in park management, according to municipal officials, further marginalizing community needs.
- **Planning Vacuum:** Interviews with planners confirmed the absence of ward-level greening plans or monitoring, revealing a systemic failure in urban planning. Tree-planting drives occur sporadically, but without strategic targeting of underserved areas, resulting in inefficient resource allocation.These findings illustrate that Dehradun's green infrastructure is currently insufficient and uneven, mirroring patterns seen in larger Indian cities and underscoring a broader national challenge. The five wards studied collectively represent diverse typologies, implying that most of Dehradun faces a serious UGS shortfall that could undermine public health and resilience, necessitating urgent intervention.Nehru Colony, a dense residential area of Dehradun. Street trees and small private gardens provide limited greenery in an otherwise built-up urban landscape. The paucity of accessible parks means many residents rely on informal green fragments such as roadside trees or school grounds shown in one such neighborhood scene.

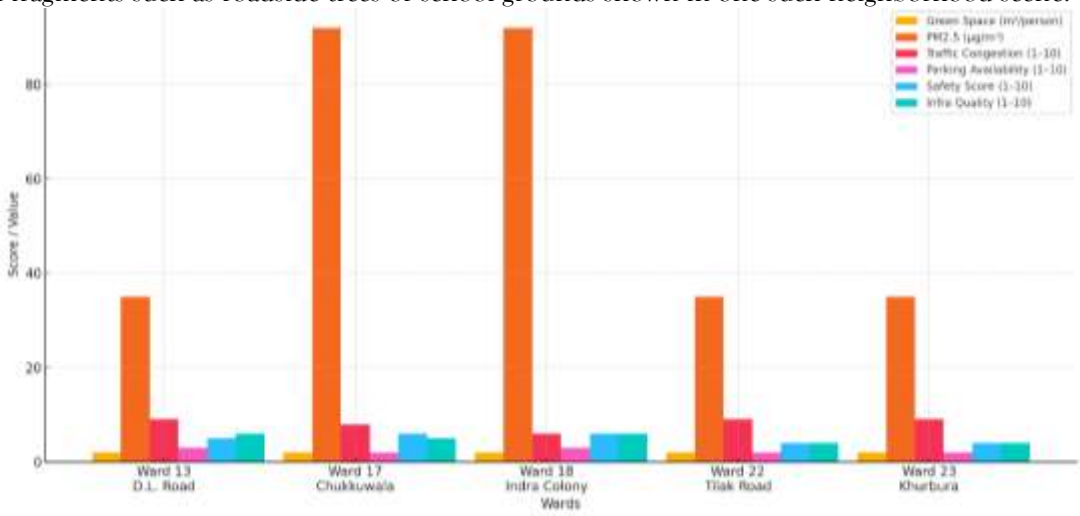

Figure 6: Ward-level Urban Indicator in Dehradun

These findings illustrate that Dehradun's green infrastructure is currently **insufficient and uneven**, mirroring patterns seen in larger Indian cities. The five wards studied collectively represent diverse typologies, implying that most of Dehradun faces a serious UGS shortfall that could undermine public health and resilience.

Nehru Colony (Ward 17), a dense residential area of Dehradun. Street trees and small private gardens (foreground) provide limited greenery in an otherwise built-up urban landscape. The paucity of accessible parks (none of significant size in Wards 18 or 22) means many residents rely on informal green fragments such as roadside trees or school grounds shown in one such neighborhood scene.

DISCUSSION

The ward-level evidence underscores the environmental and social dimensions of Dehradun's livability challenges. The pronounced disparity in green space provision mirrors broader research concerning urban environmental justice, wherein areas with limited vegetation tend to coincide with high-density, lower-income neighborhoods. Such inequity may exacerbate heat stress, pollution exposure, and social deprivation for the most vulnerable residents. Our results are consistent with findings from other urban centers, which demonstrate a positive correlation between green space availability and community well-being.

Table 2: Major Challenging Parameters in Dehradun Scenario

Parameter	Current Status	Key Issues & Impact on Green Spaces

Air Pollution	PM2.5: 45-49 μg/m³ (above 40 μg/m³ CPCB limit); Winter AQI often "Poor"	Vehicle emissions and construction dust worsen with limited tree cover; Valley topography traps pollutants; Green spaces critical for air purification
Green Cover Loss	Lost 170 hectares (2015-2022); Road widening projects threaten 28,000+ more trees	Infrastructure expansion prioritized over green preservation; Failed tree transplantation; Urban green buffer under constant threat
Traffic Congestion	~1 million vehicles for 1.2 million residents; Only 200 public buses vs. 350 needed	Chronic road congestion reduces walkability to parks; Weak public transport increases private vehicle dependency; Limited parking encourages road encroachment
Urban Flooding	Frequent waterlogging during modest rains; Areas like Mothrowala, Baniyawala severely affected	Poor drainage maintenance; Natural waterways encroached/filled; Green spaces essential for stormwater management and flood mitigation
Children's Safety	60%+ wards lack playgrounds; Children play on roads due to missing parks	Kids forced to unsafe street play; Accidents from lack of designated play areas; Green space deficit directly impacts child safety and development
Waste Management	95% collection but only 43% processing; 0.5 million tonnes legacy dump at Sahastradhara	Poor waste segregation (2-3%); Open dumping/burning in green areas; Contaminated spaces reduce usable green area for recreation

These interconnected challenges highlight how green space deficiency exacerbates urban problems, while adequate green infrastructure could provide natural solutions for air quality, flood management, recreation, and overall urban resilience.

Crucially, the ward-scale focus of this study is itself an original contribution. By zooming in on the primary planning units of Dehradun, we expose granular gaps that city-level surveys can miss. For example, a municipal report might note that "Dehradun has 15% green cover overall," but this masks the reality that within Ward 22, nearly 99% of the land is impervious. Our integration of spatial metrics with residents' voices provides actionable insight: planners now know which wards and locales need intervention, and how citizens perceive the deficits.

Policy implications are clear. First, the persistence of per-capita green space well below national standards means that new targets and investments are urgently needed. Adopting a ward-level green space master plan would ensure each neighborhood sets achievable goals and identifies underutilized land for greening. Second, equity should guide prioritization. Wards 18 and 22, as the most deficient, should be focal points for new projects such as linear green corridors along streets, community gardens, and tree planting in slum areas. Community engagement must be strengthened. The high public awareness found in surveys suggests strong latent demand for parks; formalizing "Green Committees" in each ward could help translate this into volunteer park upkeep and neighborhood greening campaigns. Finally, municipal governance needs coordination: responsibilities between the Dehradun Municipal Corporation, Uttarakhand Forest Department, and development authorities must be clarified, perhaps by establishing an inter-agency urban greening cell. In sum, our findings contribute original evidence that ward-scale disparities in UGS are a critical and addressable aspect of urban livability. Addressing these requires mainstreaming green infrastructure as an essential part of spatial planning, rather than an afterthought.

Urban green spaces are vital for environmental quality and human well-being, particularly in rapidly urbanizing cities. Policymakers are increasingly recognizing the importance of investing in urban greening initiatives to improve public health and promote sustainable development (Leboeuf et al., 2023).

1.1 Urban Green Space and Livability Interdependence

This study provides concrete, ward-level evidence that urban green spaces are fundamental to enhancing the quality of life in a rapidly urbanizing city like Dehradun (Addas, 2023). The findings confirm that while residents are well aware of the multiple benefits of green spaces, ranging from improved air quality to stress reduction, actual access to such spaces is highly constrained. This contradiction underscores the disconnect between citizen demand and planning practice.

The urban sprawl that followed Dehradun's designation as Uttarakhand's capital in 2000 has outpaced green infrastructure provision. Our spatial analysis reveals that park areas and tree-lined spaces have not kept pace with population growth, particularly in high-density wards. Older neighborhoods such as Tilak Road and Indra Colony, which should ideally have embedded green zones, now suffer from high built-up ratios and minimal per-capita open space.

1.2 Socio-Spatial Inequity and Green Infrastructure

The unequal distribution of UGS across wards mirrors broader patterns of socio-spatial exclusion prevalent in Indian cities. Affluent, low-density areas typically benefit from greater green cover, whereas lower-income neighborhoods encounter compounded disadvantages, including limited space, degraded facilities, and hazardous access routes (Kamble et al., 2022). As indicated in the surveys, women and elderly residents are disproportionately affected by these deficits in accessibility and quality. This confirms that green inequity is both spatial and social in nature, thereby exacerbating urban vulnerability and environmental injustice.

1.3 Institutional and Planning Deficiencies

The study also highlights significant institutional fragmentation. Despite the presence of national guidelines (Yan et al., 2024), no ward in Dehradun meets the prescribed standards, revealing a systemic failure. This shortfall is not merely due to land scarcity but is also a result of poor policy integration, inadequate budget allocations, and a demonstrable lack of coordination between the Dehradun Municipal Corporation and allied bodies like the Forest Department and MDDA. Urban green planning remains reactive rather than anticipatory, tree plantation drives are seasonal and ceremonial, rather than spatially targeted or impact-monitored. This ad hoc approach undermines long-term sustainability and livability.

1.4 Role of Communities and the Untapped Potential

Community engagement represents a significantly underutilized resource. Research indicates a notable public interest in enhancing UGS; Also, structured platforms for participation are lacking (Srinivasan, 2024). The absence of mechanisms for community-based monitoring, neighborhood stewardship, and feedback loops means that the potential for bottom-up green infrastructure is not being fully realized. Actively engaging citizens, particularly youth, RWAs, and NGOs, could substantially improve outcomes at a relatively low cost.

Table 3: Comparative Livability Indicators for Dehradun Wards

Parameter	Ward 13 (D.L. Road)	Ward 17 (Chukkuwala)	Ward 18 (Indra Colony)	Ward 22 (Tilak Road)	Ward 23 (Khurbura)
Population	Data not publicly available (municipal records not released)	Data not publicly available	Data not publicly available	Data not publicly available	Data not publicly available
Green space per capita (m^2/person)	Extremely low (~2 m^2, reflecting the city average)	Extremely low (~2 m^2)	Extremely low (~2 m^2)	Extremely low (~2 m^2)	Extremely low (~2 m^2)
Nearest park / accessibility	No formal parks; core area noted to "lack parks" (nearest greenspace ~1 km away)	Gandhi Park on Subhash Rd (~0.5 km, within ward)	Indira Nagar Park (Vasant Vihar, inside ward)	No dedicated park (nearest small green areas ~0.5-1 km away); open space scarce	No dedicated park; "lack of parks and open spaces" reported (nearest parks ~1 km)
Air pollution ($PM_{2.5}$ / AQI)	Very poor (central business area). City-average PM2.5 ≈35 µg/m^3 (AQI ~Moderate); peak pollution in winter	Very poor. Local sensor (Chandranagar) recorded PM2.5 ~92 µg/m^3 (AQI≈100) (indicative of W17-level pollution)	Very poor (similar to Ward17 conditions)	Very poor (commercial/market area). City-average PM2.5 ≈35 µg/m^3 (AQI moderate to poor)	Very poor (inner-city). City-average PM2.5 ≈35 µg/m^3; heavy traffic raises local AQI

Waste collection/disposal	Managed by DNN Public Health Dept. (SWM Circle-1). 2025 reforms: new contractor for 47 wards, causing gaps	Managed under SWM Circle-4. Service disrupted in 2025 (agency change/strikes)	Circle-4. Similar collection gaps due to 2025 transition	Circle-3. Frequent complaints of skipped pickups during contractor change	Circle-3. Faces the same municipal collection issues (e.g. strike/contractor turnover)
Parking (availability)	MDDA 3-storey parking (near Clock Tower) for ~500 cars; on-street parking is very limited and congested	Virtually none (narrow lanes; mostly informal roadside parking)	Very limited (small lanes; mostly on-street/residential parking)	Very limited (no public lots; streets crowded with market vehicles)	Very limited (congested bazaar; no dedicated parking, spillover onto roads)
Traffic congestion / flow	Severe congestion (major downtown junction; narrow roads)	Severe (zig-zag narrow lanes); residential/commercial mix	Moderate (primarily residential streets, but access to main roads)	Severe (market and railway access roads; heavy through traffic, narrow lanes)	Severe (busy inner-core streets; narrow lanes with high pedestrian and vehicle mix)
Safety (children/women)	Crowded markets and heavy traffic create hazards; stray animals scatter garbage during breakdowns	Mixed residential/commercial area; narrow dark lanes can be unsafe	Mostly residential (some street-light dark spots); typical city issues (traffic)	Crowded Khurbura market area (hawkers, theft risk); heavy traffic	Core area (Khurbura) with continuous activity; inadequate lighting noted for women's safety (see streetlights)
Public infrastructure (drainage, lighting, etc.)	Aging drainage (Rispana River by Ward13 is highly polluted, often flooding); generally adequate street lighting reported	Frequent streetlight outages (e.g. Subhash Road); drains are old and prone to clogging	Generally maintained lighting; urban drainage (legacy lines) prone to blockages in rain	Many streetlights non-functional (Rajpur Road); poor/drained sewers cause waterlogging after heavy rain	Similar to W22: broken streetlights; old drains overflow during monsoon

RECOMMENDATIONS

Based on the empirical findings, the following strategic interventions are proposed to address the UGS deficit and promote environmental equity in Dehradun:

1. Ward-Level Green Space Planning

Each municipal ward should develop a Green Space Action Plan integrated within the city's broader master plan. These plans must:

- Be based on comprehensive, GIS-enabled green inventories that map existing resources and needs.
- Set evidence-based, per-capita green space targets that align with national benchmarks and community needs.
- Identify priority zones for greening, focusing on areas with the greatest deficits and vulnerable populations.
- Include zoning provisions and incentives for mandatory green components in private and public developments, ensuring compliance and long-term sustainability.

2. Creation of Micro-Parks and Green Corridors

Given the constraints in acquiring large plots in densely built-up wards:

- Systematically convert vacant plots, residual public land, and road medians into strategically located pocket parks, ensuring accessibility for all residents.
- Actively promote rooftop gardens, vertical green walls, and green balconies through incentives and regulatory support, maximizing green cover in constrained spaces.
- Develop green corridors along stormwater drains, footpaths, and railway lines to connect fragmented green spaces, enhancing ecological connectivity and promoting biodiversity.

3. Strengthening Community Participation

Local citizens must be empowered through:

- Establishing ward-level "Green Committees" or "Friends of the Park" groups, providing platforms for residents to voice their needs and participate in decision-making.
- Providing micro-grants for RWA-led gardening, composting, and park beautification projects, fostering community ownership and stewardship.
- Implementing school-based tree plantation programs and environmental clubs to instill environmental stewardship among youth, creating a culture of sustainability.

4. Enhanced Budgeting and Maintenance

UGS quality can be greatly improved with strategic and sustained investments:

- Allocate separate, ring-fenced green infrastructure budgets for each ward, ensuring adequate resources for development and maintenance.
- Improve safety features (lighting, pathways) and inclusivity (accessible design, diverse programming) to encourage use by all community members.
- Contract local NGOs and community groups for maintenance to increase efficiency, accountability, and local economic benefit.

5. Institutional Integration and Monitoring

Dehradun needs better inter-agency governance and performance tracking:

- Form a dedicated Urban Greening Cell with clear mandates and authority to coordinate DMC, Forest Department, MDDA, and Smart City Office efforts.
- Mandate annual, transparent green audits at the ward level, using standardized metrics to assess progress and identify gaps.
- Integrate UGS indicators into the city's livability and sustainability metrics, ensuring that green space provision is a core component of urban development planning.

2. CONCLUSION

This ward-level analysis reveals a critical urban green space crisis in Dehradun, with all surveyed wards providing only 0.5-3.7 m^2/person—far below the required 9 m^2/person standard. The most vulnerable neighborhoods suffer the greatest deficits, creating severe environmental injustice. Rapid urbanization has reduced green cover by 170 hectares (2015-2022), directly impacting public health through increased pollution exposure, heat stress, and limited recreational opportunities. The consequences extend beyond environmental degradation to encompass rising respiratory diseases, compromised child safety, and reduced urban resilience. Immediate intervention through ward-level green space planning, micro-park development, and community engagement is essential. Dehradun must redefine green infrastructure as critical civic infrastructure, prioritizing equity-based interventions in underserved wards. Without urgent action, Dehradun risks permanent ecological degradation and public health deterioration. This study's methodology and findings provide a replicable framework for other rapidly urbanizing Indian cities facing similar green space challenges.

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