

Spatial Distribution and Coverage of Urban Green Spaces: Public Parks in Pune

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Abstract

With the rapid urbanisation, Green Spaces (GS) are shrinking steeply in urban areas. Parks not only provide green spaces in an urban area, but play a pivotal role in the life of individuals. Apart from being the lungs of the city, they help to reduce the effect of urban heat islands. The current study aims at mapping all public parks sourced and integrated from Open Street Map, Google Earth and Pune Municipal Corporation (PMC) database in PMC using Geographic Information Systems (GIS). As per the integrated database, there are 216 public parks in the PMC area. We have analysed the spatial distribution and coverage of green spaces in the PMC. The spatial distribution reveals that the public parks are located in all 15 administrative wards of Pune. However, the analysis indicates a clustered pattern; most of the parks are concentrated in the central part of the city and as the city limits expand, there is a noticeable drop in the coverage of public parks. Cluster boundaries of the existing public parks collectively indicate that many residential areas of PMC are deprived of this GS. In the future, it will be useful to study the existing infrastructure and the usage of existing public parks. Also, an additional important aspect is studying the proximity and access to GS from densely packed informal settlements in the PMC area.

1. Introduction

There is general agreement that urban green spaces (GS), of which parks are an important constituent, are essential for creating liveable and sustainable cities and towns, and for directly or indirectly promoting human or societal well-being (Konijnendijk et al., 2012). Urban parks specifically are known to provide important environmental and social benefits to residents of large cities (Kabisch and Haase, 2014). Among their many benefits, urban parks are known to reduce Urban Heat Islands (UHI), provide benefits through enhanced biodiversity, as well as provide spaces for socializing and other stress-reducing activities. For example, the presence of large urban parks has been known to reduce the UHI effect up to 500m away (Doick et al., 2014). Additionally, amongst GS, parks are the most species-rich, although one where exotics (particularly plant species) constitute a large share (Nielsen et al., 2014). It is also well known that parks are important locations for socialization and recreation (Paul and Nagendra, 2017). Thus, apart from being the lungs of the city, it is generally accepted that parks also offer a recreational and social interaction place, a serene environment for better mental and physical wellbeing, a medium to reduce the effect of UHI, and an element of beauty and aesthetics enhancement of the city.

1.1 Research Rational

The distribution of parks within a city is noted to be unequal, with inequalities observed between parks and population, which can be attributed to social differences, and accessibility based on social status or ethnicity (Comber et al., 2008; Kabisch and Haase, 2014; Ziari and Zebardast, 2024; Du et al., 2020). Others have also noted a difference in greenspace accessibility between residents living in cities of the global north versus the south (Chen et al., 2022). Moreover, this inequality exacerbates existing issues linked to development. For example, under the pressures of development and extensive urbanization, the

prevalence of parks and green spaces is shrinking in the expanding cities of the global south (Byomkesh et al., 2012; Haaland et al., 2015; Sushmitha and Chandrashekara, 2024). Therefore, it is important to understand the spatial distribution of parks to properly estimate their accessibility within a city, and to inform decision-makers about the need to protect and expand urban parks in newly developed suburban areas.

Pune, the cultural capital of Maharashtra, has benefited from its unique landscape, featuring hills, rivers, and a network of canals throughout the Pune Municipal Corporation area. Pune has several historical sites, including parks, which are important factors in the city's development. Pune stands as one of India's most significant cities, renowned for its rich cultural heritage, academic excellence, and the dynamic automobile and IT sectors. In 1950, when the Municipal Corporation came into existence, a new phase in the history of gardens began. The Pune Municipal Corporation (PMC) took control of approximately 18 gardens in the municipal and suburban areas. On April 1, 1950, a separate account was started for managing all the gardens in the city. At the time, the PMC's area was 243.48 sq. km. With the inclusion of 23 new villages within the PMC limits, the total area has now expanded to 484.61 sq. km. According to the 2011 census, the population of the city of Pune (including newly added areas) is over 35,56,824 people.

The continuous growth of the suburbs is one of the major reasons for the population growth in the city, resulting in an increased demand for infrastructure development. But as observed in other regions of the world, rapid urbanisation and socio-demographic transition in Indian metro cities like Pune resulted in the shrinking (in size and numbers) of green spaces, including parks (Choudaj et al., 2024; Imam and Banerjee, 2016). However, a study comparing the distribution of parks across the various city wards has not yet been attempted for the city. Since each city ward represents different spatio-temporal developmental phases of the city, such an analysis can yield important insights into how parks and their occurrence have evolved as the city has grown.

1.3 Use of geospatial technology in detecting parks

In several other Indian cities, scholars have used Geospatial technologies to automate the detection of green spaces, particularly parks, and analyze their distribution. The most common methods used are satellite data in conjunction with common remote sensing indices, e.g., Normalized Difference Vegetation Index (NDVI), and object-based recognition, to detect the presence of large green spaces and hence identify them as parks (Shekhar and Aryal, 2019; Gaikadi and Vasantha Kumar, 2024). Because this method may not properly identify all green spaces (or over-estimate the presence of publicly accessible urban parks in Indian metro cities), ground-based LiDAR has additionally been used to highlight the specific vegetative structure of individual parks (Gaikadi and Vasantha Kumar, 2024). This use of ground-based LiDAR, however, is a time-consuming process that makes its deployment to study a large number of parks infeasible.

For the study, we review the distribution of public parks within the Pune Municipal Corporation (PMC) boundary, and specifically highlight their spatial distribution across administrative wards. We use as an initial starting point (a) data from 2019 on 196 parks available from PMC as an pdf file, and (b) the ward boundary published by PMC for 2022, giving the area of 505.69 sq. km. Further, the 196 parks are developed by PMC under the garden department, within the jurisdiction of 15 regional offices, as per Section 66(10) of the Maharashtra Municipal Act, 1949. These were geolocated using Google Earth. However, additional development of public parks since 2019 has resulted in a total of 216 parks across the city. Data on these additional parks was obtained from analyzing Google Earth and OpenStreet maps, as highlighted in the methods section.

1.2 Objective

The purpose of this research is to systematically catalogue public parks within the Pune Municipal Corporation (PMC) area and analyze their spatial distribution across administrative wards. Specifically, the study seeks to:

- Construct a comprehensive geospatial database of public parks in the PMC jurisdiction.
- Examine spatial patterns and potential clustering of parks to determine whether certain wards enjoy a disproportionately high or low level of access.

This analysis will provide a robust spatial planning tool, enabling data-driven decision-making to ensure equitable access to parks across all wards to contribute to SDG 11: Sustainable Cities and Communities.

2. Methodology

The primary objective of the study is to develop a comprehensive database of parks within PMC, with a secondary goal of analyzing the spatial distribution and clustering of these parks within ward boundaries. This will be a powerful tool for planning, execution and preservation of the parks to maximise the usage and benefits for society. Spatial data were analysed using QGIS (3.40.6), and numerical data were analysed using MS Excel.

Since electoral ward boundaries are subject to change due to election cycles, administrative ward (15 in number) boundaries are used for comparison and consistency in analysis. The admin ward-wise population is taken from the census 2011, with the

inclusion of newly added 34 areas, the total population of PMC is 35,56,824. The spatial data used for administrative ward boundaries is sourced from an open-source database and is validated with PMC's GIS portal. The list of Parks, including their addresses, is taken from the PMC's official website. Pune city is characterised by the presence of hills in and around the city. Green spaces located on the hills that do not have access to a motorable road are excluded from the study.

Identification, verification of locations of parks are done by triangulating the information from Google Earth Pro (GE) and Open Street Map (OSM) using QGIS (3.40.6). Preparation of maps and other GIS/RS techniques, including georeferencing, digitisation, data attachment, clustering and layouting of maps is done using QGIS (3.40.6). A systematic process followed in the study is represented by the diagram given below (Figure 1).

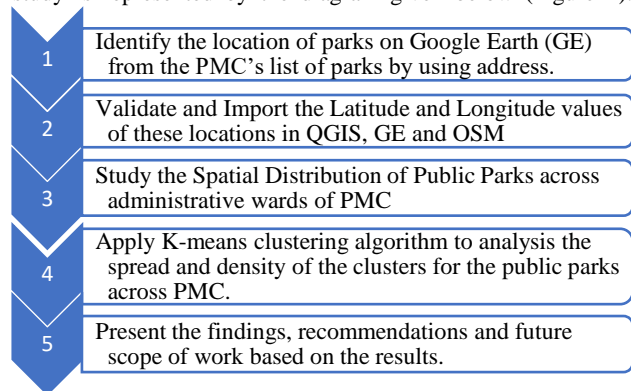


Figure 1: Workflow to create a comprehensive database of Pune parks and analyze their spatial clustering by wards

3. Spatial Analysis and Results

3.1 Identification and verification of Public Parks

In the PMC area, 216 Public Parks are identified by the integration of data from PMC, GE and OSM (Figure 2 and Table 1). Spatial distribution of 216 public parks is shown on the map (Figure 2). The ward-wise count and the approximate area of the parks are summarised in Table 1. The calculation of the areas of the public park for which PMC has not provided the area, is approximate, as it is extracted from GE and OSM using QGIS, with the limitation that the boundaries of the parks are not visible and identifiable accurately, due to the tree canopy, and they often get merged with the surrounding areas (Gaikadi and Vasantha Kumar, 2024). Hence, on-ground verification is required and will be conducted at a later stage.

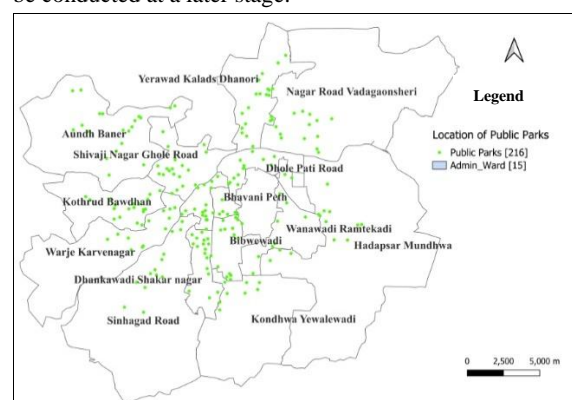


Figure 2: The Spatial Distribution of Public Parks, Pune City.

Sr. No / Zone		Admin Ward Name	No. of Parks	Area of public parks ¹	Area of Ward ²
1	1	Dhole Patil Road	15	149233	12583767
2	1	Nagar Road Vadagaon sheri	14	131330	82002352
3	1	Yerawada Kalas Dhanori	20	121390	23948713
4	2	Aundh Baner	20	107005	51799940
5	2	Kothrud Bavdhan	19	75156	22209838
6	2	Shivaji Nagar Ghole Road	19	236884	16519672
7	3	Dhankawadi Sahakar nagar	17	770884	10374787
8	3	Sinhgad Road	13	139455	71758771
9	3	Warje Karvenagar	12	52336	38638564
10	4	Hadapsar Mundhwa	12	167962	101559772
11	4	Kondhwa Yewalewadi	8	314326	41741708
12	4	Wanawadi Ramtekadi	9	121705	14484113
13	5	Bhavani Peth	6	39000	2998133
14	5	Bibwewadi	15	94904	9225469
15	5	Kasba Vishrambag wada	17	177000	5830031
Total			216	2698570	505690624

Table 1: Distribution of public parks across 15 administrative wards of PMC

3.2 Public Park in Pune from historical roots to modern multidimensional landscape

Pune is very close to the Sahyadri mountain range, which is part of the Western Ghats known for its biodiversity and multifaceted geography. This includes small hills in and around the city, rivers and canals flowing through the city. As a historic city, Pune has a rich heritage of lakes and parks from the Peshwa rulers. Now with the various Government schemes, PMC has been reimagining public spaces with walkable streets, waterfronts, and inclusive parks. The city is harmonising blue elements (rivers, lakes, nallas) with green elements (parks, native tree plantation, conservation of hills) to mitigate climate change and urban flooding. This has given impetus for building a beautiful landscape of parks along these water bodies. 25% of Public parks are located within a 100-meter buffer of rivers, canals and lakes within the city. The location of these parks are represented in the Figure 3.

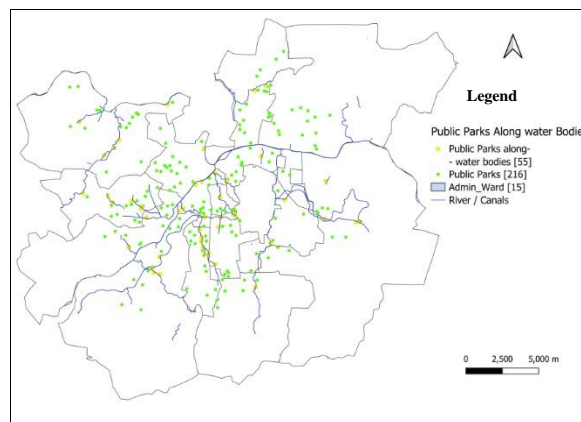


Figure 3: Public Parks located along water bodies in Pune.

As the city expands vertically and horizontally, it is essential to have public parks that are accessible to all age groups. In line with this objective, PMC's initiative of developing Nani-Nani Park has started demonstrating an impact on the ground. There are 9 such parks for senior citizens across the city.

3.3 Availability of Public Parks across Wards

In PMC, 15 administrative wards are located under 5 Zones. To study the presence of public parks across the wards, a comparison is made. The size-wise categorisation is done to compare the ward-wise distribution of parks (Chart 1). Quartiles are used for categorising the parks. 30% parks are of small size i.e. up to 2000 sq.m. and 25% of the parks are of large size parks i.e. more than 10,000 sq. m. Yerwada Kalas - Dhanori, and Aundh wards have the highest number of parks, 20 each, followed by Shivaji Nagar-Ghole Road and Kothrud ward, 19 each. However, when it comes to the wards having large-sized parks, Hadapsar is at the top with 50% parks more than 10,000 sq.m. followed by Wanwadi Ramtekdi. In contrast, Warje-Karve Nagar had the lowest, only 8.33% of large parks, followed by Yerwada Kalas - Dhanori (10%) and Kothrud-Bavdhan wards (10.5%). It denotes that though Yerwads Kalas Dhanori has the highest number of parks, the number of large parks is very low (only 2 out of 20 parks). Strikingly, 84% of parks in Kothrud are less than 4,000 sq.m. Followed by Warje-Karve Nagar ward with 75%. Only Kasaba-Vishrambagwada ward has more than 70% of parks with a size larger than 4,000 sq.m.

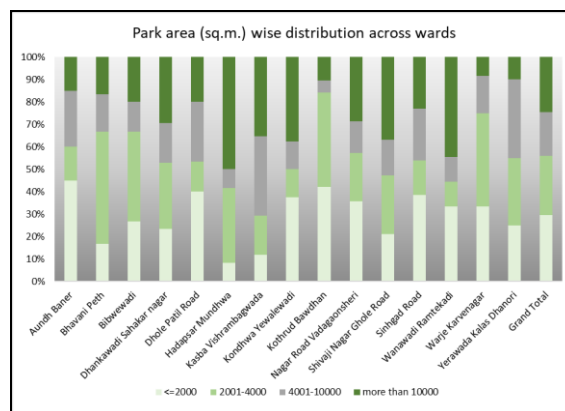


Chart 1: Admin ward-wise distribution of Public Parks by size (sq. m.) of the park

¹ Approximate area of parks derived based on satellite imagery.
² Approximate area is derived from shape file of ward boundary.

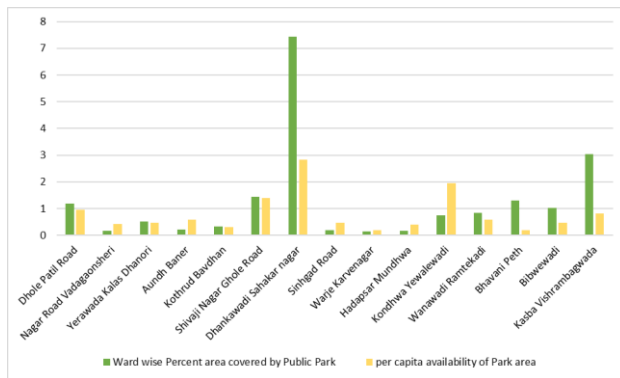


Chart 2: Admin ward-wise distribution of percentage of area covered by Public Parks and per capita green space

The above Chart 2 depicts that the largest percentage of coverage is in Dhankawadi-Sahakar Nagar ward, followed by Kasba Vishrambagwad Ward. This is due to the presence of Rajiv Gandhi Zoo and Park in Katraj area of Dhankawadi-Shakar Nagar ward, which is the largest Park in the city, whereas in Kasba Vishrambagwada ward, historical parks like Sarasbag, Peshave Udyan are the major contributors. In Kondhwa-Yewalewadi ward, the development of a park around the Nanasaheb Peshave Lake is resulting in its ranking as the third highest among all wards in the city. The integration of green space with natural water bodies not only improves ecological balance but also promotes community well-being and reduces the urban heat island effect. Even though here only public parks are considered, the coverage of GS for Pune city as compared with the global norm (20-25%), is very low (less than 1%), resulting in Pune falling behind on these criteria. While the WHO norm for per capita green space is 9 sq m per person, Pune offers less than 1 sq m of green space per person. So, there is a dire need for the development of new parks in the city. The development of parks along Nalas and Canals needs to be explored in various parts of the city. Here, only public parks are considered under green spaces.

3.4 Clustering of Public Parks in Pune Municipal Corporation area

Further, a deep dive into the patterns in the Spatial distribution of parks reveals that the central part of the city has a greater number of parks, and as the city limits expand, the number of parks is reduced. This pattern is so prevalent that in many parts of the city, there are no public parks at all. Especially, the newly added areas in PMC limits from Nagar Road Vadgaonsheri, Hadapsar-Mundhwa, Kondhwa-Yewalewadi, Sinhgad Road, Warje-Karve Nagar and Aundh Baner are all lacking access to Public parks. In Figure 4, which portrays the results obtained by running a kernel density estimate of all parks, the area within the dark green circle portrays a high concentration of public parks, resulting in better access to public parks. In contrast, the regions outlined by light green circles represent areas with limited and/or no public parks, contributing to reduced livability in the region. As a subsequent step, the pattern and clustering of public parks across the city are studied using machine learning techniques, i.e., clustering algorithms supports data-driven decisions for equitable access to public parks in the city. Here, k-means clustering is used based on the latitude and longitude of all park locations. The number of clusters is finalised using the elbow method, which uses Within-Cluster Sum of Squares (WCSS) as a deciding criterion (Chart 3). The result signifies that the WCSS curve flattens after 6

clusters. This affirms that 6 clusters may be ideal to understand the spatial distribution and accessibility of public parks across PMC.

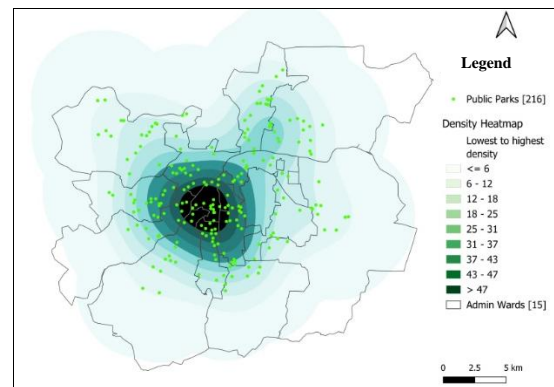


Figure 4: Density of Public Parks in Pune City.

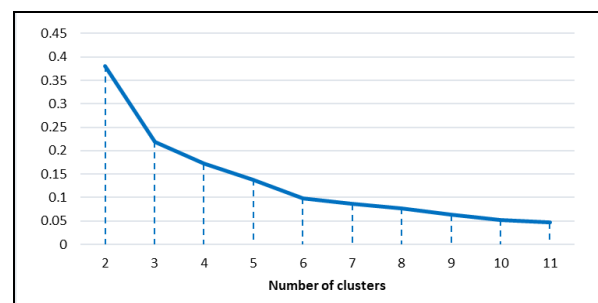


Chart 3: Within Cluster Sum of Squares for 2-11 Clusters

In Table 2, the number in the bracket gives the count of points belonging to the classification of clusters based on the 1 nearest point distance. The distance matrix indicates that the parks located in cluster number 2, are sparse, with the smallest number of (20) parks, whereas cluster number 5 is a dense cluster with the largest number (52) of parks. It is interesting to see how the clusters are placed spatially in the city. Figure 5 shows the 6 clusters of public parks across the city. Cluster 2 is the smallest in terms of area, and Cluster 3 is the largest. Cluster 2 covers the smallest area and the smallest number of parks, with the average distance between the parks being maximum.

Cluster No.	1	2	3	4	5	6	Av. Dist.
1	537 (21)				791 (2)		559.6
2		636 (20)					636.1
3			460 (37)		545 (2)		465.2
4				444 (38)			444.5
5			741 (1)		353 (52)	202 (1)	357.3
6					202 (1)	463 (41)	457.3
Av. Dist.	537.6	636.2	468.2	444.5	372.4	457.3	458.9 (216)

Table 2: Distance matrix for six clusters.

Spatial distribution of the Clusters and sizes of clusters are shown in the figures below.

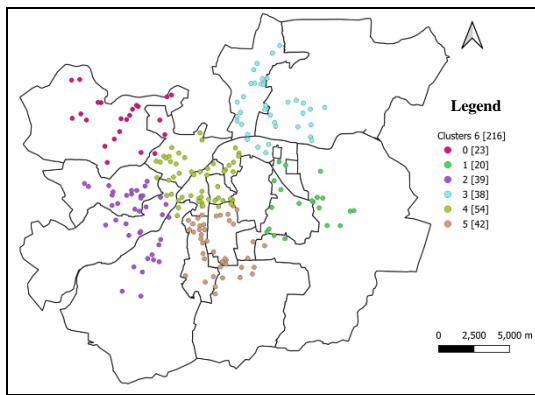


Figure 5: The six clusters of Public Parks in Pune City.

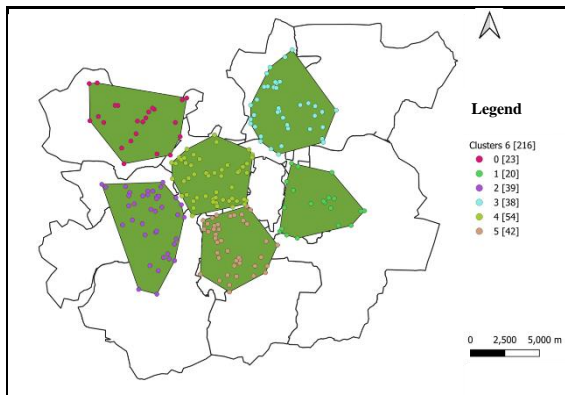


Figure 6: Convex hull polygon around each cluster highlighting coverage of wards by clusters in Pune City.

4. Discussion

The study shows that the Public parks are concentrated in the central part of Pune city and has a good coverage only in specific wards. Spatial distribution reveals that the outskirts are deprived of access to the public parks. Figure 6 shows the clusters identified with a convex hull polygon around each cluster to highlight this fact. Outskirts of the city, which have recently are developed, are lacking in parks. Currently, Pune city is lagging far behind in terms of per capita green space as well as the percentage of area under green space as compare to global standards. Additionally, emerging urban areas of Pune city have a high risk of unplanned development.

Therefore, at a town planning level itself plans have to be made for the development of large parks for catering the future growth and to achieve WHO norms. Not only the number of parks but locations of the parks has to be planned so as to cover all residential areas located in each ward, outskirts and also the dense areas of the city. These dense areas could be the informal settlements which lack of open space as well as vegetation.

Cluster analysis of parks indicates that though Sinhgad Road, Warje-Karve Nagar and Kothrud-Bavdhan are three separate ward areas, they make one cluster which is the largest cluster in the city having lesser number of parks compared to its area size. Also, it is pertinent to note that most of the areas from Hadpsar, Kondhwa-Yewalewadi and Nagar Road wards have very low access to public parks. Following the recent expansion of city boundaries, five municipal wards have undergone significant

territorial expansion which has led to corresponding rise in population density within each ward. As a result, there is a pressing need to establish and expand public infrastructure and more particularly the recreational and green spaces.

To address this, it is recommended that each ward be allocated additional public parks of substantially larger size. Spatial planning will aid in identifying probable locations for the public parks in each ward so that all the residents will have access to them within a circle of 500 m radius.

The potential of developing additional public parks along with rivers and canals within the city needs to be tapped-in to boost ecological balance of the city. Spatial planning should incorporate public green spaces with equitable access to diverse population. It can be also an method where large societies are required to have greater and accessible green spaces for their residents.

Even though the spatial distribution of existing public parks shows a concentration in the central part of the city, there is a caveat that these areas are densely populated and have large informal settlements in close vicinity, making it difficult to have adequate and equitable accessibility to the residents in these areas.

Therefore, it is emphasized that there is a need to undertake the planning for development and integration of green spaces at the town planning stage itself by taking a holistic planning approach for accessible and equitable green spaces for the livable city. Further there is a dire need to study the status and usage pattern of these parks to benefit future planning for city development.

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