# Carbon Storage and Sequestration Potential of Tree Species in District Park, Hauz Khas: Implication for Urban Green Space Management


Dissertation Submitted by

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For the partial fulfilment of the requirements for the award of the degree of

**B.Sc. (Hons.) Forestry**


**Amity Institute of Forestry and Wildlife (AIFW)**

**Amity University, Noida (Uttar Pradesh)**

# Carbon Storage and Sequestration Potential of Tree Species in District Park, Hauz Khas: Implication for Urban Green Space Management

District Park, Hauz Khas


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## TO WHOM SO EVER IT MAY CONCERN

This is to certify that **Ms. Jaspreet Kaur** from Amity University, has successfully completed her **internship** as an **Intern** with **Give Me Trees Trust,** under the mentorship of **Dr. Anand Kumar.** Her internship tenure was from **Feb 3, 2025 to May 28, 2025**.

During the internship, she majorly worked on field and participated in the plantation activities at our plantation sites. Her role involved assisting with plantation activities, sapling care, and community engagement.

She has shown a keen interest in learning and gaining knowledge and experience while working here, which is really commendable. We found her extremely inquisitive, sincere and hardworking during her tenure at Give Me Trees Trust.

We wish her all the best for her future endeavors.

**Dr Anand Kumar**
**External Mentor**

Yours Sincerely,

**For Give Me Trees Trust**

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This is to certify that Ms JASPREET KAUR with Enrollment Number A137120321002, a student of Programme B.Sc. (Hons) - Forestry Batch 2021-2025 Semester at Amity Institute of Forestry and Wildlife has pursued Dissertation NRESDS100 on topic Assessment of ecosystem services of some selected public green spaces based on i-Tree Eco Model. under my guidance from 17/12/2024 to 13/05/2025. The Student has submitted 15 out of total 16 Weekly Progress Reports.Ms JASPREET KAUR has completed the project-related work and the work done is satisfactory.

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# SELF DECLARATION

I, Jaspreet Kaur, student of B.Sc. (Honors) Forestry, hereby declare that the project titled "Carbon Storage and Sequestration Potential of Tree Species in District Park, Hauz Khas: Implication for Urban Green Space Management", which is submitted by me to the Amity Institute of Forestry and Wildlife, Amity University, Noida, Uttar Pradesh, in partial fulfilment of the requirement for the award of the degree of Bachelors in Forestry, is my original work. I further declare that this project has not previously formed the basis for the award of any degree, diploma, or any other similar title or recognition in this or any other university or institution.

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Jaspreet Kaur

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## 1. Abstract:

Urban green spaces (UGS) are defined as "land covered with some form of vegetation" (Warren, 1973). These spaces are vital in providing ecosystem services like climate regulation, recreation, and carbon mitigation. Carbon storage is "the amount of carbon retained in biomass and soil," while carbon sequestration is "the capture and secure storage of carbon that would otherwise be emitted to, or remain, in the atmosphere" (Herzog & Golomb, 2004). This study assessed carbon storage and sequestration potential of the tree species in District Park, Hauz Khas using the i-Tree Eco model. A total of 140 plots were randomly sampled, recording Species, DBH, height, and crown dimensions. The results showed *Pongamia pinnata* stored the highest carbon (270.5 tons), followed by *Ficus virens* (252.1 tons). *Ficus benjamina* showed the highest annual sequestration rate (11.12 tons/year). The >100 cm DBH class contributed the most to both carbon storage (247.8 ton). Native species contributed more to total carbon values than compared to exotic ones. These findings emphasize the critical role of species selection to maximize carbon benefits. Incorporating high-performing native trees in future planting strategies can enhance climate resilience. Thus, UGS should be actively managed and preserved as essential infrastructure in Delhi's climate mitigation efforts.

## Keywords:

Urban Green Spaces; Ecosystem Services; i-Tree Eco; Carbon Storage; Carbon Sequestration; Delhi NCR

## 2. Introduction:

The 21st century has seen a global change to urban life, with over 55% of the global population currently living in cities, a number projected to increase to 68% by 2050 (UNDESA, 2019). This demographic shift poses significant difficulties for environmental sustainability, particularly in swiftly developing nations such as India. Urban growth is often impelled by the necessity to support rising populations, frequently leading to chaotic land-use alterations that negatively affect ecological systems (Seto et al., 2012).

Urban green spaces (UGS) are becoming more known as essential elements of sustainable urban environments. These spaces, comprising public parks, urban woodlands, gardens, and street trees, provide various ecosystem services that are essential for its population.

Carbon sequestration can be defined as the capture and secure storage of carbon that would otherwise be emitted to, or remain, in the atmosphere (Herzog & Golomb, 2004). In urban ecosystems, trees act as key players in carbon capture and storage, combining this global ecological role with local environmental advantages. While urban trees might not equal the biomass of fully grown forest trees, their strategic arrangement in urban areas boosts their overall benefit in climate control, particularly by diminishing emissions tied to energy consumption in buildings and transportation (McPherson et al., 1994). City trees absorb carbon by accumulating it in their woody structures and by reducing surrounding temperatures, thereby decreasing the energy needed for air conditioning (Nowak & Crane, 2002). Even minor urban green areas, if managed properly, can provide substantial benefits. Research conducted in different metropolitan areas indicates that urban trees in the United States capture 25.6 million tons of carbon each year, equating to around 643 million tons of carbon storage (Nowak et al., 2013).

Moreover, the significance of this sequestration is not only ecological but also financial. The financial assessment of the advantages provided by urban forests like lower energy expenses, enhanced air quality, and stormwater management has demonstrated that planting and caring for trees frequently represent economical urban strategies (Salmond et al., 2016). Instruments such as i-Tree Eco and Urban Forest Effects (UFORE) models enable city planners and researchers to assess these advantages with greater accuracy, facilitating the integration of green infrastructure into urban policy structures.

Urban forests, while typically smaller in size compared to rural forests, significantly influence local climates, enhance air quality, mitigate the urban heat island effect, and support public health and well-being (Livesley et al., 2016). Studies have quantified the UHI intensity in Delhi, revealing substantial temperature differences. For instance, during summer days, the UHI intensity can range from 3.8°C to 7.6°C in the afternoon and from 2.8°C to 8.3°C at night (Mohan et al., 2012). These elevated temperatures are primarily due to anthropogenic heat emissions from vehicles, industrial activities, and reduced vegetation cover (Mallick et al., 2024). Furthermore, Delhi consistently places among the most polluted cities worldwide, with $PM_{2.5}$ concentrations significantly surpassing WHO recommendations (IQAir, 2024). Plant life, particularly trees, is essential in improving these conditions by capturing particulate matter, storing carbon, and reducing surrounding temperatures via evapotranspiration (Escobedo et al., 2011).

India, amidst its swiftly urbanizing population, confronts mounting issues associated with urban environmental deterioration. The increasing urban population requires additional infrastructure, frequently at the expense of natural green spaces.

Delhi, the capital of the nation, illustrates the conflict between development and the preservation of the environment. The development of roads, metro, and various urban infrastructure in Delhi has resulted in a notable reduction in plant cover and biodiversity (Begam et al., 2024). The growth of infrastructure results in the loss of these green spaces, causing a fractured and diminishing urban forest area. This trend not only reduces the ecological benefits offered by trees but also exacerbates problems such as rising ambient temperatures and declining air quality (Chaudhry & Tewari, 2011).

As a response, UGS such as neighbourhood parks act as crucial buffers, providing both leisure activities and environmental regulation roles, including carbon storage and sequestration. Urban forestry in Delhi involves a complex relationship of challenges and opportunities, influenced by swift urban growth, environmental issues, and the necessity for sustainable development. The city's green areas are vital for lowering air pollution and improving the quality of life for its inhabitants (Bhalla & Bhattacharya, 2015).

A major challenge in Delhi's urban forestry is the absence of comprehensive, long-term planning and maintenance strategies. Although tree planting initiatives are commonly conducted, there is often insufficient emphasis on the appropriate selection of species, care after planting, and monitoring of survival rates. Adverse soil conditions, inadequate watering, limited root zones, and elevated pollution levels lead to higher death rates of saplings (Menon & Kohli, 2022). Moreover, the regular use of exotic ornamental species in place of native trees prompts worries about ecological compatibility and long-term sustainability (Babu & Singh, 2024).

While the benefits of UGS and tree-based carbon sequestration have been widely acknowledged globally, there remains a significant lack of localized, species-specific studies in Indian cities. Particularly in Delhi, most existing research focuses either on general vegetation cover or broad ecological impacts, without evaluating the carbon sequestration potential of individual tree species within urban parks. Furthermore, the integration of field-based tree measurements with tools like i-Tree Eco for urban carbon accounting is still underutilized. This study aims to bridge this gap by conducting a species-specific assessment of carbon storage and sequestration potential within District Park, Hauz Khas combining empirical field data (such as DBH, tree height, crown dimensions, etc.) with data analysis tools. By doing so, it provides a structured model for UGS management that supports both ecological sustainability and informed policymaking in Indian urban contexts.

## 3. Aim:

To assess the carbon storage and sequestration potential of trees in District Park, Hauz Khas using the i-Tree Eco model and provide recommendations for enhancing carbon benefits.

## Objectives:

1. Compile a comprehensive inventory of the park's tree species and DBH classes.
2. To assess carbon stock and sequestration potential of tree species using i-Tree Eco Model in District Park, Hauz Khas.
3. To develop framework and strategy for future planting and maintenance of park to maximize carbon benefits.

## 4. Literature Review:

UGS confer a multitude of interlinked benefits like environmental, health, social, and economic that underpin sustainable urban development. Ecological functions include air-pollutant removal, microclimate regulation, and stormwater management. The health outcomes span physical activity facilitation, stress reduction, and improved birth outcome socially, UGS foster cohesion, recreation, and educational opportunities; economically, they enhance property values and reduce public-health expenditures. These benefits have been robustly documented across global case studies and systematic reviews, underscoring the critical role of UGS in resilient, liveable cities.

Table 1: Urban Forest Benefits

| Urban Forest Benefit | Description | Research Source |
|---|---|---|
| **Carbon Sequestration** | Trees absorb $CO_2$ and store it as biomass, helping mitigate climate change. | (Nowak & Crane, 2002); (Salmond et al., 2016) |
| **Air Quality Improvement** | Trees filter pollutants like $PM_{10}$, $SO_2$, $NO_2$, and CO. | (Escobedo et al., 2011); (Baró et al., 2014) |
| **Urban Heat Island Reduction** | Shade and evapotranspiration from trees lower ambient urban temperatures. | (Livesley et al., 2016); (Norton et al., 2015) |
| **Stormwater Management** | Tree canopies and root systems reduce surface runoff and promote infiltration. | (Xiao & Mcpherson, 2002); (Armson et al., 2012) |
| **Biodiversity Enhancement** | Urban forests provide habitat for birds, insects, and small mammals. | (Tzoulas et al., 2007); (Hope et al., 2003) |
| **Mental and Physical Health** | Access to green spaces is linked to reduced stress, anxiety, and increased physical activity. | (Ulrich et al., 1991); (Mitchell & Popham, 2008) |
| **Energy Use Reduction** | Shading from trees reduces energy demand for air conditioning in buildings. | (Akbari et al., 2001); (Nowak & Dwyer, 2007) |

The urgent issue of urban sustainability amidst global climate change has led to increased research on how urban forests can help reduce carbon emissions. Urban forests, which include trees in parks, beside streets, and within other green urban areas, serve as essential carbon sinks. Their capacity to capture and store the carbon plays a crucial role in lowering atmospheric carbon dioxide concentrations. This ecosystem service, though having a local effect, contributes to global climate objectives. As urban growth speeds up, assessing and improving the ability of urban forests to absorb carbon is essential for the sustainable urban development. The incorporation of tools such as i-Tree Eco into these evaluations has enhanced our understanding of urban forest functions, structure, and their wider ecological impacts.

In the United States, considerable research has examined the carbon dynamics of urban forests using standardized models. Nowak and Crane in 2002 created the Urban Forest Effects (UFORE) model, which was later transformed it into the i-Tree Eco tool, now utilized in various North American cities to measure ecosystem services. This model integrates on-site field data with local weather and pollution information to deliver thorough evaluations of the structure and ecological roles of urban trees. For example, in New York City, utilizing i-Tree Eco yielded valuable information regarding tree species makeup and carbon processes, resulting in policy measures based on evidence for improving green infrastructure (Nowak & Crane, 2002). Comparable research in Chicago, Los Angeles, and Atlanta has highlighted the significance of managing urban forests to mitigate the urban heat island phenomenon and absorb atmospheric carbon, especially in highly populated areas (McPherson et al., 2011).

Similarly, in Latin American cities research utilizing the i-Tree Eco model has appeared more recently, but it is increasing in both usage and complexity. In cities such as Bogotá, Colombia, urban tree assessments conducted with i-Tree Eco have emphasized the importance of incorporating green planning into the city development strategies. Researchers highlighted that the significance of choosing tree species, upkeep methods, and the socio-economic factors related to urban forestry (Arroyave-Maya et al., 2019). These results correspond with wider urban forestry initiatives in Latin America that seek to harmonize ecological goals with concerns related to equity, urban poverty, and informal housing where access to green spaces may be limited or unevenly allocated (Barona et al., 2020).

Europe has led strong research efforts on urban forests, with numerous cities integrating climate resilience into their environmental plans. Research conducted in cities like London, Berlin, and Barcelona has utilized i-Tree Eco to examine the spatial arrangement and carbon advantages of urban tree networks. Research in Barcelona carried out a comprehensive i-Tree Eco evaluation, highlighting the importance of species diversity and urban structure on the carbon capture potential of urban forest (Baró et al., 2014). In London, the i-Tree Eco initiative was an innovative effort to evaluate ecosystem services within a complicated urban setting. Utilizing field data from over 700 plots and exceeding 20,000 trees, the project provided a reference point for other urban centres in Europe (Tree Economics London, 2015). These research efforts have directly impacted urban forestry approaches, improving biodiversity, resilience against severe weather, and carbon sequestration effectiveness.

In contrast, African cities use of models such as i-Tree Eco is newer, yet essential in the framework of quickly urbanizing cities facing significant environmental risks. Urban green infrastructure faces mounting pressure from growing population centres and uncontrolled land-use alterations. Research conducted in Addis Ababa, Ethiopia utilized a hybrid approach that combined field inventories with ecosystem service modelling to assess carbon storage in chosen urban un-conserved forests (Solomon et al., 2025a).

In Australia, research on urban forests is intricately connected with national climate policies and sustainability standards. Research conducted in Melbourne and Sydney utilized i-Tree Eco to assess the contributions of urban trees to carbon sequestration and various environmental advantages. It emphasized the efficacy of thoughtfully placed trees in managing microclimates and lowering urban energy requirements (Livesley et al., 2016). The i-Tree Eco evaluation in Melbourne offered a methodological framework for cities in the Asia-Pacific area, highlighting the necessity of continual monitoring, particularly due to droughts and fire hazards prompted by climate change (Speak et al., 2012).

Worldwide, the implementation of the i-Tree Eco tool has shown persistent methodological themes and difficulties. The model's power is its flexibility adjusting to local weather conditions, tree species characteristics, and pollution patterns. Nonetheless, effective execution relies significantly on thorough field data gathering, precise species identification, and the accessibility of region-specific growth and biomass formulas. Moreover, numerous studies highlight the necessity of embedding i-Tree Eco results into city governance frameworks to guarantee that ecological advantages are transformed into tangible urban planning results (USFS, 2021).

The use of i-Tree Eco in China has been widespread. A research project in Changchun employed the model to assess the ecological advantages of urban forests, concentrating on carbon capture and oxygen production. The study emphasized that the composition of tree species plays a crucial role in determining ecological advantages, as linear urban forests demonstrate a wider range of effects than planar designs (Zhao et al., 2023). In a similar fashion, the model was employed in Beijing to evaluate the carbon storage and sequestration abilities of urban forests, indicating that the choice of species and their spatial arrangement are essential for optimizing carbon advantages (Ma et al., 2021).

South Korea has also adopted the i-Tree Eco framework to assess urban forestry benefits. A research project in Seoul utilized the model to assess the carbon storage and sequestration potential of vegetation in urban parks. The results highlighted the significance of precise tree inventory data, such as species identification and diameter measurements, in improving the dependability of the model's outputs (Kim et al., 2024).

In Southeast Asia, Indonesia has utilized the i-Tree Eco model to evaluate the advantages of urban forests. A study performed in Jakarta's urban forests estimated a total carbon sequestration of around 184.8 metric tons annually. The research highlighted the importance of tree vitality and variety in affecting carbon capture levels, promoting better management strategies to boost urban forest health (Mosyaftiani et al., 2022a).

Singapore's strategy for urban greening, although not explicitly using the i-Tree Eco model, is consistent with its core concepts. The incorporation of green infrastructure, like vertical gardens and green roofs, in the city-state aids in carbon sequestration and helps cool the urban environment. These efforts highlight the possibilities of integrating urban planning with ecological factors to alleviate climate change effects (Tan et al., 2013).

Building on these global applications, India has increasingly adopted similar methods to evaluate urban tree ecosystem services. In India, UGS have progressively gained attention in both academic and policy-oriented research, especially regarding their contribution to alleviating climate change effects via carbon sequestration. In Bhopal, research evaluated the carbon sequestration capacity of roadside trees through non-destructive techniques. Species like *Leucaena leucocephala* and *Ficus religiosa* were recognized as key carbon sinks, highlighting the significance of choosing the right species in urban development (Dugaya et al., 2020).

Likewise, in Kolhapur it was assessed ten urban gardens, emphasizing the significant carbon storage potential of mature trees in these areas. The research highlights the importance of urban gardens in improving carbon capture (Vasagadekar et al., 2023). In Katni, study performed a thorough evaluation of 26 parks, uncovering a yearly $CO_2$ sequestration potential of 414 tons. The study recognized native species such as *Ficus benghalensis* and *Azadirachta indica* as ideal for urban planting because of their significant sequestration rates (Bhatnagar et al., 2024). Nagpur's urban green areas were examined, and it was discovered that the highest biomass densities were in roadside plantations and playgrounds. The research highlighted the importance of maintaining mature trees and integrating fast-growing, pollution-resistant species in urban development (Lahoti et al., 2019). In Delhi, the i-Tree Eco model was employed to assess carbon sequestration on the Guru Gobind Singh Indraprastha University campus. The results emphasized the efficiency of the model in measuring ecosystem services within educational institutions (Som et al., 2021). The Urban Afforestation Initiative by Centre for Environmental Research and Education (CERE) has played a key role in enhancing green cover in cities such as Mumbai, New Delhi, and Pune. By planting more than 42,000 native trees and assessing their carbon absorption capacity, the project highlights the potential for scaling urban reforestation efforts. In Naya Raipur, a study evaluated the carbon sink capacity of urban street trees, highlighting the significance of tree diversity and thoughtful planting in improving carbon storage in urban areas (Singh et al., 2024).

Delhi, being one of the most densely populated urban areas globally, illustrates these difficulties. The fast pace of urbanization has led to the increase of impervious surfaces such as roads, buildings, and parking lots that displace natural environments and diminish the ability for carbon absorption and temperature control. These surfaces likewise enhance surface runoff, put pressure on stormwater systems, and add to flash flooding (Zhou et al., 2011). The substitution of green spaces with concrete results in decreased photosynthetic activity, subsequently lowering the carbon sink capability of the environment. In this setting, urban green infrastructure such as parks, street trees, green roofs, and wetlands arises as a crucial approach for boosting urban resilience. Urban forests specifically serve as multifunctional resources that provide climate control, enhance biodiversity, lower energy consumption, and boost human well-being (Tzoulas et al., 2007). However, even with their demonstrated advantages, these areas are frequently overlooked in urban planning and susceptible to developmental intrusions.

Diameter at Breast Height (DBH) is commonly acknowledged as a key measure for assessing tree biomass and carbon sequestration in both forest and urban environments. Many studies indicate that trees with higher DBH values typically possess greater above-ground biomass, playing a crucial role in carbon sequestration. India's tropical dry forests showed that larger

DBH categories significantly affect total carbon stocks (Raha et al., 2020). Their research highlights the ecological importance of maintaining mature trees, which, despite being less numerous, contains most of the carbon stored in the ecosystem.

This trend is mirrored in conserved environments like the Chinnar Wildlife Sanctuary, where it was discovered that trees with DBH measurements over 70 cm possessed greater biomass and carbon densities, emphasizing their significance in long-term carbon retention (Padmakumar et al., 2018). The investigators emphasized the supportive role of medium and small DBH category trees, which signify future carbon storage capacity and continuous forest rejuvenation. These insights highlight the significance of maintaining a balanced distribution among DBH classes for effective forest management and carbon accounting.

The class-wise analysis of DBH has also demonstrated its usefulness in urban settings. Research on urban forests in the United States revealed that the ideal DBH distribution for enhancing carbon sequestration differs based on the goals of urban forests. Although bigger trees hold more carbon, ensuring a consistent influx of young trees is crucial for sustainable carbon sequestration overall (Morgenroth et al., 2020). This variety in age and size also improves resilience to urban challenges like pollution, drought, and physical damage.

Studies conducted on UGS in Tehran further support the significance of DBH in carbon research. Employing the i-Tree Eco model, gathered field data regarding species, DBH, and overall height to assess carbon sequestration and storage (Rasoolzadeh et al., 2024). Their research revealed that even in extremely polluted mega-cities, DBH continues to be a dependable metric for measuring ecosystem services, particularly in urban tree populations that are mixed-species and unevenly spaced.

Similarly, studies in community-managed forests such as those in Nepal have used DBH size-class distribution curves to visualize and interpret vegetation structure and carbon sequestration potential (Sharma et al., 2020). It reported that pine plantations with a healthy range of DBH classes not only had greater carbon stock but also showed promising signs of natural regeneration, ensuring continued sequestration into the future.

Despite these challenges, Delhi presents considerable prospects for improving its urban forestry environment. Incorporating urban forestry into city and climate action strategies can promote lasting resilience in the city's ecosystems (Borelli et al., 2023). Community-oriented methods, such as engaging citizens in greening initiatives, conducting tree inventories, and monitoring efforts, can enhance stewardship and boost tree survival rates (Esperon-Rodriguez et al., 2025). Technological resources such as i-Tree Eco now allow for more accurate assessment of the ecosystem services offered by urban trees, including carbon storage, air purification, and temperature control (Tripathi & Joshi, 2015).

To sum up, urban forestry in Delhi stands at a pivotal point. Although there are significant risks from policy deficiencies, environmental challenges, and urban growth pressures, there are also new chances available via data-informed planning, sustainable design, and community involvement. By viewing trees not just as components of the landscape but as vital infrastructure offering essential ecosystem services, Delhi can improve its sustainability and resilience amidst increasing environmental challenges (Babu & Singh, 2024).

# 5. Material & Methods:

## 5.1. Study Area

The present study was carried out in District Park, Hauz Khas, located in South Delhi. Enclosing about 149 acres, the park is among the city's large green spaces and is taken care of by the Delhi Development Authority (DDA) (Figure 1). A District Park has a sizeable area which is developed to provide vital lung spaces (Urban Greening Guidelines, 2014). The park is situated in larger Hauz Khas complex comprising of Deer Park, Rose Garden, a huge lake surrounded by monuments and a combination of the forest area and the ornamental garden. The park is well connected to major roads, metro stations (Hauz Khas metro station), residential and institutional zones, which makes it an excellent study site as it serves as a crucial recreational as well as ecological space. This region supports a diverse range of tree species, both native and exotic such as *Azadirachta indica*, *Ficus religiosa, Prosopis juliflora, Delonix regia* and more, thereby making it an area with high biodiversity. Some bird species that were observed during the study are Jungle Babbler, Indian Grey Hornbill, Red-Naped Ibis, Greater Coucal, Indian Peafowl, Red-whiskered Bulbul, and more. These features make District Park the perfect place to use i-Tree Eco to evaluate ecosystem services and develop well-informed urban forest management plans.

Delhi encloses an area of 1483 square kilometres (28° 22' N to 28° 54' N, 76° 48' E to 77° 23'), of which 1113.65 square kilometres is designated under urban area (Economic Survey of Delhi, 2023-24). It is projected that from 2018 to 2030, the population of Delhi will increase by 10 million inhabitants (World Urbanization Prospect, 2018). The population density is about 11,320 persons per square kilometres (Census India, 2011) (Table 2). The city experiences a semi-arid climate with extreme seasonal variation. The summer months (April- June) are extremely hot with temperatures rising above 45°C, while winter has temperature drop below 5°C. The rainy season begins in June and continues till October (Delhi Heat Action Plan, 2024-25).

Table 2: Delhi District Wise Population (Source: Delhi Heat Action Plan, 2024-25)

| Districts | Population (2011) |
|---|---|
| **North-East** | 22,40,749 |
| **East** | 17,07,725 |
| **Central** | 14,27,910 |
| **West** | 25,31,583 |
| **North** | 8,87,978 |
| **North-West** | 22,46,311 |
| **South** | 12,33,401 |
| **New Delhi** | 11,73,902 |
| **South-West** | 17,49,492 |
| **South-East** | 15,00,351 |
| **Shahdara** | 22,40,749 |

Over time, Delhi's green cover has changed. Delhi's total green cover, which includes both forest and tree cover, is estimated to be 371.3 square kilometres, or 25% of its total land area (India State of Forest Report, 2023). This includes 195.28 square kilometres that fall under the forest department. The forest structure of the city is varied, with important regions such as the Central Ridge and the Northern Aravalli Range acting as essential green spaces. The area under different forest types in Delhi based on Champion & Seth Forest Classification, 1968 (Forest Cover Map, ISFR-2023) is shown below (Table 3).

Table 3: Area Statistics of the Forest Types Found in Delhi (Source: India State of Forest Report, 2023)

| Forest Type | Area ($km^2$) | % of the total mapped area |
|---|---|---|
| 5B/C2 Northern dry mixed deciduous forest | 20.41 | 10.33 |
| 6B/C2 Ravine thorn forest | 64.48 | 32.62 |
| **Sub Total** | **84.89** | **42.95** |
| Trees Outside Forest (TOF) Plantation | 112.78 | 57.05 |
| **Total (Forest Cover & Scrub)** | **197.67** | **100.00** |

The city's biodiversity is enhanced by the variety of native and exotic tree species found in these areas. Some of the common species of Delhi are *Cassia fistula, Nyctanthes arbor-tristis, Ehretia laevis, Neolamarckia cadamba, Acacia auriculiformis, Mimusops elengi*, and more (Delhi Forest Department, 2025).

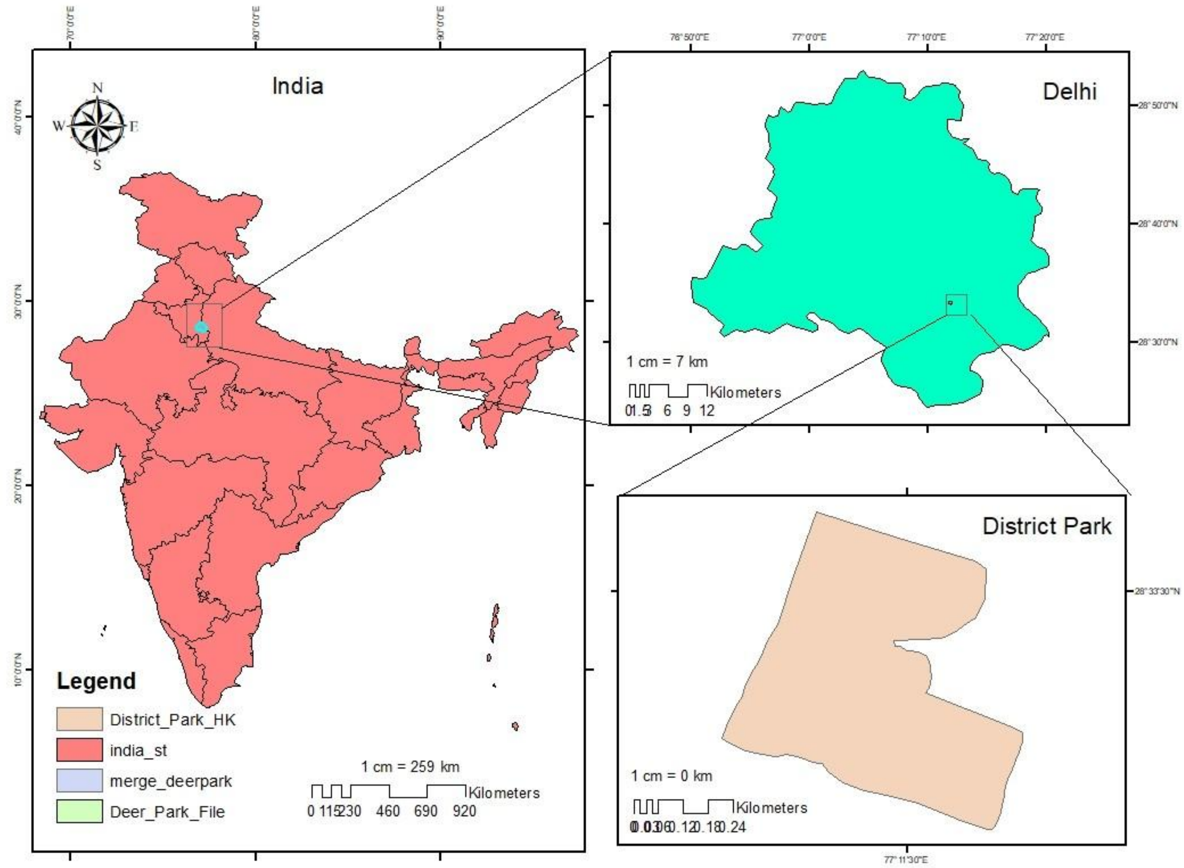


Figure 1: Study Area Map

### 5.2. Methodology

The structure and ecosystem services offered by the tree in District Park, Hauz Khas, Delhi was evaluated using the i-Tree Eco method and software (6.1.53). The U.S. Forest Service Northern Research Station (NRS), USDA State and Private Forestry's Urban and Community Forestry Program and Northeastern Area, Davey Tree Expert Company, and SUNY College of Environmental Science and Forestry collaborated to develop the Urban Forest Effects (UFORE) model, which is adapted in i-Tree Eco.

#### 5.2.1. Sampling Design and Plot Distribution:

The sampling strategy for estimating the potential for carbon sequestration by trees was a plot-based inventory approach. A random sampling technique was used to produce results that were statistically significant. Plots were distributed at random throughout the park. As recommended by the i-Tree Eco manual, each plot had a standard size of 0.04 hectares (400 m² or 12 m radius). To achieve the best possible balance between accuracy and efficiency, the number of plots to be surveyed was determined based on the park's size and vegetation density. A total of 140 plots were selected based on i-Tree Eco’s guidelines, which recommend enough plots to ensure that the data collected is representative of the park's overall tree population (USFS, 2021b). The decision to take 140 plots was made to provide a robust sample size that would allow for statistically significant estimates of carbon sequestration potential while maintaining efficiency in terms of time and resources (USFS, 2021a). This number of plots helped ensure that the variability in tree species, sizes, and conditions within the park was adequately captured, thus providing accurate and reliable results for the study.

#### 5.2.2. Field Data Collection:

It was conducted using standardized i-Tree Eco protocols from February to May. The following parameters were recorded for each randomly selected plot:

**Tree-Level Attributes:**

- Tree species identification
- Diameter at Breast Height (DBH) at 1.37 m (4.5 feet)
- Total Tree Height
- Total Crown Height

- Crown width (measured in two perpendicular directions)
- Crown Dieback percentage
- Crown Missing percentage

**Plot-Level Attributes:**

- GPS Coordinates of Plot Centres
- Land-Use Classifications

**The Instruments and tools used during data collection:**

- Measuring Tape (30m): For measuring crown width in two perpendicular directions and to assist in tree spacing measurements within plots. It was also used to measure the DBH of tree at 1.37 meters above ground level.
- GPS Device (Garmin eTrex 20 or equivalent): Used to record the geographic coordinates of the plot centre to ensure accurate mapping and future revisit.
- Clinometer: Used to measure the height of the tree.
- Compass: Used to find the plot accurately.
- Field Datasheets and Clipboard: For recording field data manually during collection (Annexure1).
- Smartphone: It was used to enter the data on i-Tree Software.
- Species Identification Guides: Including field guidebook Trees of Delhi by Pradip Krishen and mobile applications (such as Google Lens and PlantNet) to assist in accurate species identification when uncertainties arose.

**5.2.3. Data Processing and Model Execution in i-Tree Eco:**

Once the field data was collected, it was uploaded and processed in the i-Tree Eco software during the month of May. After processing the data, the outcomes were examined to assess species distribution, carbon sequestration rates, and to determine the most efficient species for future planting initiatives. The findings from the i-Tree Eco model facilitated the creation of suggestions to improve carbon capture and the park's overall sustainability. The information was likewise analysed alongside national and global benchmarks to contextualize the park's role in efforts to mitigate climate change. This detailed data processing phase was vital for guaranteeing the precision and dependability of the carbon sequestration estimates, which are important for guiding urban forestry management and climate policy choices.

Figure 2: Field Activities

### 5.2.4. Framework for Evaluation and Recommendation of Tree Species

In urban green space assessments, a structured, trait-based scoring system provides a practical means to quantify and compare ecosystem service contributions across multiple tree species. The scoring basis adopted ranged from 1 to 5 for each indicator and was developed to evaluate key traits linked with ecosystem functions such as carbon storage, carbon sequestration, tree height, DBH, etc. This approach is directly aligned with the "trait–service" framework proposed by a study who emphasized that specific tree traits including DBH, height, crown size, foliage type, and origin strongly determine the magnitude and type of ecosystem services delivered in urban areas. For instance, trees with larger DBH and height were found to sequester more carbon and support higher biomass, indicating their maturity and long-term contribution to carbon storage. Thus, higher scores (e.g., 5 for DBH > 80 cm) are allocated to trees with these traits, reflecting their superior functional role in carbon retention (Liang & Huang, 2023).

Similarly, crown area and height are directly associated with the provision of shade, temperature regulation, and rainfall interception. The study also highlighted that these traits are crucial for mitigating urban heat island effects, with studies showing that larger canopy size and higher leaf area index (LAI) enhance both shading and transpiration-based cooling. Therefore, in the scoring scheme, trees with crown areas above 40 $m^2$ and heights exceeding 20 m are awarded the highest scores, recognizing their higher efficiency in microclimate regulation. Foliage type is another critical parameter, evergreen species retain their leaves year-round and offer continuous regulatory benefits such as dust retention, air pollution mitigation, and noise reduction. This study noted that evergreens, with denser leaf morphology and longer leaf retention, have stronger pollutant adsorption capabilities. Hence, evergreen trees are scored highest in this category (Liang & Huang, 2023).

The scoring also considers the ecological origin of the species, distinguishing between native and exotic trees. Native species often support local biodiversity more effectively and exhibit greater ecological compatibility. The research observed that planting native species contributes to overall ecosystem resilience and enhances provisioning services such as food and habitat supply (Liang & Huang, 2023). As such, species are scored progressively from highly invasive exotics (score 1) to native species (score 5). In terms of urban utility, traits such as medicinal value, shade provision, pollution tolerance, and biodiversity support are combined to reflect multifunctionality. According to the same study, trees that serve multiple urban functions provide not just environmental benefits but also social and psychological ones, contributing to landscape aesthetics, health outcomes, and community wellbeing.

This structured scoring system thus operationalizes the complex relationships between tree traits, and their ecosystem service outputs into a clear, actionable framework. It allows for comparative evaluation and prioritization of species in urban planning, echoing the study's call for trait-based selection to optimize ecosystem service delivery (Liang & Huang, 2023). By numerically encoding key ecological attributes, this method supports informed decision-making in urban forestry, sustainable planning, and biodiversity conservation. The framework supports data-driven, sustainable species selection in urban green space planning (Table 4).

Table 4: Criteria and Scoring Framework for Evaluating Tree Species in Urban Ecosystems

| Criteria | Indicator | Rationale of Criteria | Scoring basis (1-5) |
|---|---|---|---|
| **Carbon Storage** | Total carbon stored (in tonnes) | Indicates long-term carbon retention; helps in carbon accounting | 1 = < 5 t, 2 = 5-20 t, 3 = 20.1–40 t, 4 = 40.1–60 t, 5 = >60 t |
| **Carbon Sequestration** | Annual sequestration (t/year) | Measures annual climate benefit from ongoing photosynthesis | 1 = < 0.1 t/year, 2 = 0.1–0.3 t/year, 3 = 0.31–0.5 t/year, 4 = 0.51–0.8 t/year, 5 = >0.8 t/year |
| **DBH** | Proportion of individuals in mature DBH classes | Reflects biomass potential and maturity; useful for estimating growth rates | 1 = < 20 cm, 2 = 20.1–40 cm, 3 = 40.1–60 cm, 4 = 60.1–80 cm, 5 = >80 cm |
| **Tree Height** | Top height of tree (in metres) | Taller trees contribute more to skyline and shade | 1 = < 5 m, 2 = 5.1–10 m, 3 = 10.1–15 m, 4 = 15.1–20 m, 5 = >20 m |
| **Crown Area** | Average crown area of tree ($m^2$) | Larger crowns provide more shade, cooling, and pollution filtration | 1 = < 10 $m^2$, 2 = 10.1–20 $m^2$, 3 = 20.1–30 $m^2$, 4 = 30.1–40 $m^2$, 5 = >40 $m^2$ |
| **Native vs. Exotic** | Origin of species (Native/Exotic) | Native species are ecologically better adapted and support biodiversity | 1 = Highly invasive exotic, 2 = Exotic with neutral ecological role, 3 = Mixed origin, 4 = Semi-native, 5 = Native species |
| **Foliage Type** | Evergreen / Deciduous / Perennial | Evergreens sequester year-round and provide year-long foliage benefits | 1 = Deciduous (short duration), 2 = Deciduous (longer duration), 3 = Perennial, 4 = Mix with evergreen, 5 = Evergreen |
| **Urban Utility** | Benefits such as shade, medicinal, biodiversity, pollution tolerance | Multi-utility species are more valuable in urban design and ecosystem services | 1 = Single benefit (e.g., only shade), 2 = Shade + aesthetic, 3 = Shade + pollution tolerance, 4 = Shade + multiple ecosystem services, 5 = Shade + medicinal + biodiversity + pollution mitigation |

# 6. Results:

### 6.1. Objective 1: Inventory of Tree Species and DBH Classes

#### 6.1.1. Species Composition

The study provides a detailed enumeration of 415 individual trees belonging to 45 different species and classified under 29 families. The species listed include both native and exotic origins, encompassing a diverse range of evergreen, deciduous, and perennial trees. The most abundant species in terms of number is *Polyalthia longifolia*, with 51 individuals categorized under the Annonaceae family. This is followed by *Ficus benjamina* with 48 individuals and *Caryota urens* with 44 individuals. Both species are evergreen and serve ornamental and shade purposes.

*Alstonia scholaris*, with 28 individuals, belongs to the Apocynaceae family and is noted for its bark use in traditional medicine. *Bombax ceiba*, with 26 individuals, is deciduous and used for ornamental avenues and seasonal flowers, also providing lightweight timber. The list continues with *Pongamia pinnata*, a nitrogen-fixing deciduous species with 26 individuals known for its use in biodiesel and roadside shade. *Putranjiva roxburghii* follows with 21 individuals. It is an evergreen tree known for small green shade and sacred grove planting.

*Syzygium cumini* and *Grevillea robusta* are represented by 17 and 16 individuals, respectively. *Syzygium cumini* is a fruit-bearing evergreen tree, while *Grevillea robusta* is a fast-growing evergreen tree with fine dappled shade. The palm species *Roystonea regia*, with 15 individuals, serves primarily as a formal ornamental tree. *Cassia fistula* is deciduous and used for seasonal flowering and traditional medicine, present in 13 individuals. *Eucalyptus globulus* is recorded with 12 individuals, known for its fast-growing nature and allelopathic effects.

*Terminalia bellirica* and *Ficus virens* have 11 and 8 individuals, respectively. Both are native species; *Terminalia bellirica* is used in traditional medicine and tanning, while *Ficus virens* provides deep shade and is valued in ecological buffer zones. *Ficus racemosa* and *Ficus religiosa* represent the Moraceae family with 7 and 6 individuals. Both are ecologically and culturally significant, used in traditional medicine and religious contexts. *Prosopis juliflora*, an exotic species with 6 individuals, is drought-tolerant and useful for soil stabilization via nitrogen fixation.

Other trees with 5 or more individuals include *Bauhinia racemosa*, *Dalbergia sissoo*, *Albizia lebbeck*, and *Mimusops elengi*. These species are commonly planted for their timber, shade, or medicinal properties. *Phyllanthus emblica* is known for its edible fruit rich in vitamin C and is represented by 4 individuals. *Pterygota alata* also has 4 individuals, and it serves as an ornamental tree and is known for its shade. *Jacaranda mimosifolia*, and *Morus alba* are each listed with 3 individuals, known for their ornamental or economic uses.

Species with fewer individuals include *Ailanthus excelsa*, *Azadirachta indica*, *Artocarpus heterophyllus*, *Ehretia laevis*, *Lagerstroemia speciosa*, and *Leucaena leucocephala*. These are either native or exotic, offering diverse urban benefits like shade, medicinal uses, or fast growth. Trees with minimal representation, typically one or two individuals, include *Pithecellobium dulce*, *Plumeria obtusa*, *Callistemon viminalis*, *Ceiba speciosa*, *Citrus limon*, *Delonix regia*, *Diospyros melanoxylon*, and *Ficus benghalensis*. These species span a range of urban utilities including timber, ornamental use, and cultural value.

The list also features lesser-known but valuable species like *Moringa oleifera*, *Peltophorum pterocarpum*, *Populus deltoides*, *Senna siamea*, *Terminalia arjun*, and *Ziziphus mauritiana*. Most of these have applications in urban greening, traditional medicine, or agroforestry. They are underrepresented in the current population, highlighting a need for more diversified planting.

Habit-wise, evergreen trees dominate the list, especially in urban planting schemes due to their year-round foliage. Species like *Ficus benjamina*, *Polyalthia longifolia*, *Syzygium cumini*, and *Grevillea robusta* are repeatedly seen for their consistent canopy and ornamental value. Deciduous species like *Cassia fistula*, *Bombax ceiba*, and *Terminalia bellirica* are seen for their flowering or shade-providing qualities, while perennials like *Roystonea regia* offer long-term landscape structure.

In terms of origin, the distribution leans heavily on native species, reflecting ecological adaptation and cultural significance. However, a considerable number of exotic species are also present, particularly those introduced for fast growth, ornamental use, or resilience in urban conditions. Examples include *Prosopis juliflora*, *Grevillea robusta*, *Callistemon viminalis*, and *Peltophorum pterocarpum*.

Each species is associated with a specific urban utility, whether it's for ornamental use, shade provision, medicinal applications, fruit production, ecological services like nitrogen fixation, or material benefits such as timber or fiber. Trees like *Ficus religiosa*, *Ficus racemosa*, *Azadirachta indica*, and *Phyllanthus emblica* emphasize traditional medicine and cultural utility, while others like *Dalbergia sissoo* and *Pterygota alata* are more valued for their timber.

This distribution illustrates a moderate diversity in species and family representation. The species count of 45 across 29 different families indicates a fair spread, although certain families such as Moraceae and Fabaceae are more prominent. Moraceae is well-represented by various *Ficus* species, each fulfilling different ecological and cultural roles (Table 5).

Table 5: Inventory of Tree Species in District Park, Hauz Khas

| Species Name | Common Name | No. of Individuals | Family | Origin | Habit | Urban Utility |
|---|---|---|---|---|---|---|
| *Polyalthia longifolia* | False Ashok | 51 | Annonaceae | Native | Evergreen | Ornamental; noise buffer |
| *Ficus benjamina* | Weeping Fig | 48 | Moraceae | Native | Evergreen | Ornamental; small-tree street planting; air-purifying |
| *Caryota urens* | Fishtail Palm | 44 | Arecaceae | Native | Evergreen | Ornamental; shade under canopy |
| *Alstonia scholaris* | Scholar Tree | 28 | Apocynaceae | Native | Evergreen | Avenue tree; dense evergreen shade |
| *Bombax ceiba* | Silk Cotton Tree | 26 | Malvaceae | Native | Deciduous | Tropical ornamental; seasonal flowers |
| *Pongamia pinnata* | Karanj | 26 | Fabaceae | Native | Deciduous | Nitrogen-fixing; oilseed (biofuel); roadside shade |
| *Putranjiva roxburghii* | Putranjiva | 21 | Putranjivaceae | Native | Evergreen | Dense evergreen shade; small avenue tree; sacred grove planting |
| *Syzygium cumini* | Jamun | 17 | Myrtaceae | Native | Evergreen | Fruit; shade |
| *Grevillea robusta* | Silk Oak | 16 | Proteaceae | Exotic | Evergreen | Ornamental; fine dappled shade; nectar source for birds |
| *Roystonea regia* | Royal Palm | 15 | Arecaceae | Exotic | Perennial | Formal ornamental; avenue tree; minimal canopy spread |
| *Cassia fistula* | Amaltas | 13 | Caesalpiniaceae | Native | Deciduous | Iconic golden flowers; ornamental avenues |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Eucalyptus globulus* | Blue Gum | 12 | Myrtaceae | Exotic | Evergreen | Fast-growing windbreak/shade; allelopathic understorey |
| *Terminalia bellirica* | Baheda | 11 | Combretaceae | Native | Deciduous | Small shady tree; Edible fruit; Medicinal |
| *Ficus virens* | Pilkhan | 8 | Moraceae | Native | Deciduous | Avenue and park shade; robust urban survivor; ecological buffer |
| *Ficus racemosa* | Cluster Fig | 7 | Moraceae | Native | Evergreen | Ecological fruit tree; moderate shade |
| *Ficus religiosa* | Peepal | 6 | Moraceae | Native | Deciduous | Sacred cultural/medicinal; deep shade; wildlife habitat |
| *Prosopis juliflora* | Mesquite | 6 | Mimosaceae | Exotic | Deciduous | Drought-tolerant shade; fuelwood; soil stabilization via Nitrogen-fixation |
| *Bauhinia racemosa* | Bidi Leaf Tree | 5 | Caesalpiniaceae | Native | Deciduous | Ornamental flowering |
| *Dalbergia sissoo* | Shisham | 5 | Fabaceae | Native | Deciduous | Timber; avenue and park shade; nitrogen fixation |
| *Albizia lebbeck* | Siris Tree | 4 | Mimosaceae | Native | Perennial | Ornamental; light-dappled shade; nitrogen-fixing |
| *Mimusops elengi* | Maulsari | 4 | Sapotaceae | Native | Perennial | Fragrant flowers; small-tree ornamental |
| *Phyllanthus emblica* | Amla | 4 | Phyllanthaceae | Native | Deciduous | Fruit (high-vitamin C); herbal medicine; small canopy |
| *Pterygota alata* | Buddha Coconut | 4 | Sterculiaceae | Native | Evergreen | Large shade tree; timber; ornamental |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Jacaranda mimosifolia* | Neeli Gulmohar | 3 | Bignoniaceae | Exotic | Deciduous | Iconic lavender flowers; formal avenues; medium shade |
| *Morus alba* | Mulberry | 3 | Moraceae | Exotic | Perennial | Fruit; silk-worm forage; small-to medium shade |
| *Ailanthus excelsa* | Indian Tree of Heaven | 2 | Simaroubaceae | Native | Deciduous | Fast-growing shade tree; timber (poles) |
| *Artocarpus heterophyllus* | Jackfruit | 2 | Moraceae | Native | Evergreen | Urban food tree (fruit); large shade canopy; timber from pruned branches |
| *Azadirachta indica* | Neem | 2 | Meliaceae | Native | Evergreen | Street tree; air-purification; insect-repellent canopy; medicinal leaves |
| *Ehretia laevis* | Chamror | 2 | Boraginaceae | Native | Deciduous | Small-tree Street planting; medicinal fruit; wildlife-friendly |
| *Lagerstroemia speciosa* | Pride of India | 2 | Lythraceae | Native | Evergreen | Ornamental flowering; street tree; seasonal shade |
| *Leucaena leucocephala* | Subabul | 2 | Mimosaceae | Exotic | Evergreen | Nitrogen-fixing; fast cover/shade; fodder; erosion control |
| *Pithecellobium dulce* | Sweet Tamarinf | 2 | Mimosaceae | Exotic | Perennial | Edible pods; fodder; wildlife attraction; light shade |
| *Plumeria obtusa* | White Frangipani | 2 | Apocynaceae | Exotic | Evergreen | Fragrant ornament; small-tree or shrub; temple planting |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Callistemon viminalis* | Weeping Bottle Brush | 1 | Myrtaceae | Exotic | Evergreen | Ornamental flowering hedge or screen; bird-attracting |
| *Ceiba speciosa* | Silk Floss Tree | 1 | Malvaceae | Exotic | Perennial | Lightweight fibre from pods |
| *Citrus limon* | Lemon | 1 | Rutaceae | Native | Perennial | Fruit production; container-grown ornamental; fragrant blossoms |
| *Delonix regia* | Gulmohar | 1 | Caesalpiniaceae | Exotic | Evergreen | Spectacular flowering; broad shade canopy; street and park ornamental |
| *Diospyros melanoxylon* | Black Ebony | 1 | Ebenaceae | Native | Deciduous | High-value timber; fine ornamental; traditional lac-resin |
| *Ficus benghalensis* | Banyan | 1 | Moraceae | Native | Evergreen | Landmark shade; ecological (bird/insect habitat); aerial root support |
| *Moringa oleifera* | Drumstick Tree | 1 | Moringaceae | Native | Deciduous | Edible pods and leaves; medicinal; light shade |
| *Peltophorum pterocarpum* | Peeli Gulmohar | 1 | Caesalpiniaceae | Exotic | Evergreen | Golden-flowered shade tree; avenue planting; light timber |
| *Populus deltoides* | Poplar | 1 | Salicaceae | Exotic | Deciduous | Fast-growing windbreak and shade; light timber |
| *Senna siamea* | Siamese Cassia | 1 | Caesalpiniaceae | Native | Evergreen | Ornamental; light filtered shade |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Terminalia arjuna* | Arjun | 1 | Combretaceae | Native | Evergreen | Riverbank stabilizer; medicinal bark; medium canopy |
| *Ziziphus mauritiana* | Ber | 1 | Rhamnaceae | Native | Deciduous | Drought-tolerant; edible fruit; small-tree amenity; bird habitat |

### 6.1.2. Native & Exotic Species Composition:

The study in District Park, Hauz Khas, revealed that 32 (71%) of the species are native, while the remaining 13 (29%) are exotic. This distribution indicates a strong preference or prevalence of native species in the selected urban environment (Figure 3).

Native species play a crucial role in maintaining the ecological balance of a region. They are better adapted to local climatic, soil, and biotic conditions, and they tend to require less maintenance compared to exotic counterparts. Additionally, native trees often support a wider range of local fauna, including birds, insects, and mammals, thereby enhancing biodiversity and ecological resilience.

On the other hand, the 29% representation of exotic species suggests a degree of diversification in urban planning strategies. Exotic trees are often introduced for their aesthetic appeal, faster growth, or ecological functions such as nitrogen fixation or drought tolerance. However, while some exotic species integrate well with native ecosystems, others may pose ecological risks, including competition with native flora, reduced habitat suitability for native fauna, or invasive tendencies that disrupt local biodiversity.

This ratio of native to exotic species can inform future urban planning and ecological restoration efforts. Emphasizing native species in green infrastructure projects promotes sustainability and ecological compatibility, while the cautious and strategic use of exotic species can enhance certain ecosystem services without compromising the integrity of local ecosystems.

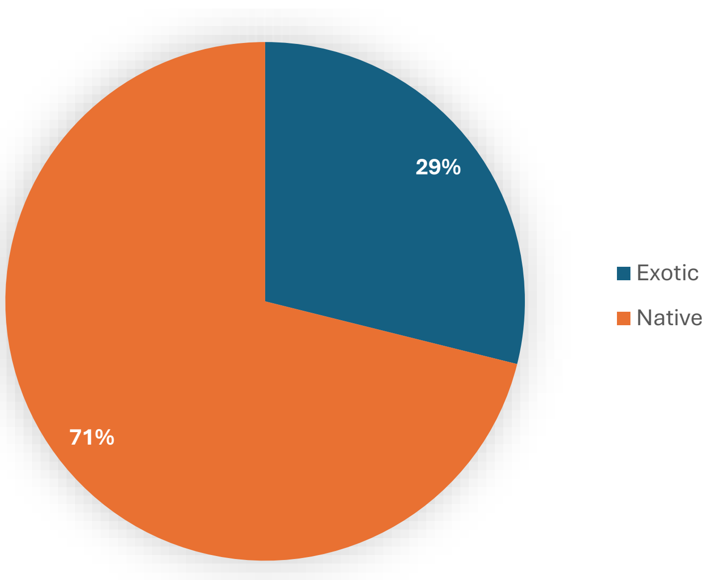


Figure 3: Species Composition based on Origin

### 6.1.3. Leaf Retention based Species Composition:

According to the data, evergreen species make up the largest portion, constituting 21 (47%) of the total species. Deciduous trees follow closely behind at 17 (38%), while perennial species account for 7 (15%) (Figure 4).

The dominance of evergreen species suggests a preference for trees that maintain their foliage throughout the year, providing consistent shade, visual greenery, and ecosystem services such as air purification and carbon sequestration. These trees are particularly valuable in urban environments, as they help mitigate heat islands and offer year-round aesthetic and environmental benefits.

Deciduous trees, which shed their leaves seasonally, also play a significant role, making up more than a third of the total. Their presence contributes to seasonal variation in the landscape, supports biodiversity by allowing light penetration during the dormant season, and provides organic litter that enriches the soil. Moreover, their leaf shedding allows for natural cooling in summers and light penetration in winters, making them energy-efficient choices in urban planning.

Perennial species, though fewer in number at 15%, offer specific ecological benefits such as long-term ground cover, soil stabilization, and habitat provision. These species can be crucial in supporting understory biodiversity and maintaining ecosystem functions over extended periods, especially in mixed-species landscapes.

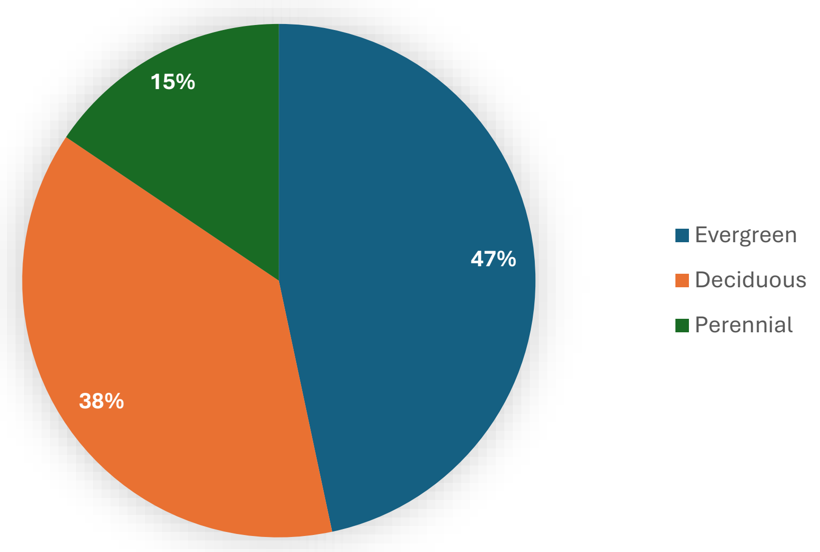


Figure 4: Species Composition based on Leaf Retention

### 6.1.4. Functional Uses of Tree Species

A comprehensive inventory of various tree species and their associated functions in urban environments, highlighting their ecological and utilitarian significance is formulated. It includes the scientific names of 45 tree species, each evaluated for a range of urban utility roles. These roles are categorized under several abbreviations, where OR represents Ornamental, SP stands for Shade Provider, AV for Avenue Plantation, FB for Fruit Bearer, NF for Nitrogen Fixing, WB for Wind Breaker, TI for Timber, HM for Herbal & Medicinal, AP for Air Purification, FO for Fodder, WP for Wildlife Protection, and DT for Drought Tolerant (Figure 5).

A notable trend in the data is that many tree species serve multifunctional roles, fulfilling multiple ecosystem services. For example, *Azadirachta indica* is highlighted across numerous categories. It is listed under ornamental, shade provision, avenue plantation, nitrogen fixation, air purification, drought tolerance, herbal and medicinal, and timber utility. This reflects neem's vast ecological importance, including its capacity to purify air, withstand drought, improve soil fertility through nitrogen fixation, and provide herbal medicinal value making it a cornerstone species in any urban greening initiative.

Another versatile species is *Ficus religiosa*, which is listed under ornamental, shade provider, avenue plantation, herbal and medicinal, air purification, and wildlife protection. The broad canopy and ability to survive in various urban conditions make members of the *Ficus* genus including *F. benjamina*, *F. benghalensis*, *F. racemosa*, and *F. virens* highly beneficial for enhancing urban biodiversity, controlling microclimate, and supporting wildlife. Their presence is crucial in densely populated cities where natural habitats are shrinking, providing refuge to birds and small mammals.

*Pongamia pinnata* is another example of a highly utilitarian tree. It is identified as a shade provider, nitrogen fixer, and is recognized for its roles in air purification, drought tolerance, and as a wind breaker. Such traits are extremely valuable in urban areas like Delhi, where heat stress, dust, and pollution levels are alarmingly high. *Pongamia pinnata* contributes to soil enrichment and can also be used as a biofuel source, adding to its ecological and economic value.

While many species offer multi-dimensional benefits, some are included in the table primarily for their ornamental value. For instance, *Callistemon viminalis* is marked only under ornamental, highlighting its appeal in beautifying landscapes rather than offering broader ecosystem services. Similarly, *Jacaranda mimosifolia* is included for ornamental, shade, and avenue planting purposes, indicating its visual appeal and potential for urban aesthetics.

Fruit-bearing species are well represented in the table under the FB category. *Artocarpus heterophyllus*, *Morus alba*, and *Phyllanthus emblica* are notable examples. These species not only provide nutritional benefits but also contribute to food security and the greening of city landscapes. Their integration into urban forests and parks encourages biodiversity and supplies fruits for both humans and urban wildlife.

Nitrogen-fixing species like *Albizia lebbeck*, *Leucaena leucocephala*, and *Pithecellobium dulce* enhance soil fertility, which is particularly useful in degraded urban soils that lack essential nutrients. These species contribute to long-term ecological restoration, making them ideal candidates for reforestation projects in urban and peri-urban areas.

Trees listed under drought-tolerant are especially crucial for sustainable urban greening in water-scarce environments. Species such as *Prosopis juliflora*, *Syzygium cumini*, *Pithecellobium dulce*, and *Polyalthia longifolia* are examples that exhibit high adaptability in arid conditions, making them suitable for water-deficient urban landscapes. These drought-tolerant trees ensure longevity and ecosystem stability with minimal maintenance.

Timber-providing trees such as *Cassia fistula*, *Dalbergia sissoo*, and *Delonix regia* offer economic benefits, especially in peri-urban regions where communities may utilize wood for construction or fuel. However, care must be taken to balance these uses with conservation goals to ensure sustainable harvest.

Air purification is a vital urban ecosystem service, especially in pollution-heavy cities like Delhi. Species like *Polyalthia longifolia*, *Terminalia arjuna*, *Syzygium cumini*, and *Roystonea regia* are marked under this category for their ability to trap dust, absorb pollutants, and release oxygen. They serve as natural filters and improve overall air quality, contributing significantly to public health.

The category of wildlife protection includes trees such as *Ficus racemosa*, *Ficus religiosa*, and *Pithecellobium dulce*, which provide habitat and food for birds, insects, and other small urban wildlife. These species are instrumental in maintaining urban biodiversity, especially in areas where natural ecosystems are rapidly declining due to urban sprawl.

Lastly, herbal, and medicinal trees like *Grevillea robusta*, *Phyllanthus emblica*, and *Moringa oleifera* offer both health and economic benefits. Their parts leaves, bark, seeds are used in traditional medicine and contribute to the cultural and medicinal landscape of the urban environment (Table 6).

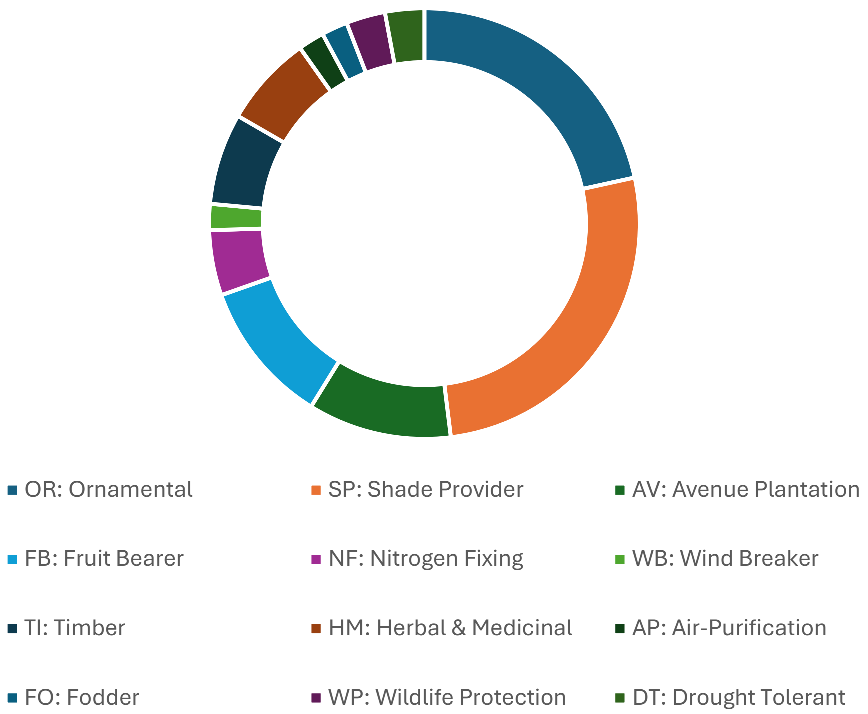


Figure 5: Utility based classification of Tree Species

Table 6: Urban Utilities Provided by Tree Species

| Species | Urban Utility | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **OR** | **SP** | **AV** | **FB** | **NF** | **WB** | **TI** | **HM** | **AP** | **FO** | **WP** | **DT** |
| *Ailanthus excelsa* | ✓ | | | | | | ✓ | | | | | |
| *Albizia lebbeck* | ✓ | ✓ | | | ✓ | | | | | | | |
| *Alstonia scholaris* | ✓ | ✓ | ✓ | | | | | | | | | |
| *Artocarpus heterophyllus* | | ✓ | | ✓ | | | ✓ | | | | | |
| *Azadirachta indica* | | | | | | | | ✓ | ✓ | | | |
| *Bauhinia racemosa* | ✓ | | | | | | | | | | | |
| *Bombax ceiba* | ✓ | | | | | | | | | | | |
| *Cassia fistula* | ✓ | | | | | | | | | | | |
| *Senna siamea* | ✓ | ✓ | | | | | | | | | | |
| *Caryota urens* | ✓ | ✓ | | | | | | | | | | |
| *Callistemon viminalis* | ✓ | | | | | | | | | | | |
| *Ceiba speciosa* | | | | | | | | | | | | |
| *Citrus limon* | ✓ | | | ✓ | | | | | | | | |
| *Dalbergia sissoo* | | ✓ | ✓ | | ✓ | | ✓ | | | | | |
| *Delonix regia* | ✓ | ✓ | ✓ | | | | | | | | | |
| *Diospyros melanoxylon* | ✓ | | | | | | ✓ | | | | | |
| *Ehretia laevis* | | | ✓ | ✓ | | | | ✓ | | | ✓ | |
| *Eucalyptus globulus* | | | | | | ✓ | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ficus benjamina* | ✓ | | ✓ | | | | | ✓ | | | |
| *Ficus benghalensis* | | ✓ | | | | | | | | ✓ | |
| *Ficus racemosa* | | ✓ | | ✓ | | | | ✓ | | | | |
| *Ficus religiosa* | | ✓ | | | | | | | | | ✓ | |
| *Ficus virens* | | ✓ | ✓ | | | | | | | | | |
| *Grevillea robusta* | ✓ | ✓ | | | | | | | | | | |
| *Jacaranda mimosifolia* | ✓ | ✓ | ✓ | | | | | | | | | |
| *Lagerstroemia speciosa* | ✓ | ✓ | ✓ | | | | | | | | | |
| *Leucaena leucocephala* | | ✓ | | | ✓ | | | | | ✓ | | |
| *Mimusops elengi* | ✓ | ✓ | | | | | | | | | | |
| *Morus alba* | | ✓ | | ✓ | | | | | | | | |
| *Moringa oleifera* | | ✓ | | ✓ | | | | ✓ | | | | |
| *Peltophorum pterocarpum* | ✓ | ✓ | ✓ | | | | ✓ | | | | | |
| *Phyllanthus emblica* | | | | ✓ | | | | ✓ | | | | |
| *Pithecellobium dulce* | | ✓ | | ✓ | | | | | | ✓ | ✓ | |
| *Plumeria obtusa* | ✓ | | | | | | | | | | | |
| *Pongamia pinnata* | | ✓ | | | ✓ | | | | | | | |
| *Populus deltoides* | | ✓ | | | | ✓ | ✓ | | | | | |
| *Polyalthia longifolia* | ✓ | | | | | | | | | | | |
| *Prosopis juliflora* | | ✓ | | | ✓ | | | | | | | ✓ |
| *Pterygota alata* | ✓ | ✓ | | | | | ✓ | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Putranjiva roxburghii* | | ✓ | ✓ | | | | | | | | | |
| *Roystonea regia* | ✓ | | ✓ | | | | | | | | | |
| *Syzygium cumini* | | ✓ | | ✓ | | | | | | | | |
| *Terminalia arjuna* | | | | | | | | ✓ | | | | |
| *Terminalia bellirica* | | ✓ | | ✓ | | | | ✓ | | | | |
| *Ziziphus mauritiana* | | | | ✓ | | | | | | | | ✓ |

### 6.1.5. DBH Class Distribution

The study presents the distribution of tree species according to DBH classes. DBH is divided into six size categories: 0–20 cm, 20–40 cm, 40–60 cm, 60–80 cm, 80–100 cm, and above 100 cm. Each species is represented by the percentage of individuals falling into each DBH class. Several species show a concentration in a specific DBH range, while others are more evenly distributed across classes.

*Albizia lebbeck* shows a balanced structure with 25% of individuals in each of the 20–40 cm, 40–60 cm, above 100 cm, and 0–20 cm classes. *Alstonia scholaris* is mainly in the 20–60 cm range, with 46.4% in 20–40 cm, 32.1% in 40–60 cm, and some in 60–80 cm (10.7%), while a small portion (3.6%) falls in above 100 cm. *Artocarpus heterophyllus* is entirely in the 40–60 cm class (100%). *Azadirachta indica* has 50% in the 20–40 cm range and the other 50% in the 40–60 cm class.

*Bauhinia racemosa* displays a 60% concentration in 20–40 cm and 40% in 40–60 cm. *Bombax ceiba* shows distribution across four classes: 15.4% in 0–20 cm, 46.2% in 20–40 cm, 23% in 40–60 cm, and 15.4% in 60–80 cm. *Cassia fistula* is heavily concentrated in the 20–40 cm class at 84.6%, with 15.4% in the 40–60 cm class. *Senna siamea* has 100% in the 20–40 cm class.

*Caryota urens* shows dominance in the 20–40 cm class (81.8%), with 6.8% in 0–20 cm and 11.4% in 40–60 cm. *Callistemon viminalis*, *Ceiba speciosa*, and *Citrus limon* are all concentrated 100% in a single DBH class 0–20 cm for *Callistemon viminalis* and *Citrus limon*, and 80–100 cm for *Ceiba speciosa*. *Dalbergia sissoo* has 40% in the 40–60 cm class and 60% in 60–80 cm.

*Delonix regia* shows 100% of individuals in the 60–80 cm class. *Diospyros melanoxylon*, *Ehretia laevis*, *Ficus benghalensis*, and *Ficus virens* are entirely found in the above 100 cm class. *Eucalyptus globulus* displays a broader distribution: 33.3% in 0–20 cm, 41.7% in 20–40 cm, and 25% in 40–60 cm.

*Ficus benjamina* is more distributed with 25% in 0–20 cm, 58.3% in 20–40 cm, 12.5% in 40–60 cm, and 4.2% in 60–80 cm. *Ficus racemosa* is distributed among five classes, with the highest in 80–100 cm at 42.9%, followed by 28.5% in 40–60 cm, 14.3% in 0–20 cm and 60–80 cm, and a small proportion in above 100 cm.

*Ficus religiosa* has 16.7% in 20–40 cm, 33.3% in 40–60 cm, and 50% in above 100 cm. *Grevillea robusta* shows 18.8% in 0–20 cm, 56.2% in 20–40 cm, and 25% in 40–60 cm.

*Jacaranda mimosifolia* and *Lagerstroemia speciosa* are each entirely in the 20–40 cm class (100%). *Leucaena leucocephala* and *Mimusops elengi* are fully in the 0–20 cm range.

*Morus alba*, *Moringa oleifera*, and *Peltophorum pterocarpum* are each 100% in the 0–20 cm class. *Phyllanthus emblica* is 25% in 0–20 cm and 75% in 20–40 cm. *Pithecellobium dulce* is split evenly, with 50% in 20–40 cm and 50% in 40–60 cm.

*Plumeria obtusa* is also evenly distributed between 20–40 cm and 40–60 cm, both at 50%. *Pongamia pinnata* has a varied spread with 3.8% in 0–20 cm, 26.9% in 20–40 cm, 30.8% each in 40–60 cm and 60–80 cm, and 7.7% in above 100 cm. *Populus deltoides* is entirely found in the 40–60 cm DBH class.

*Polyalthia longifolia* is heavily concentrated in the 0–20 cm class, at 94.1%, with only 5.9% in 20–40 cm. *Prosopis juliflora* is divided with 33.3% in 20–40 cm, 50% in 40–60 cm, and 16.7% in 60–80 cm. *Pterygota alata* is fully in the 40–60 cm class. *Putranjiva roxburghii* has 4.8% in 0–20 cm, 42.9% in 20–40 cm, 38% in 40–60 cm, and 14.3% in 60–80 cm.

*Roystonea regia* is distributed across three classes: 13.3% in 0–20 cm, 46.7% in 20–40 cm, and 40% in 40–60 cm. *Syzygium cumini* has a concentration in smaller DBH classes, with 70.6% in 0–20 cm and 29.4% in 20–40 cm. *Terminalia arjuna* is fully in the above 100 cm class. *Terminalia bellirica* shows 27.3% in 20–40 cm and 72.7% in 40–60 cm. *Ziziphus mauritiana* is completely found in the 40–60 cm DBH category (100%).

From this table, it is evident that many species show dominant representation in a single DBH class, while others have a more diverse distribution. Species such as *Polyalthia longifolia*, *Syzygium cumini*, *Phyllanthus emblica*, and *Roystonea regia* are skewed towards the lower DBH classes. In contrast, species like *Ficus religiosa*, *Ficus racemosa*, and *Ficus benghalensis* are concentrated in the higher DBH classes, including above 100 cm. Several species such as *Callistemon viminalis*, *Citrus limon*, *Ehretia laevis*, *Leucaena leucocephala*, *Moringa oleifera*, and *Morus alba* show 100% representation in only one DBH class, indicating a uniform structure among the sampled individuals.

The presence of DBH percentages in multiple classes for species like *Putranjiva roxburghii*, *Ficus racemosa*, *Alstonia scholaris*, and *Pongamia pinnata* indicates a broader age or size distribution, suggesting a more dynamic or regenerating population structure. Meanwhile, species like *Delonix regia* and *Ceiba speciosa* are entirely within a single mature DBH class, pointing to mature individuals in those species (Table 7).

Table 7: Distribution of Tree Species along DBH Classes in Study Area (The value in parentheses is percentages)

| Species | DBH Class (cm) | | | | | |
|---|---|---|---|---|---|---|
| | 0- 20 cm | 20-40 cm | 40-60 cm | 60-80 cm | 80-100 cm | >100 cm |
| *Ailanthus excelsa* | | | | 2 (100) | | |
| *Albizia lebbeck* | 1 (25) | | 1 (25) | 1 (25) | | 1 (25) |
| *Alstonia scholaris* | 2 (7.2) | 13 (46.4) | 9 (32.1) | 3 (10.7) | 1 (3.6) | |
| *Artocarpus heterophyllus* | | | 2 (100) | | | |
| *Azadirachta indica* | | 1 (50) | | 1 (50) | | |
| *Bauhinia racemosa* | 3 (60) | 2 (40) | | | | |
| *Bombax ceiba* | 4 (15.4) | 12 (46.2) | 6 (23) | 4 (15.4) | | |
| *Cassia fistula* | | 11 (84.6) | 2 (15.4) | | | |
| *Senna siamea* | | | 1 (100) | | | |
| *Caryota urens* | 3 (6.8) | 36 (81.8) | 5 (11.4) | | | |
| *Callistemon viminalis* | 1 (100) | | | | | |
| *Ceiba speciosa* | | | | | 1 (100) | |
| *Citrus limon* | 1 (100) | | | | | |
| *Dalbergia sissoo* | | 2 (40) | 3 (60) | | | |
| *Delonix regia* | | | | 1 (100) | | |
| *Diospyros melanoxylon* | 1 (100) | | | | | |
| *Ehretia laevis* | | 2 (100) | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Eucalyptus globulus* | | 4 (33.3) | 5 (41.7) | 3 (25) | | |
| *Ficus benjamina* | 12 (25) | 28 (58.3) | 6 (12.5) | 2 (4.2) | | |
| *Ficus benghalensis* | | | | 1 (100) | | |
| *Ficus racemosa* | | 1 (14.3) | 2 (28.5) | 1 (14.3) | 3 (42.9) | |
| *Ficus religiosa* | | | 1 (16.7) | 2 (33.3) | | 3 (50) |
| *Ficus virens* | | 1 (12.5) | 1 (12.5) | | 1 (12.5) | 5 (62.5) |
| *Grevillea robusta* | 3 (18.8) | 9 (56.2) | 4 (25) | | | |
| *Jacaranda mimosifolia* | | 3 (100) | | | | |
| *Lagerstroemia speciosa* | | 2 (100) | | | | |
| *Leucaena leucocephala* | | 2 (100) | | | | |
| *Mimusops elengi* | 4 (100) | | | | | |
| *Morus alba* | | 3 (100) | | | | |
| *Moringa oleifera* | | 1 (100) | | | | |
| *Peltophorum pterocarpum* | | 1 (100) | | | | |
| *Phyllanthus emblica* | | 1 (25) | 3 (75) | | | |
| *Pithecellobium dulce* | 1 (50) | | 1 (50) | | | |
| *Plumeria obtusa* | 1 (50) | 1 (50) | | | | |
| *Pongamia pinnata* | 1 (3.8) | 7 (26.9) | 8 (30.8) | 8 (30.8) | 2 (7.7) | |
| *Populus deltoides* | | | 1 (100) | | | |
| *Polyalthia longifolia* | 48 (94.1) | 3 (5.9) | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Prosopis juliflora* | | 2 (33.3) | 3 (50) | 1 (16.7) | | |
| *Pterygota alata* | | 4 (100) | | | | |
| *Putranjiva roxburghii* | 1 (4.8) | 9 (42.9) | 8 (38) | 3 (14.3) | | |
| *Roystonea regia* | 2 (13.3) | 7 (46.7) | 6 (40) | | | |
| *Syzygium cumini* | 12 (70.6) | 5 (29.4) | | | | |
| *Terminalia arjuna* | | 1 (100) | | | | |
| *Terminalia bellirica* | | 3 (27.3) | 8 (72.7) | | | |
| *Ziziphus mauritiana* | | | | 1 (100) | | |
| **Total** | **101** | **177** | **86** | **34** | **8** | **9** |

## 6.2. Objective 2: Carbon Sequestration and Storage Potential of Tree Species

### 6.2.1 Carbon Storage & Sequestration by Species

The research quantifies each species' contribution in terms of total carbon storage, expressed in tons and as a percentage of the total, and their annual gross carbon sequestration rates. The carbon sequestration is also translated into its $CO_2$ equivalent, reflecting each species' role in mitigating atmospheric carbon dioxide. The data are instrumental for urban green space management as they offer insights into the ecological value of different species with respect to their carbon sink capacity.

Among all species, *Pongamia pinnata* emerges as the most significant contributor, with a carbon storage of 270.5 tons, which constitutes 12.7% of the total storage. It also has the highest $CO_2$ equivalent of carbon storage at 992 tons and an impressive gross annual sequestration rate of 9.45 tons, resulting in a $CO_2$ equivalent of carbon sequestration of 34.65 tons per year. Closely following is *Ficus virens*, storing 252.1 tons (11.8%) of carbon, with a $CO_2$ equivalent of 924.6 tons and an annual carbon sequestration rate of 1.86 tons, equivalent to 6.82 tons of $CO_2$. These figures underline the significance of these two species in urban forestry strategies aimed at climate mitigation.

Other species making notable contributions include *Putranjiva roxburghii* and *Ficus benjamina*. *Putranjiva roxburghii* stores 157 tons of carbon (7.4%), translating to a $CO_2$ equivalent of 575.7 tons, with a sequestration rate of 6.36 tons per year, equalling 23.32 tons of $CO_2$. Meanwhile, *Ficus benjamina* stores 150.3 tons of carbon (7%), with a $CO_2$ equivalent of 551 tons and an extremely high annual sequestration rate of 11.12 tons, which equates to 40.76 tons of $CO_2$ per year, making it one of the most efficient carbon-sequestering species in the park. *Ficus religiosa* also performs well, storing 149.7 tons (7%) of carbon, with a $CO_2$ equivalent of 548.9 tons and a sequestration rate of 6.56 tons/year (24.07 tons $CO_2$).

Trees such as *Alstonia scholaris*, *Eucalyptus globulus*, *Ficus racemosa*, and *Bombax ceiba* also make important contributions. *Alstonia scholaris* stores 129.6 tons of carbon, with a $CO_2$ equivalent of 474.7 tons and an annual sequestration of 3.75 tons, which corresponds to 13.77 tons of $CO_2$. *Eucalyptus globulus* shows significant values with 123.6 tons stored carbon and 453.2 tons $CO_2$ equivalent, and a sequestration rate of 7.36 tons/year, equating to 26.97 tons of $CO_2$. *Ficus racemosa* accounts for 93.4 tons (4.4%) of carbon storage and 341.4 tons $CO_2$ equivalent with a high sequestration rate of 9.53 tons/year, translating to 34.95 tons $CO_2$.

*Bombax ceiba* contributes 78.1 tons (3.7%) of carbon and a $CO_2$ equivalent of 286.2 tons, with an annual sequestration of 4.46 tons (16.34 tons $CO_2$).

Several species like *Albizia lebbeck*, *Cassia fistula*, *Prosopis juliflora*, *Terminalia bellirica*, and *Grevillea robusta* store moderate amounts of carbon ranging from 50 to 65 tons and show balanced $CO_2$ equivalent values and sequestration rates. These species contribute between 2–3% of the total carbon storage, indicating their moderate but still valuable role in urban forest carbon dynamics. For instance, *Albizia lebbeck* stores 61.6 tons (2.9%) of carbon with a $CO_2$ equivalent of 225.7 tons and sequesters 2.11 tons/year (7.74 tons $CO_2$), while *Grevillea robusta* stores 51.4 tons (2.4%) and sequesters 2.84 tons/year (10.42 tons $CO_2$).

Smaller contributors such as *Ailanthus excelsa*, *Phyllanthus emblica*, *Caryota urens*, and *Polyalthia longifolia* each store around 30 to 45 tons of carbon and display annual sequestration rates between 1.5 and 3 tons/year. While individually less impactful, collectively they add considerable value to the ecosystem's carbon management. For instance, *Ailanthus excelsa* stores 49.2 tons (2.3%) of carbon and sequesters 2.78 tons/year (10.19 tons $CO_2$), demonstrating efficient carbon cycling despite its lower absolute figures.

Other less prominent species like *Ceiba speciosa*, *Syzygium cumini*, *Ziziphus mauritiana*, and *Artocarpus heterophyllus* contribute modestly, with carbon storage values ranging between 18–35 tons and annual sequestration around 1–2 tons/year. *Syzygium cumini* stores 19.4 tons (0.9%) with a sequestration rate of 1.77 tons/year (6.49 tons $CO_2$), and *Ceiba speciosa* shows slightly higher values with 31.5 tons stored and 4.07 tons $CO_2$ sequestered annually.

The table also includes species with minimal contributions to carbon storage, often below 20 tons, such as *Roystonea regia*, *Dalbergia sissoo*, *Ficus benghalensis*, *Pterygota alata*, and *Pithecellobium dulce*, among others. These trees typically contribute less than 1% to the total carbon pool and sequester under 1.5 tons/year. Nonetheless, they still play a role in maintaining biodiversity and ecosystem resilience.

Interestingly, species like *Morus alba*, *Jacaranda mimosifolia*, *Bauhinia racemosa*, and *Lagerstroemia speciosa* store small amounts of carbon under 10 tons indicating their limited capacity in carbon management despite being valued for aesthetic or shade-providing purposes. For instance, *Morus alba* stores just 9.3 tons (0.4%), with a sequestration of 0.53 tons/year (1.94 tons $CO_2$). *Jacaranda mimosifolia* stores 6.9 tons, with a sequestration rate of 0.57 tons/year.

The lowest contributing species in this analysis include *Leucaena leucocephala*, *Ehretia laevis*, *Plumeria obtusa*, *Peltophorum pterocarpum*, *Terminalia arjuna*, *Moringa oleifera*, *Callistemon viminalis*, *Citrus limon*, *Mimusops elengi*, and *Diospyros melanoxylon*. Each of these stores less than 5 tons of carbon and sequesters less than 0.5 tons per year. Their total impact on the park's carbon dynamics is marginal, yet their ecological or ornamental value may justify their inclusion in the green space.

Summing up all contributions, the total carbon storage across all species in the park amounts to 2,133.3 tons, with a $CO_2$ equivalent of 7,822.7 tons. The gross carbon sequestration per year stands at 95.41 tons, which corresponds to a $CO_2$ equivalent of 349.07 tons annually. This comprehensive evaluation underscores the critical role that urban trees play in mitigating climate change by acting as effective carbon sinks. It also helps inform policymakers and urban planners about the relative value of different tree species in long-term carbon sequestration strategies, guiding future planting and conservation priorities within urban green spaces like District Park, Hauz Khas (Table 8).

Table 8: Species-wise Carbon Storage and Sequestration Potential in District Park, Hauz Khas (The value in parentheses is in percentages. Carbon Storage and its $CO_2$ equivalent are in ton and Carbon Sequestration and its $CO_2$ equivalent are in ton/yr)

| Species | Carbon Storage | $CO_2$ Equivalent of Carbon Storage | Gross Carbon Sequestration | $CO_2$ Equivalent of Carbon Sequestration |
|---|---|---|---|---|
| *Pongamia pinnata* | 270.5 (12.7) | 992 | 9.45 | 34.65 |
| *Ficus virens* | 252.1 (11.8) | 924.6 | 1.86 | 6.82 |
| *Putranjiva roxburghii* | 157 (7.4) | 575.7 | 6.36 | 23.32 |
| *Ficus benjamina* | 150.3 (7) | 551 | 11.12 | 40.77 |
| *Ficus religiosa* | 149.7 (7) | 548.9 | 6.56 | 24.04 |
| *Alstonia scholaris* | 129.5 (6.1) | 474.7 | 3.75 | 13.76 |
| *Eucalyptus globulus* | 123.6 (5.8) | 453.2 | 7.36 | 26.97 |
| *Ficus racemosa* | 93.9(4.4) | 344.2 | 1.40 | 5.13 |
| *Bombax ceiba* | 78.1 (3.7) | 286.2 | 4.46 | 16.34 |
| *Albizia lebbeck* | 61.6 (2.9) | 225.7 | 2.11 | 7.74 |
| *Cassia fistula* | 58.6(2.7) | 215 | 3.90 | 14.30 |
| *Prosopis juliflora* | 57.6 (2.7) | 211.3 | 2.33 | 8.54 |
| *Terminalia bellirica* | 54 (2.5) | 198.2 | 3.04 | 11.14 |
| *Grevillea robusta* | 51.4 (2.4) | 188.6 | 4.18 | 15.32 |
| *Ailanthus excelsa* | 49.2 (2.3) | 180.4 | 2.78 | 10.19 |
| *Phyllanthus emblica* | 45 (2.1) | 164.8 | 2.71 | 9.95 |
| *Caryota urens* | 38.5 (1.8) | 141.3 | 2.21 | 8.12 |
| *Polyalthia longifolia* | 33.9 (1.6) | 124.4 | 5.36 | 19.66 |
| *Azadirachta indica* | 33.2 (1.6) | 121.7 | 0.65 | 2.37 |
| *Ceiba speciosa* | 31.3 (1.5) | 114.8 | 0.43 | 1.57 |
| *Syzygium cumini* | 19.4 (0.9) | 71.2 | 1.77 | 6.49 |
| *Ziziphus mauritiana* | 19 (0.9) | 69.8 | 0.44 | 1.60 |
| *Artocarpus heterphullus* | 18.3 (0.9) | 67 | 1.16 | 4.26 |
| *Roystonea regia* | 18.1 (0.8) | 66.3 | 1.15 | 4.21 |
| *Dalbergia sissoo* | 16 (0.7) | 58.6 | 0.81 | 2.98 |
| *Ficus benghalensis* | 15.7 (0.7) | 57.7 | 0.62 | 2.26 |

| | | | | |
|---|---|---|---|---|
| *Pterygota alata* | 15.6 (0.7) | 57.1 | 1.68 | 6.17 |
| *Pithecellobium dulce* | 14.8 (0.7) | 54.2 | 0.68 | 2.49 |
| *Senna siamea* | 14.6 (0.7) | 53.5 | 0.70 | 2.57 |
| *Populus deltoides* | 11 (0.5) | 40.3 | 0.49 | 1.79 |
| *Delonix regia* | 10.6 (0.5) | 38.7 | 0.66 | 2.43 |
| *Morus alba* | 9.3 (0.4) | 33.9 | 0.53 | 1.94 |
| *Jacaranda mimosifolia* | 6.9 (0.3) | 25.4 | 0.57 | 2.08 |
| *Bauhinia racemosa* | 5.7 (0.3) | 20.9 | 0.25 | 0.91 |
| *Lagerstroemia speciosa* | 4.6 (0.2) | 17 | 0.39 | 1.41 |
| *Leucaena leucocephala* | 4.5 (0.2) | 16.6 | 0.64 | 2.35 |
| *Ehretia laevis* | 3.1 (0.1) | 11.3 | 0.30 | 1.12 |
| *Plumeria obtusa* | 2.7 (0.1) | 9.8 | 0.10 | 0.37 |
| *Peltophorum pterocarpum* | 1.3 (0.1) | 4.6 | 0.12 | 0.45 |
| *Terminalia arjuna* | 1.2 (0.1) | 4.3 | 0.07 | 0.26 |
| *Moringa oleifera* | 1 (0.1) | 3.7 | 0.09 | 0.33 |
| *Callistemon viminalis* | 0.5 (0.05) | 1.7 | 0.07 | 0.25 |
| *Citrus limon* | 0.4 (0.05) | 1.3 | 0.06 | 0.22 |
| *Mimusops elengi* | 0.1(0) | 0.5 | 0.04 | 0.16 |
| *Diospyros melanoxylon* | 0 (0) | 0.1 | 0.01 | 0.04 |
| **Total** | **2133.3 (100)** | **7822.7** | **95.41** | **349.87** |

### 6.2.2. Carbon Storage & Sequestration: Native vs. Exotic

The carbon accounting by species origin shows a clear dominance of native trees in both storage and uptake. Of the 45 species surveyed, the 32 native taxa collectively store 1509.0 t C, representing 70.7 % of the park's total carbon pool, and they sequester 73.05 t C $yr^{-1}$, or 76.6 % of the annual gross sequestration. In contrast, the 13 exotic species store 624.4 t C (29.3 %) and account for 22.37 t C $yr^{-1}$ of sequestration (23.4 %) (Table 9).

Table 9: Carbon Storage and Sequestration Potential based on Origin

| Origin | No. of Species | Total Carbon Storage (t C) | % of Total Storage | Annual Gross Sequestration (t C $yr^{-1}$) | % of Total Sequestration |
|---|---|---|---|---|---|
| **Exotic** | 13 | 624.4 | 29.30% | 22.37 | 23.40% |
| **Native** | 32 | 1509.0 | 70.70% | 73.05 | 76.60% |
| **Total** | 45 | 2133.4 | 100% | 95.41 | 100% |

### 6.2.3. Carbon Storage & Sequestration: Leaf Retention

Evergreen species (n = 21) stored a total of 956.9 t C, representing 44.90 % of the park's above-ground carbon stock, and sequestered 41.06 t C $yr^{-1}$ (43.00 % of total annual uptake). Deciduous species (n = 17) contributed 867.3 t C (40.70 % of total storage) and 41.51 t C $yr^{-1}$ (43.50 % of total sequestration). Perennial species (n = 7) accounted for 309.2 t C (14.50 % of storage) and 12.85 t C $yr^{-1}$ (13.50 % of sequestration). Altogether, the 45 surveyed species stored 2 133.4 t C and sequestered 95.41 t C $yr^{-1}$ (Table 10).

Table 10: Carbon Storage and Sequestration based on Leaf Retention

| Leaf Retention | No. of Species | Total Carbon Storage(t C) | % of Total Storage | Annual Gross Sequestration(t C $yr^{-1}$) | % of Total Sequestration |
|---|---|---|---|---|---|
| **Evergreen** | 21 | 956.9 | 44.90% | 41.06 | 43.00% |
| **Deciduous** | 17 | 867.3 | 40.70% | 41.51 | 43.50% |
| **Perennial** | 7 | 309.2 | 14.50% | 12.85 | 13.50% |
| **Total** | 45 | 2 133.4 | 100.00% | 95.41 | 100.00% |

### 6.2.4. Carbon Storage and Sequestration Trends Across DBH Classes

This study examined the carbon storage and sequestration potential of trees in District Park, Hauz Khas, categorized by DBH class intervals. The data is categorized into six DBH classes ranging from 0–20 cm to over 100 cm and includes a total of 415 trees. The metrics evaluated include total carbon storage (in tons), total $CO_2$ equivalence of carbon storage (in tons), annual carbon sequestration (in tons/year), and the total $CO_2$ equivalence of carbon sequestration (in tons/year).

Among the DBH classes, trees with a DBH of 20–40 cm make up the largest group with 177 individuals. These trees are responsible for storing 655.585 tons of carbon, which is the highest carbon storage among all DBH classes. Their carbon storage corresponds to 2,403.28 tons of $CO_2$ equivalence, which underlines the significance of this class in contributing to long-term carbon mitigation goals. Furthermore, this class also exhibits the highest annual carbon sequestration rate of 32.48 tons per year and a corresponding $CO_2$ sequestration of 127.374 tons per year. This suggests that most mid-sized trees in the urban forest are actively involved in carbon uptake, underscoring the critical role of managing and preserving this age class for sustained ecosystem service delivery.

The second most abundant DBH class is the 0–20 cm group, consisting of 101 trees. While their individual contribution to carbon storage is low, collectively they store 165.335 tons of carbon and sequester 13.2 tons annually. This results in a $CO_2$ storage equivalence of 589.255 tons and an annual $CO_2$ sequestration of 48.001 tons. Despite their smaller biomass, these young trees indicate the future potential of the forest, representing a growing stock that, with proper management, can significantly enhance carbon sequestration in the years to come. Their existence reflects active regeneration and underscores the importance of promoting sapling recruitment and survival for long-term forest health.

Moving to the 40–60 cm DBH class, which includes 86 trees, this group stores 567.91 tons of carbon and sequesters 26.98 tons per year. The $CO_2$ storage equivalence for this group is 2,084.135 tons, with a sequestration equivalence of 92.47 tons annually. These trees are approaching maturity and contribute significantly both to stored and annually sequestered carbon, making them valuable assets in terms of carbon economics. The data reveals their dual role in acting as both carbon sinks and carbon stores, which is crucial for mitigating urban carbon emissions.

The 60–80 cm DBH class, though smaller in number with only 34 trees, continues to play a substantial role. These trees store 368.125 tons of carbon and sequester 16.43 tons annually. Their $CO_2$ equivalence figures stand at 1,368.255 tons for storage and 56.31 tons/year for sequestration. The high contribution per tree suggests that older and larger trees, although less in number, offer high ecosystem value. Their preservation is essential, not only due to their carbon dynamics but also due to the structural and biodiversity benefits they offer in an urban setting.

The larger DBH classes, 80–100 cm and above 100 cm, include 8 and 9 trees, respectively. Despite their small numbers, their contribution to carbon storage is impressive. Trees in the 80–100 cm class store 128.465 tons of carbon and sequester 1.99 tons annually, resulting in 470.29 tons of $CO_2$ storage and 7.77 tons/year of $CO_2$ sequestration. Meanwhile, the above 100 cm class stores 247.8 tons of carbon with a sequestration rate of 4.15 tons per year. Their $CO_2$ equivalence is recorded at 908.795 tons for storage and 18.215 tons/year for sequestration. These data highlight the disproportionate impact of large trees on carbon storage and validate their essential role in any urban forestry strategy. It is noteworthy that older trees provide long-term ecological value, and protecting these legacy trees should be a key priority in urban forest management plans.

Cumulatively, the 415 trees evaluated in this study have stored a total of 2,133.3 tons of carbon. This translates to a total $CO_2$ equivalence of 7,822.7 tons, illustrating the substantial capacity of urban trees to act as carbon sinks. In terms of annual sequestration, the trees collectively sequester 95.41 tons of carbon each year, equivalent to 349.87 tons of $CO_2$. These figures are significant, especially when contextualized against rising atmospheric carbon levels and the urgency of climate mitigation in urban centres. The data affirms the efficacy of urban forests as tools for reducing greenhouse gas concentrations, improving air quality, and delivering co-benefits such as temperature regulation and enhanced biodiversity (Table 11).

The implications of these findings are far-reaching. Firstly, the distribution of carbon storage and sequestration across different DBH classes indicates a healthy structural diversity in the urban forest, which is vital for resilience against pests, diseases, and climate change impacts. Secondly, the evident potential of medium to large-sized trees in sequestering and storing carbon supports the need for focused conservation policies that prevent premature removal of mature trees, often threatened due to urban development. Additionally, the growing cohort of young trees indicates future potential, and proper nurturing of these trees through watering, mulching, and pruning could ensure that they transition into higher DBH classes over time, thus perpetuating the carbon sink function.

Finally, these findings may also be used to inform urban policy frameworks in assigning economic value to urban trees through carbon credits. Based on the reported carbon storage and annual sequestration, the carbon credit potential of this urban forest could be monetized using prevailing carbon pricing mechanisms. This economic valuation provides a strong incentive for municipal bodies and private stakeholders to invest in urban greening programs, not merely for aesthetic or ecological purposes but also as a viable climate mitigation strategy that aligns with national and international climate commitments .

Table 11: Carbon Storage and Sequestration Potential Across DBH Classes in Study Area

| DBH Class (cm) | No. of Trees | Total Carbon Storage (ton) | Total $CO_2$ Equivalence of Carbon Storage (ton) | Annual Carbon Sequestration (ton/yr) | Total $CO_2$ Equivalence of Carbon Sequestration (ton/yr) |
|---|---|---|---|---|---|
| **0-20** | 101 | 165.335 | 589.255 | 13.2 | 48.001 |
| **20-40** | 177 | 655.585 | 2403.28 | 32.48 | 127.374 |
| **40-60** | 86 | 567.91 | 2084.135 | 26.98 | 92.47 |
| **60-80** | 34 | 368.125 | 1368.255 | 16.43 | 56.31 |
| **80-100** | 8 | 128.465 | 470.29 | 1.99 | 7.77 |
| **>100** | 9 | 247.8 | 908.795 | 4.15 | 18.215 |
| **Total** | **415** | **2133.3** | **7822.7** | **95.41** | **349.87** |

### 6.2.5. Average Carbon Storage and Sequestration per Tree across DBH Classes:

This study analysed average carbon storage and annual carbon sequestration across different DBH classes of trees. As the DBH class increases, the average carbon storage also rises, indicating that larger trees store significantly more carbon. For instance, trees in the smallest class (0–20 cm) store an average of 1.63 tons of carbon, while those in the largest class (>100 cm) store 27.53 tons (Table12).

Similarly, the rate of carbon sequestration increases with DBH up to the 60–80 cm class, which sequesters the most at 0.48 tons per year. Although trees in the >100 cm class store more total carbon, their sequestration rate slightly declines to 0.46 tons/year, possibly due to slower growth rates in mature trees. Interestingly, the 80–100 cm class shows a drop in sequestration rate (0.25 tons/year) despite having higher storage, which may suggest physiological limitations or reduced growth at that stage. Overall, the data highlights the vital role of mature trees in long-term carbon storage and the importance of maintaining a diverse range of DBH classes in urban forests for effective carbon management.

Table 12: Average Carbon Storage and Sequestration per Tree across DBH Classes

| DBH Class(cm) | Average Carbon Storage (ton) | Average Carbon Sequestration (ton/yr) |
|---|---|---|
| **0-20** | 1.63 | 0.13 |
| **20-40** | 3.7 | 0.18 |
| **40-60** | 6.6 | 0.31 |
| **60-80** | 10.83 | 0.48 |
| **80-100** | 16.06 | 0.25 |
| **>100** | 27.53 | 0.46 |

### 6.3. Objective 3: Strategy for Future Planting of Tree Species for Maximum Carbon Benefits

#### 6.3.1. Scoring-Based Evaluation of Tree Species for Sustainable Urban Green Space Management

The results of Objective 3 focus on the evaluation and scoring of tree species found in District Park, Hauz Khas, based on a framework that incorporates multiple ecological and functional criteria. These include carbon storage, carbon sequestration, average Diameter at Breast Height (DBH), tree height, crown area, native or exotic origin, evergreen or deciduous habit, and urban utility. Each species was assigned a composite score derived from these criteria, aiming to identify species most suitable for future planting and urban forest enhancement based on their multifunctional benefits. The scoring framework assists in prioritizing species that are not only ecologically beneficial but also well-suited for the urban environment in Delhi.

From the results, it is evident that several species have emerged with high cumulative scores across all criteria, signifying their exceptional utility for urban greening and carbon management. Among these, *Ficus religiosa* achieved one of the highest scores. This native, deciduous species is known for its generous size, deep-rooted cultural significance, and ecological benefits. It stores substantial amounts of carbon, sequesters carbon at a high rate, and provides dense canopy cover, which contributes to urban cooling and biodiversity support.

*Ficus virens* is another top-scoring species. A native deciduous tree, it demonstrates high carbon storage potential and large crown dimensions, making it effective in ecosystem service delivery. Its ecological robustness and adaptation to urban settings further enhance its standing. Similarly, *Ficus benjamina*, though smaller in stature than its counterparts, scores highly due to its perennial nature, significant carbon sequestration, and superior performance as a shade and ornamental tree in urban spaces.

*Pongamia pinnata* also ranks among the highest. A native, nitrogen-fixing tree, *Pongamia sp.* offers outstanding carbon storage capacity. Its multipurpose utility including biofuel potential and shade provision elevates its value in sustainable urban forestry models. Furthermore, its tolerance to varying urban stressors and ability to grow in diverse soils make it a reliable choice for long-term greening projects.

*Putranjiva roxburghii* scores prominently as well. With notable carbon storage figures and evergreen foliage, this native species combines aesthetic appeal with practical function, providing year-round shade and contributing to the regulation of urban microclimates. Its compact canopy also suits smaller urban spaces.

*Eucalyptus globulus*, although exotic, ranks high based on rapid growth, high carbon sequestration, and substantial biomass accumulation. However, its inclusion in future planting strategies should be weighed cautiously due to allelopathic traits and potential ecological invasiveness in some contexts.

*Alstonia scholaris* scores strongly for its tall stature, large crown area, and evergreen habit. Known for its medicinal bark and air-purifying qualities, it provides dense shade and supports urban biodiversity, thus making it a versatile urban tree species.

*Grevillea robusta*, another high scorer, is valued for its rapid growth and finely dissected foliage which allows dappled sunlight making it ideal for street-side and avenue planting. Its adaptability and carbon uptake rate contribute to its performance in urban conditions.

*Cassia fistula*, with its iconic yellow blooms, stands out not only for aesthetic value but also for substantial carbon sequestration. This native deciduous tree is particularly suited for ornamental avenue plantings and cultural landscapes.

*Bombax ceiba* scores high due to its large biomass, high carbon storage, and visually impactful seasonal flowers. Though deciduous, it contributes significantly to urban biodiversity and aesthetic enhancement.

*Terminalia bellirica*, another native species with a strong score, combines carbon storage ability with traditional medicinal uses. Its adaptability and large canopy make it suitable for multifunctional urban landscapes.

*Polyalthia longifolia* features among the top-scoring trees as well. It is frequently used in urban areas for its slim form, tolerance to pollution, and minimal space requirements, making it suitable for roadsides and narrow spaces.

Other noteworthy high scorers include *Phyllanthus emblica*, valued for its medicinal fruit and carbon storage; *Caryota urens*, with a tall, palm-like structure and consistent carbon performance; and *Albizia lebbeck*, a nitrogen-fixing tree that scores well on urban utility, carbon contribution, and ecological function.

In addition, *Ailanthus excelsa*, *Syzygium cumini*, *Ficus racemosa*, and *Pterygota alata* were also among those with higher scores. Each of these species offers unique combinations of carbon functions, native resilience, and urban adaptability, further reinforcing their potential for inclusion in sustainable urban forestry practices (Table 13).

Overall, the high-scoring species are characterized by their multifunctionality, ecological adaptability, significant contributions to carbon regulation, and capacity to withstand urban stress. These species form the core recommendations for future planting strategies within District Park and similar urban green spaces, with the aim of enhancing carbon benefits and supporting long-term urban ecological resilience.

Table 13: Scoring Tree Species based on Carbon and Ecosystem Service Criteria

| Species | Carbon Storage | Carbon Sequestration | DBH | Tree Height | Crown Area | Native vs. Exotic | Foliage Type | Urban Utility | Total |
|---|---|---|---|---|---|---|---|---|---|
| *Ficus religiosa* | 5 | 5 | 5 | 4 | 5 | 5 | 4 | 3 | 36 |
| *Pongamia pinnata* | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 5 | 36 |
| *Alstonia scholaris* | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 3 | 34 |
| *Ficus virens* | 5 | 5 | 4 | 3 | 5 | 5 | 4 | 3 | 34 |
| *Artocarpus heterophyllus* | 2 | 5 | 3 | 4 | 5 | 5 | 5 | 4 | 33 |
| *Azadirachta indica* | 3 | 4 | 3 | 4 | 5 | 5 | 4 | 5 | 33 |
| *Putranjiva roxburghii* | 5 | 5 | 2 | 3 | 5 | 5 | 5 | 3 | 33 |
| *Ailanthus excelsa* | 4 | 5 | 4 | 5 | 5 | 5 | 2 | 2 | 32 |
| *Ficus benjamina* | 5 | 5 | 2 | 3 | 5 | 5 | 5 | 2 | 32 |
| *Ficus racemosa* | 5 | 5 | 4 | 4 | 5 | 5 | 2 | 2 | 32 |
| *Albizia lebbeck* | 5 | 5 | 2 | 4 | 5 | 5 | 2 | 3 | 31 |
| *Cassia fistula* | 4 | 5 | 2 | 3 | 5 | 5 | 4 | 3 | 31 |
| *Eucalyptus globulus* | 5 | 5 | 3 | 4 | 5 | 1 | 5 | 3 | 31 |
| *Bombax ceiba* | 5 | 5 | 2 | 4 | 4 | 5 | 2 | 3 | 30 |
| *Ficus benghalensis* | 2 | 4 | 2 | 4 | 5 | 5 | 5 | 3 | 30 |
| *Phyllanthus emblica* | 4 | 5 | 2 | 3 | 5 | 5 | 2 | 4 | 30 |
| *Dalbergia sissoo* | 2 | 5 | 3 | 3 | 5 | 5 | 2 | 4 | 29 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Terminalia bellirica* | 4 | 5 | 2 | 3 | 5 | 5 | 2 | 3 | 29 |
| *Ziziphus mauritiana* | 2 | 3 | 4 | 3 | 5 | 5 | 2 | 4 | 28 |
| *Caryota urens* | 3 | 5 | 2 | 2 | 2 | 5 | 5 | 3 | 27 |
| *Grevillea robusta* | 4 | 5 | 2 | 4 | 3 | 2 | 5 | 2 | 27 |
| *Ceiba speciosa* | 3 | 3 | 5 | 4 | 5 | 2 | 2 | 2 | 26 |
| *Delonix regia* | 2 | 4 | 3 | 4 | 5 | 2 | 4 | 2 | 26 |
| *Prosopis juliflora* | 4 | 5 | 3 | 3 | 5 | 1 | 2 | 3 | 26 |
| *Pterygota alata* | 2 | 4 | 2 | 4 | 4 | 5 | 2 | 3 | 26 |
| *Syzygium cumini* | 2 | 5 | 1 | 2 | 3 | 5 | 4 | 4 | 26 |
| *Morus alba* | 2 | 4 | 2 | 3 | 5 | 3 | 2 | 4 | 25 |
| *Pithecellobium dulce* | 2 | 4 | 2 | 3 | 5 | 3 | 2 | 4 | 25 |
| *Ehretia laevis* | 1 | 2 | 2 | 4 | 5 | 5 | 2 | 3 | 24 |
| *Moringa oleifera* | 1 | 1 | 2 | 4 | 5 | 5 | 2 | 4 | 24 |
| *Senna siamea* | 2 | 4 | 3 | 3 | 2 | 2 | 5 | 2 | 23 |
| *Lagerstroemia speciosa* | 1 | 3 | 2 | 3 | 5 | 5 | 2 | 2 | 23 |
| *Populus deltoides* | 2 | 3 | 3 | 3 | 5 | 2 | 2 | 3 | 23 |
| *Polyalthia longifolia* | 3 | 5 | 1 | 1 | 1 | 5 | 5 | 2 | 23 |
| *Roystonea regia* | 2 | 5 | 2 | 2 | 3 | 2 | 5 | 2 | 23 |
| *Terminalia arjuna* | 1 | 1 | 2 | 2 | 5 | 5 | 2 | 5 | 23 |
| *Leucaena leucocephala* | 1 | 4 | 2 | 2 | 4 | 1 | 5 | 3 | 22 |
| *Jacaranda mimosifolia* | 2 | 4 | 2 | 3 | 4 | 2 | 2 | 2 | 21 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Citrus limon* | 1 | 1 | 1 | 3 | 1 | 3 | 5 | 4 | 19 |
| *Bauhinia racemosa* | 2 | 2 | 1 | 2 | 2 | 5 | 2 | 2 | 18 |
| *Mimusops elengi* | 1 | 1 | 1 | 1 | 1 | 5 | 5 | 3 | 18 |
| *Diospyros melanoxylon* | 1 | 1 | 1 | 1 | 1 | 5 | 2 | 4 | 16 |
| *Peltophorum pterocarpum* | 1 | 2 | 1 | 2 | 4 | 2 | 2 | 2 | 16 |
| *Callistemon viminalis* | 1 | 1 | 1 | 2 | 1 | 2 | 5 | 2 | 15 |
| *Plumeria obtusa* | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 13 |

## 7. Discussion

The results obtained from the assessment of tree species in District Park, Hauz Khas, offer a rich landscape of ecological insights that are applicable to the broader domain of urban green space management. This study, which utilized the i-Tree Eco model, contributes to the growing literature that validates the role of urban trees as critical agents in carbon storage and sequestration, especially within the increasingly impervious landscapes of metropolitan India. As climate change intensifies, and urbanization accelerates, urban parks emerge not only as recreational zones but also as strategically important ecological infrastructures. The findings from District Park point to several management implications and can be robustly compared with studies from other regions that have employed similar models and analytical frameworks.

The carbon storage of 2,133.3 tons and annual sequestration of 95.41 tons from the 45 species surveyed in the park underscore the potential of even medium-sized urban green spaces to significantly offset urban emissions. This quantity of sequestered carbon aligns well with findings from other urban centres where i-Tree Eco has been implemented. For instance, a study in Jakarta, Indonesia, estimated an annual sequestration of 184.8 metric tons across various urban green spaces using similar methods (Mosyaftiani et al., 2022b). Although the sequestration figure in District Park is lower in absolute terms, the per-hectare rate is comparable and even slightly higher, especially considering the biodiversity and native tree dominance observed in the Hauz Khas park. Similarly, research conducted in Melbourne using the i-Tree Eco framework concluded that even fragmented urban tree networks could meaningfully contribute to mitigating urban carbon emissions (Livesley et al., 2016). The results from District Park, therefore, validate a global trend localized urban green interventions, when backed by rigorous species-specific data, can produce carbon savings that are both ecologically and economically significant.

This finding becomes more compelling when species-level contributions are analysed. In the current study, native and semi-native species such as *Pongamia pinnata*, *Ficus religiosa*, *Ficus virens*, and *Putranjiva roxburghii* emerged as the top performers in both carbon storage and sequestration. This supports previous studies in other Indian cities such as Bhopal and Katni, where similar species were identified as dominant carbon sinks (Bhatnagar et al., 2024; Dugaya et al., 2020). For example, in Bhopal, *Leucaena leucocephala* and *Ficus religiosa* were highlighted for their carbon benefits, particularly because of their large biomass and extended lifespan. Likewise, in Katni, species such as *Azadirachta indica* and *Ficus benghalensis* demonstrated high carbon storage potential, especially in areas with stable soil and fewer anthropogenic disturbances. These parallels strongly suggest that carbon-efficient tree species often exhibit similar characteristics across different Indian urban environments typically being large-canopy, long-living, and native or naturalized trees that are adapted to tropical or subtropical urban conditions.

The dominance of native species in carbon accumulation and ecosystem functionality reinforces the ecological argument for prioritizing native over exotic species in urban forestry programs. This is not merely a cultural or aesthetic preference but is grounded in ecological science. Native species tend to support higher biodiversity, resist local pests more effectively, and maintain long-term resilience. A report emphasized that many exotic trees planted for quick shade or aesthetic appeal, such as *Eucalyptus globulus* and *Grevillea robusta*, can become problematic over time due to their allelopathic behavior, water demands, or poor integration into the native ecosystem (Babu & Singh,2024). Interestingly, while the current study observed significant carbon benefits from *Eucalyptus globulus* and *Grevillea robusta*, the decision to plant such species in the future should be weighed against potential ecological trade-offs. This dilemma is echoed in global literature; for instance, research conducted in Beijing and London emphasized the necessity of balancing carbon sequestration with ecological integrity when selecting species for urban greening projects (Ma et al., 2021; Tree Economics London, 2015).

Another essential dimension in urban forest management that this study contributes to is the structural diversity of trees, particularly with respect to DBH. The results from District Park show a clear correlation between DBH and carbon stock, with higher DBH classes particularly those above 40 cm contributing disproportionately to total carbon stored. This result mirrors findings from studies in U.S. cities such as New York and Chicago, where it has been consistently observed that a small fraction of large trees holds most of the biomass and carbon (Nowak & Crane, 2002). In the Indian context, this trend is also supported by research from Chinnar Wildlife Sanctuary and tropical dry forests where large-DBH trees stored most of the carbon, and medium and small DBH trees served as future reservoirs (Padmakumar et al., 2018; Raha et al., 2020). Importantly, the presence of younger trees in the 20–40 cm DBH class in District Park suggests a regenerating urban forest structure, which is crucial for long-term carbon dynamics and urban forest sustainability.

The study also reveals key insights about the composition and age structure of the urban forest in Hauz Khas, which should directly inform management practices. For instance, *Ficus* *religiosa* and *Ficus benghalensis* were found in the higher DBH classes, indicating their mature status and high carbon storage capacity. These trees should be prioritized for protection, including measures like restricting physical disturbances near their root zones, maintaining soil permeability, and pruning dead branches to increase longevity. On the other hand, species such as *Polyalthia longifolia* and *Syzygium cumini*, which dominate the lower DBH classes but have moderate sequestration rates, should be monitored for growth and provided with adequate watering, soil nutrients, and protection from mechanical damage. Such stratified management based on DBH not only sustains the carbon balance but also ensures that tree populations are resilient to diseases, climatic variability, and anthropogenic pressures.

Beyond carbon, the multifunctionality of tree species especially those that scored highly in urban utility demonstrates the broader benefits of strategic planting. Trees like *Pongamia pinnata*, which offers shade, biofuel potential, and nitrogen fixation, or *Ficus religiosa*, which supports biodiversity and holds cultural importance, underscore the value of species that deliver multiple co-benefits. Studies from European cities such as Barcelona and Berlin have emphasized the need to integrate multifunctionality into urban green space planning to enhance resilience and cost-effectiveness (Baró et al., 2014). This supports the scoring framework, where indicators such as crown area, evergreen/deciduous nature, native status, and urban utility were combined to guide species selection. Such a multi-criteria evaluation is increasingly being recognized as a best practice in urban forestry, as it allows planners to move beyond single-objective planting schemes (e.g., shade-only or aesthetics-only) towards holistic ecological design.

The implications of the present findings also extend to climate regulation and thermal comfort in urban settings. Delhi is among the world's cities most affected by the Urban Heat Island (UHI) effect, with daytime temperature differentials of up to 7.6°C and nighttime differentials exceeding 8.3°C (Mallick et al., 2024; Mohan et al., 2012). The evapotranspiration, canopy shading, and albedo modulation offered by dense tree canopies significantly mitigate these effects. By identifying species with large crowns, such as *Ficus virens* and *Bombax ceiba*, this study provides direct recommendations for reducing UHI through green infrastructure. This is particularly vital for Delhi, where impervious surfaces are expanding rapidly and natural cooling systems are being compromised.

Another vital implication of results lies in economic valuation and public policy. The carbon sequestration and storage capacity of urban trees translates into quantifiable economic value in terms of carbon credits, health cost reductions due to air purification, and decreased energy demand for cooling. Tools like i-Tree Eco are increasingly being used by municipalities in the West to inform budgeting and land-use decisions. In London, for example, i-Tree assessments have been used to justify increased public investment in urban forestry by showing net returns in ecosystem service (Tree Economics London, 2015). Similarly, in cities like Bogotá and Addis Ababa, i-Tree Eco findings have been integrated into broader climate action plans, particularly to address climate justice in underserved neighbourhoods (Arroyave-Maya et al., 2019; Solomon et al., 2025b). In Delhi's context, where policy often underrepresents green infrastructure, this data can serve as an evidence-based foundation to argue for the inclusion of urban forestry in master planning documents and climate action frameworks.

Lastly, this research findings reinforce the need for participatory management and decentralized greening strategies. Community engagement in planting native trees, maintaining existing tree stock, and monitoring growth can drastically increase tree survival rates and public awareness. Studies have shown that citizen science approaches and community forestry projects enhance not only ecological outcomes but also social cohesion and civic pride (Esperon-Rodriguez et al., 2025). In Delhi, where park management often suffers from fragmented governance and low budgets, involving citizens, resident welfare associations, and NGOs in tree inventory and maintenance could significantly amplify the impact of municipal efforts.

To summarize, the results of this study carry profound implications for urban green space management in Delhi and beyond. The performance of native species in both carbon storage and ecological resilience underlines the importance of prioritizing local biodiversity. The use of multi-criteria scoring supports a balanced approach to tree selection that integrates carbon efficiency, ecological fit, and urban utility. The structural data about DBH class distribution reveals the critical importance of maintaining a diverse age structure for long-term forest health. Furthermore, the integration of carbon and co-benefits positions urban trees as critical components of climate adaptation strategies, deserving greater attention in both policy and practice. By embedding data-informed, ecosystem-based approaches into the management of green spaces, cities can enhance their resilience, livability, and contribution to global climate goals. The case of District Park, Hauz Khas, stands as a practical and replicable model for other urban landscapes across India and the developing world.

## 8. Conclusion

The findings of this study culminate in a set of compelling conclusions with broad implications for sustainable urban green space management, particularly in fast-growing metropolitan environments like Delhi. By using the i-Tree Eco model to quantify carbon storage and sequestration potential and then integrating these results into an eight-criteria scoring framework, this research bridges data analysis with practical ecological planning. The scoring system synthesizes key metrics carbon storage, carbon sequestration, DBH, tree height, crown area, nativity, evergreen or deciduous nature, and urban utility into a single total score per species. This holistic index offers a structured and science-backed method to assess and prioritize tree species for current and future urban plantations.

The study's outcomes from District Park, Hauz Khas, clearly show that native and semi-native tree species are central to climate-responsive and ecologically resilient urban forestry. High-scoring species such as *Pongamia pinnata*, *Ficus religiosa*, *Ficus virens*, and *Putranjiva roxburghii* not only dominated in terms of carbon performance but also consistently scored between 35 and 39 out of 40 on the total score index. These species exhibit multiple ecological advantages large DBH classes, wide crown spread, perennial canopy, high urban utility, and strong carbon benefits making them ideal candidates for strategic plantation across Delhi's urban parks and green corridors. These results align with findings from other Indian cities such as Katni and Bhopal, where *Ficus religiosa* and *Leucaena leucocephala* were also noted for their robust carbon absorption and multifunctionality. Globally, similar patterns have been observed in cities like Melbourne and New York, further confirming that species with substantial biomass, crown architecture, and nativity outperform others in delivering ecosystem services.

One of the strongest conclusions that can be drawn is the urgent need to align plantation decisions with total performance scores rather than aesthetic or short-term objectives. In many urban contexts, tree species are chosen based on ornamental value or fast growth alone. However, this study reveals that some exotic species, such as *Grevillea robusta* and *Eucalyptus globulus*, while performing well in carbon sequestration, scored lower (around 28–32) in the total index due to their exotic status, ecological incompatibility, or limited multi-utility. Therefore, the total scoring framework discourages a carbon-only plantation strategy and emphasizes balanced performance, particularly across ecological, cultural, and service-related parameters.

This research also highlights that tree species with moderate scores (30–34) can be valuable in mixed-use planting schemes. Species like *Cassia fistula*, *Terminalia bellirica*, *Syzygium cumini*, and *Alstonia scholaris* fall into this category. While they may not be the absolute best in every criterion, they still offer substantial ecological value, particularly in contexts where shade, ornamental aesthetics, or fruit production are also desired. These trees are ideal for buffer zones, roadside avenues, and community parks where a mixture of ecosystem functions is preferred over specialization. For instance, *Cassia fistula*, with its iconic yellow blossoms and moderate crown area, offers seasonal aesthetics while still contributing significantly to carbon sequestration. Similarly, *Syzygium cumini* supports local fauna and offers edible fruit, making it ideal for parks that serve both ecological and social functions.

In contrast, low-scoring species (below 28) such as *Callistemon viminalis*, *Plumeria obtusa*, *Moringa oleifera*, and some ornamental exotics demonstrated weak performance across several indicators. These species often lacked sufficient crown area, had poor carbon storage, limited ecological utility, or belonged to exotic categories that provide fewer long-term services. The conclusion here is not to exclude these species entirely but to restrict their use to specific landscape features, such as boundary plantings, underplantings, or decorative patches. Their low scores indicate that they should not form the backbone of urban forest infrastructure but can serve secondary or ornamental roles.

The total score index also supports better spatial planning and planting design. For example, high-scoring species should be prioritized for large open spaces in parks, central corridors, and school campuses where their canopy, biomass, and root systems can expand without constraints. Medium scorers can be interspersed to ensure diversity and seasonal interest, while low scorers may be confined to areas with limited root space, aesthetic goals, or architectural considerations. This stratification ensures optimal use of available space and resources while maximizing the long-term ecological returns on plantation efforts.

Furthermore, the total score-based recommendations also contribute to urban forestry policy. Delhi, like many Indian cities, is under increasing pressure from rapid urbanization, rising temperatures, and deteriorating air quality. Green spaces like District Park, Hauz Khas, offer some of the last remaining urban lungs capable of regulating local climates and serving as biodiversity refuges. By adopting the scoring system into municipal planting policies, city planners can make evidence-based decisions that maximize long-term ecological gain. This aligns with global trends seen in cities such as London, Barcelona, and Seoul, where tree-planting policies now consider biodiversity value, native status, and ecosystem service potential as primary criteria.

Another major implication of this score-based strategy is its value for participatory planning. Citizen engagement in tree planting is most effective when supported by transparent tools. Sharing a simple but robust scoring system allows communities, NGOs, and resident welfare associations to understand why certain species are recommended over others. When the public sees that planting decisions are based on integrated ecological reasoning and not just aesthetics, they are more likely to participate actively in nurturing, monitoring, and protecting urban forests.

Finally, the total scoring framework presents a replicable and scalable model for other urban regions in India and globally. The adaptability of the system means it can be tailored for other cities by adjusting the weight of each criterion based on local environmental priorities. For example, in drought-prone areas, water-use efficiency could be included as an additional criterion. In coastal cities, salt tolerance might be relevant. Thus, the conclusion is that this study offers not just site-specific recommendations for District Park, Hauz Khas, but a universally adaptable tool for evidence-based species selection.

Despite the robustness of the i-Tree Eco model and a thorough plot-based sampling strategy, certain limitations of the study should be acknowledged. Seasonal variability in leaf cover and physiological processes was not explicitly accounted for, which may slightly influence carbon estimates, particularly for deciduous species. The study was also limited to one growing season, and while the sample size of 140 plots provides a strong representation, extending the study over multiple seasons would offer greater temporal accuracy. Moreover, the i-Tree Eco model, though powerful, relies on generalized biomass equations and regional data approximations that may not capture local growth nuances of some Indian species.

Future research could integrate long-term monitoring across seasons and years, allowing for dynamic modelling of sequestration rates in relation to changing urban conditions, species maturation, and management practices. Expanding the framework to include biodiversity indices, water-use efficiency, or ecosystem disservices could further enhance the multi-dimensional utility of the species selection strategy. Collaborations with urban planners, citizen scientists, and ecologists could also facilitate co-designed greening interventions based on these results.

In conclusion, this study affirms that well-informed species selection, based on integrated scoring and ecosystem service delivery, can enhance the functionality and sustainability of urban green spaces. The recommendations derived from the total score system offer a clear roadmap for planners, policymakers, and citizens to build greener, cooler, and more resilient cities. District Park, Hauz Khas, stands as a living laboratory and a scalable model for other parks in Delhi and beyond demonstrating how data-driven planning can transform urban green space management into a strategic instrument for climate mitigation and ecological well-being.

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# Annexure 1:

| i-tree Eco Data Collection Sheet | | | | |
|---|---|---|---|---|
| Date: | | | Place: | |
| Surveyor: | | | | |

| Name | | | Name | |
|---|---|---|---|---|
| Height of observer | | | Height of observer | |
| Distance b/w tree & Observer | | | Distance b/w tree & Observer | |
| CBH (cm) | | | CBH (cm) | |
| Diameter (cm) | | | Diameter (cm) | |
| Tree Total Height (m) | | | Tree Total Height (m) | |
| Canopy Top Height (m) | | | Canopy Top Height (m) | |
| Canopy Base Height (m) | | | Canopy Base Height (m) | |
| Canopy dimension (N/S) | | | Canopy dimension (N/S) | |
| Canopy dimension (E/W) | | | Canopy dimension (E/W) | |
| Canopy Missing (%) | | | Canopy Missing (%) | |
| Crown Dieback (%) | | | Crown Dieback (%) | |
| Crown Light Exposure | | | Crown Light Exposure | |

| Name | | | Name | |
|---|---|---|---|---|
| Height of observer | | | Height of observer | |
| Distance b/w tree & Observer | | | Distance b/w tree & Observer | |
| CBH (cm) | | | CBH (cm) | |
| Diameter (cm) | | | Diameter (cm) | |
| Tree Total Height (m) | | | Tree Total Height (m) | |
| Canopy Top Height (m) | | | Canopy Top Height (m) | |
| Canopy Base Height (m) | | | Canopy Base Height (m) | |
| Canopy dimension (N/S) | | | Canopy dimension (N/S) | |
| Canopy dimension (E/W) | | | Canopy dimension (E/W) | |
| Canopy Missing (%) | | | Canopy Missing (%) | |
| Crown Dieback (%) | | | Crown Dieback (%) | |
| Crown Light Exposure | | | Crown Light Exposure | |

| Name | | | Name | |
|---|---|---|---|---|
| Height of observer | | | Height of observer | |
| Distance b/w tree & Observer | | | Distance b/w tree & Observer | |
| CBH (cm) | | | CBH (cm) | |
| Diameter (cm) | | | Diameter (cm) | |
| Tree Total Height (m) | | | Tree Total Height (m) | |
| Canopy Top Height (m) | | | Canopy Top Height (m) | |
| Canopy Base Height (m) | | | Canopy Base Height (m) | |
| Canopy dimension (N/S) | | | Canopy dimension (N/S) | |
| Canopy dimension (E/W) | | | Canopy dimension (E/W) | |