Evaluating Air Pollutant Removal Efficiency of Trees in District Park, Hauz Khas Using the i-Tree Eco Model for Improved Air Quality

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This is to certify that Ms SHIVANI K with enrolment Number A137120321006, 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 green buffer areas based on i-Ttree 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 SHIVANI K has completed the project-related work and the work done is satisfactory.

(Dr. Ajay Maletha)

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TO WHOM SO EVER IT MAY CONCERN

Ther is to certify that **Ms. Shivani** 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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Shivani K

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ABSTRACT

Air pollution is a persistent and severe environmental challenge in Delhi, adversely impacting public health and urban ecosystems. Urban green spaces, particularly tree cover, play a crucial role in mitigating air pollution by removing key pollutants from the atmosphere. This study evaluates the air pollutant removal efficiency of trees in District Park, Hauz Khas, South Delhi, using the i-Tree Eco model—a widely recognized tool for quantifying urban forest ecosystem services. Field data were collected from 140 randomly selected plots within the 149-acre park, encompassing a total of 415 trees representing 45 species. The species composition, diameter at breast height (DBH), and other biometric parameters were recorded and analysed.

The results reveal that the urban forest in District Park, Hauz Khas, comprises an estimated 3,707 trees with a tree cover of 52.2%. The most prevalent species include *Polyalthia longifolia*, *Ficus benjamina*, and *Caryota urens*. The i-Tree Eco model estimated that trees in the park remove approximately 3.756 metric tons of air pollutants annually, with particulate matter (PM10) accounting for the highest removal rate (2,573.6 kg/year). The total economic value of this pollution removal is calculated at Rs551 million per year, highlighting the substantial ecosystem service provided by the park's trees.

Keywords: Air pollutants removal, i-Tree Eco model, Urban ecosystem services, Delhi Air Quality

INTRODUCTION

Air pollution in urban environments is a pervasive and escalating problem, posing severe risks to human health, ecosystem integrity, and overall quality of life (World Health Organization, 2016; Eskeland, 1997; Samet et al., 2000). Urban air quality is compromised by a complex mixture of pollutants, including particulate matter (PM2.5 and PM10), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and sulphur dioxide (SO_2), all of which are known to have detrimental effects on respiratory and cardiovascular health, as well as broader ecological impacts (Powe & Willis, 2004; World Bank, 1997; Lelieveld et al., 2015). In India, and particularly in Delhi, the situation is especially acute. Delhi has consistently ranked among the most polluted cities globally, with air quality indices frequently exceeding national and international safety standards (Chowdhury et al., 2017; Guttikunda & Gurjar, 2012). The city's unique geographical location, dense population, rapid urbanization, vehicular emissions, industrial activity, and seasonal crop residue burning contribute to persistent and often hazardous air pollution episodes (Sharma et al., 2016; Gurjar et al., 2008).

The health consequences of chronic exposure to air pollution in Delhi are well documented, including increased incidence of asthma, chronic obstructive pulmonary disease (COPD), cardiovascular disease, and premature mortality (Balakrishnan et al., 2019; Dholakia et al., 2013). The economic costs associated with healthcare, lost productivity, and reduced quality of life further underscore the urgency of effective and sustainable mitigation strategies (Baró et al., 2014). While policy interventions such as vehicular restrictions, industrial emission controls, and adoption of cleaner fuels have been implemented, their effectiveness is often limited by enforcement challenges and the sheer scale of the problem (Kumar et al., 2019).

Amidst these challenges, urban green spaces—particularly trees—have emerged as critical natural assets capable of mitigating air pollution through the process of dry deposition, wherein airborne pollutants are captured and absorbed by leaves and other plant surfaces (Nowak et al., 2006; Beckett et al., 2000). Urban forests not only improve air quality but also provide a suite of co-benefits, including carbon sequestration, microclimate regulation, noise reduction, and enhanced aesthetic and recreational value (Escobedo & Nowak, 2009; Baró et al., 2014). The effectiveness of trees in removing air pollutants is influenced by species composition, leaf morphology, canopy structure, and local environmental conditions (Gupta et al., 2018; Singh et al., 2021).

To quantify these ecosystem services, advanced modeling tools such as the i-Tree Eco model have been developed. The i-Tree Eco model, created by the U.S. Department of Agriculture Forest Service and its collaborators, is a widely recognized tool for assessing urban forest structure and estimating the magnitude and economic value of ecosystem services, including air pollutant removal (Nowak et al., 2008; USDA Forest Service, 2023). The model integrates detailed field inventory data—such as species identity, diameter at breast height (DBH), crown dimensions, and tree health—with local meteorological and pollution data to provide robust, site-specific estimates of pollutant removal and associated economic benefits (Hirabayashi et al., 2012; Rogers et al., 2015).

Despite its proven utility in North America, Europe, and East Asia (Yang et al., 2005; Rogers et al., 2015), the application of i-Tree Eco in Indian urban contexts remains limited. Most Indian studies have relied on qualitative assessments or basic quantitative approaches, often overlooking the nuanced, species-specific, and economic dimensions of urban forest ecosystem services (Singh et al., 2021; Kumar et al., 2019). This gap is particularly pronounced in Delhi, where the interplay between rapid urbanization, declining green cover, and severe air pollution necessitates a more rigorous and context-specific evaluation of nature-based solutions (Forest Survey of India, 2023).

District Park, Hauz Khas, located in the heart of South Delhi, represents a vital urban green lung amidst dense urbanization and historical landmarks. Spanning 149 acres, the park features a diverse assemblage of native and exotic tree species, making it an ideal site for evaluating the air pollutant removal efficiency of urban vegetation (Gupta et al., 2018). The park's strategic location and ecological diversity offer a unique opportunity to assess how species composition, tree age structure, and local environmental conditions influence the capacity of urban forests to mitigate air pollution.

The present study aims to address these knowledge gaps by applying the i-Tree Eco model to District Park, Hauz Khas, to assess the removal of key pollutants (PM2.5, CO, NO_2, SO_2, and O_3) by trees in the park; to examine how tree species composition and DBH class distribution influence pollution removal capacity; and to identify high-performing tree species for future afforestation and urban planning strategies. By integrating detailed field inventory data with advanced modelling and economic valuation, this research seeks to provide actionable insights for policymakers, urban planners, and environmental managers seeking sustainable solutions to Delhi's air quality crisis.

The study not only contributes to the scientific understanding of urban forest ecosystem services in a highly polluted megacity but also demonstrates the practical value of nature-based interventions in enhancing urban resilience and public health. The findings are expected to inform evidence-based policy and management strategies, supporting Delhi's efforts to achieve cleaner air and a more sustainable urban environment (Nowak et al., 2014; Baró et al., 2014; USDA Forest Service, 2023).

AIM & OBJECTIVES

Aim:

To evaluate Air Pollutant Removal Efficiency of Trees in District Park, Hauz Khas Using the i-Tree Eco Model for Improved Air Quality.

Objectives:

1. Assessing the removal of key pollutants (PM2.5, CO, NO2, SO2 and O3) by trees in District Park, Hauz Khas using the i-Tree Eco model.
2. Examine how tree species composition influence pollution removal capacity.
3. Identify high-performing tree species for future afforestation strategies.

LITERATURE REVIEW

Air pollution is recognized as one of the most critical environmental health risks worldwide, responsible for millions of premature deaths annually (World Health Organization, 2016). Major urban centres, particularly in developing countries, face acute air quality challenges due to rapid urbanization, high population density, increased vehicular traffic, and industrialization (Gurjar et al., 2008). Delhi, the capital of India, is consistently ranked among the world's most polluted cities, with particulate matter (PM2.5 and PM10) concentrations frequently exceeding safe limits (Chowdhury et al., 2017; Guttikunda & Gurjar, 2012). Exposure to these pollutants has been linked to a range of adverse health outcomes, including respiratory illnesses, cardiovascular diseases, and increased mortality (Lelieveld et al., 2015).

Urban forests and green spaces are increasingly recognized for their ecosystem services, especially their capacity to mitigate air pollution (Nowak et al., 2006; Escobedo & Nowak, 2009). Trees remove air pollutants through processes such as dry deposition, where pollutants are captured on leaf surfaces and subsequently absorbed or washed off (Beckett et al., 2000). The effectiveness of pollutant removal depends on factors such as tree species, leaf morphology, canopy structure, and local environmental conditions (Baró et al., 2014).

Numerous studies have quantified the air purification benefits of urban trees. For example, Nowak et al. (2006) estimated that trees in the United States remove approximately 711,000 metric tons of air pollution annually, providing significant public health and economic benefits. In the European context, studies have shown that urban trees can reduce local concentrations of PM10, NO2, and O3 by up to 10–20% in densely vegetated areas (Vos et al., 2013).

The i-Tree Eco model, developed by the U.S. Department of Agriculture Forest Service, has become a standard tool for assessing the structure, function, and value of urban forests (Nowak et al., 2008; Hirabayashi et al., 2012). The model uses field inventory data (species, DBH, crown dimensions) combined with local meteorological and pollution data to estimate ecosystem services, including carbon sequestration, air pollutant removal, and avoided runoff (USDA Forest Service, 2023).

Internationally, the i-Tree Eco model has been applied in cities such as London, Toronto, and Beijing to inform urban planning and policy (Rogers et al., 2015; Yang et al., 2005). In India, however, its application has been limited, and most studies have focused on qualitative assessments or small-scale quantitative analyses (Singh et al., 2021). The study addresses this gap by providing a rigorous, site-specific application of i-Tree Eco in Delhi.

Delhi's air pollution is driven by a complex interplay of local and regional sources. Vehicular emissions, industrial activities, construction dust, and crop residue burning in neighboring states are major contributors (Guttikunda & Gurjar, 2012; Sharma et al., 2016). Seasonal variations are pronounced, with winter months experiencing severe smog episodes due to temperature inversions and reduced atmospheric dispersion (Chowdhury et al., 2017).

The health impacts of Delhi's poor air quality are well documented. Studies have linked high PM2.5 and PM10 levels to increased hospital admissions, reduced lung function in children, and elevated mortality rates (Balakrishnan et al., 2019; Dholakia et al., 2013). These findings underscore the urgent need for effective, sustainable air pollution mitigation strategies.

Delhi's green cover has been declining due to urban expansion, infrastructure development, and encroachment (Forest Survey of India, 2023). Despite efforts to increase tree planting along roadsides and in parks, the overall effectiveness of these interventions in improving city-wide air quality remains debated (Kumar et al., 2019). Some studies suggest that while localized improvements are possible, broader landscape-scale planning and species selection are critical for maximizing benefits (Baró et al., 2014).

Research indicates that certain tree species are more effective at removing specific pollutants. For instance, broad-leaved species with rough leaf surfaces tend to capture more particulate matter (PM) than conifers or smooth-leaved species (Beckett et al., 2000). In the Indian context, species such as *Azadirachta indica* (neem), *Ficus religiosa* (peepal), and *Polyalthia longifolia* have been recommended for urban planting due to their high tolerance to pollution and efficient pollutant removal (Gupta et al., 2018; Singh et al., 2021).

The report's focus on species composition and DBH class distribution is supported by studies showing that younger, fast-growing trees can provide increasing ecosystem services over time, while mature trees contribute significantly to current pollutant removal (Hirabayashi et al., 2012).

Assigning monetary value to the ecosystem services provided by urban trees is a growing area of research. Nowak et al. (2014) and Baró et al. (2014) have demonstrated that the economic benefits, including healthcare cost savings and improved property values, often far exceed the costs of tree planting and maintenance. In India, economic valuation studies are still emerging, but they are crucial for informing policy and justifying investments in urban forestry (Kumar et al., 2019).

While the literature clearly establishes the importance of urban trees in air pollution mitigation, there is a paucity of detailed, site-specific studies in the Indian context that combine field inventory, advanced modeling (i-Tree Eco), and economic valuation. The study fills this gap by providing a comprehensive assessment of the air pollutant removal efficiency of trees in District Park, offering actionable insights for species selection and urban planning.

MATERIAL & METHODS

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). 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). 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 1: 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 in table 2.

Table 2: 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*, (Delhi Forest Department, 2025).

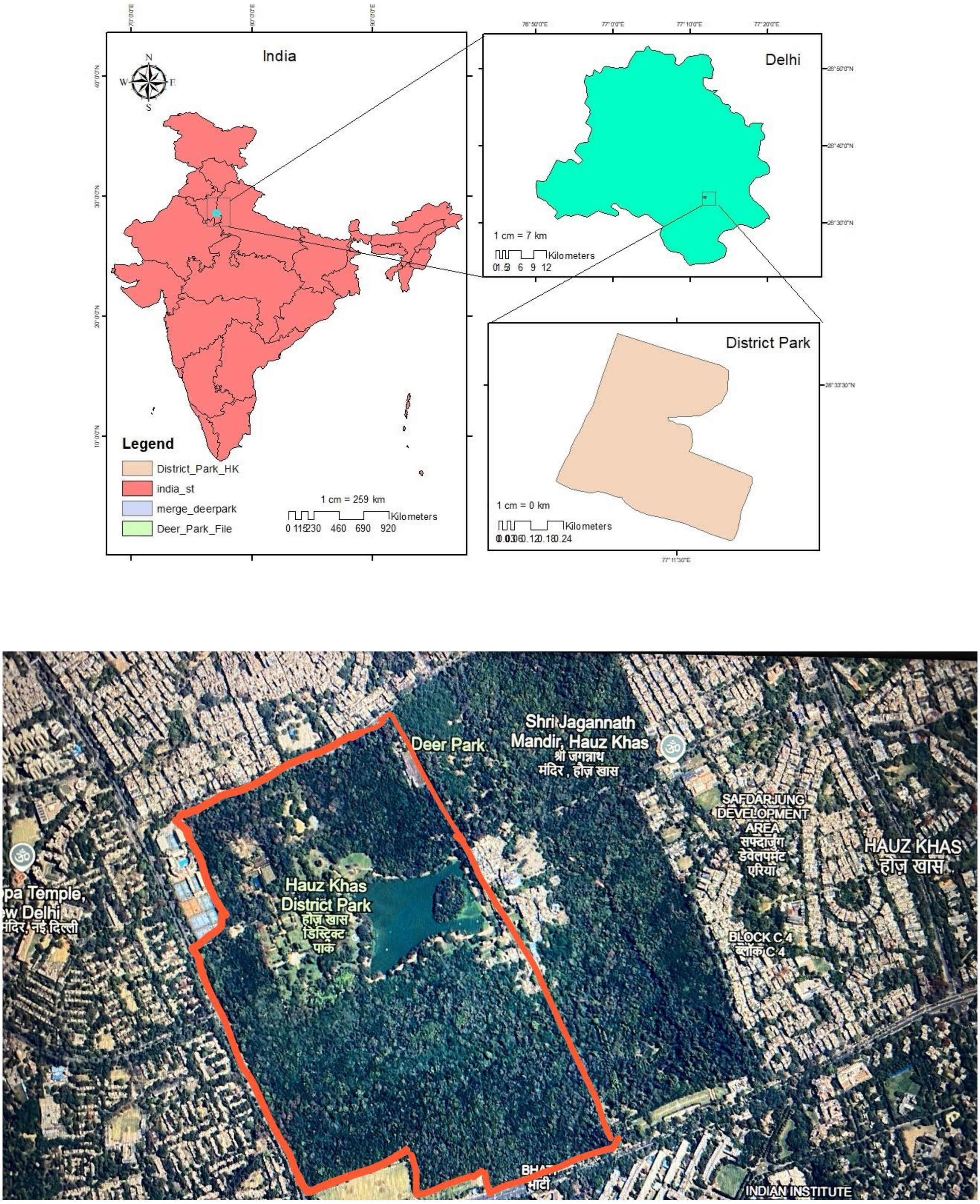

Figure 1: Map of District Park – Hauz Khas

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.

2.1. Sampling Design and Plot Distribution:

The sampling strategy for estimating the potential for air pollutant removal capacity of 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 m^2 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.

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

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.
- 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.

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.

RESULT:

Objective 1: Assessing the removal of key pollutants by trees in District Park, Hauz Khas

1.1.Species Composition

The study provides a detailed enumeration of 415 individual trees belonging to 45 different species and classified under 29 families (Table 3). 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* (Sweet Tamarind), *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* (Table 3). 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 (Table 3).

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* (Table 3).
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 3).

Table 3: Species Composition of District Park

Species Name	**Common Name**	**No. of Individuals**	**Family**	**Origin**	**Habit**
Polyalthia longifolia	False Ashok	51	Annonaceae	Native	Evergreen
Ficus benjamina	Weeping Fig	48	Moraceae	Native	Evergreen
Caryota urens	Fishtail Palm	44	Arecaceae	Native	Evergreen
Alstonia scholaris	Scholar Tree	28	Apocynaceae	Native	Evergreen
Bombax ceiba	Silk Cotton Tree	26	Malvaceae	Native	Deciduous
Pongamia pinnata	Karanj	26	Fabaceae	Native	Deciduous
Putranjiva roxburghii	Putranjiva	21	Putranjivaceae	Native	Evergreen
Syzygium cumini	Jamun	17	Myrtaceae	Native	Evergreen
Grevillea robusta	Silk Oak	16	Proteaceae	Exotic	Evergreen
Roystonea regia	Royal Palm	15	Arecaceae	Exotic	Perennial
Cassia fistula	Amaltas	13	Caesalpiniaceae	Native	Deciduous
Eucalyptus globulus	Blue Gum	12	Myrtaceae	Exotic	Evergreen
Terminalia bellirica	Baheda	11	Combretaceae	Native	Deciduous
Ficus virens	Pilkhan	8	Moraceae	Native	Deciduous
Ficus racemosa	Cluster Fig	7	Moraceae	Native	Evergreen
Ficus religiosa	Peepal	6	Moraceae	Native	Deciduous
Prosopis juliflora	Mesquite	6	Mimosaceae	Exotic	Deciduous
Bauhinia racemosa	Bidi Leaf Tree	5	Caesalpiniaceae	Native	Deciduous
Dalbergia sissoo	Shisham	5	Fabaceae	Native	Deciduous
Albizia lebbeck	Siris Tree	4	Mimosaceae	Native	Perennial

Mimusops elengi	Maulsari	4	Sapotaceae	Native	Perennial
Phyllanthus emblica	Amla	4	Phyllanthaceae	Native	Deciduous
Pterygota alata	Buddha Coconut	4	Sterculiaceae	Native	Evergreen
Jacaranda mimosifolia	Neeli Gulmohar	3	Bignoniaceae	Exotic	Deciduous
Morus alba	Mulberry	3	Moraceae	Exotic	Perennial
Ailanthus excelsa	Indian Tree of Heaven	2	Simaroubaceae	Native	Deciduous
Artocarpus heterophyllus	Jackfruit	2	Moraceae	Native	Evergreen
Azadirachta indica	Neem	2	Meliaceae	Native	Evergreen
Ehretia laevis	Chamror	2	Boraginaceae	Native	Deciduous
Lagerstroemia speciosa	Pride of India	2	Lythraceae	Native	Evergreen
Leucaena leucocephala	Subabul	2	Mimosaceae	Exotic	Evergreen
Pithecellobium dulce	Sweet Tamarinf	2	Mimosaceae	Exotic	Perennial
Plumeria obtusa	White Frangipani	2	Apocynaceae	Exotic	Evergreen
Callistemon viminalis	Weeping Bottle Brush	1	Myrtaceae	Exotic	Evergreen
Ceiba speciosa	Silk Floss Tree	1	Malvaceae	Exotic	Perennial
Citrus limon	Lemon	1	Rutaceae	Native	Perennial
Delonix regia	Gulmohar	1	Caesalpiniaceae	Exotic	Evergreen
Diospyros melanoxylon	Black Ebony	1	Ebenaceae	Native	Deciduous
Ficus benghalensis	Banyan	1	Moraceae	Native	Evergreen
Moringa oleifera	Drumstick Tree	1	Moringaceae	Native	Deciduous

Peltophorum pterocarpum	Peeli Gulmohar	1	Caesalpiniaceae	Exotic	Evergreen
Populus deltoides	Poplar	1	Salicaceae	Exotic	Deciduous
Senna siamea	Siamese Cassia	1	Caesalpiniaceae	Native	Evergreen
Terminalia arjuna	Arjun	1	Combretaceae	Native	Evergreen
Ziziphus mauritiana	Ber	1	Rhamnaceae	Native	Deciduous

The urban forest of District Park Hauz Khas has an estimated 3,707 trees with a tree cover of 52.2 percent. From the recorded species, the greatest number of individuals (figure 2) were recorded of *Polyalthia longifolia* (12.3%), followed by *Ficus benjamina* (11.6%), *Caryota urens* (10.6%), *Alstonia scholaris* (6.7%), *Bombax ceiba* (6.3%), *Pongamia pinnata* (6.3%), *Putranjiva roxburghii* (5.1%), *Syzygium cumini* (4.1%), *Greviilea robusta* (3.9%) and *Roystonea regia* (3.6%).

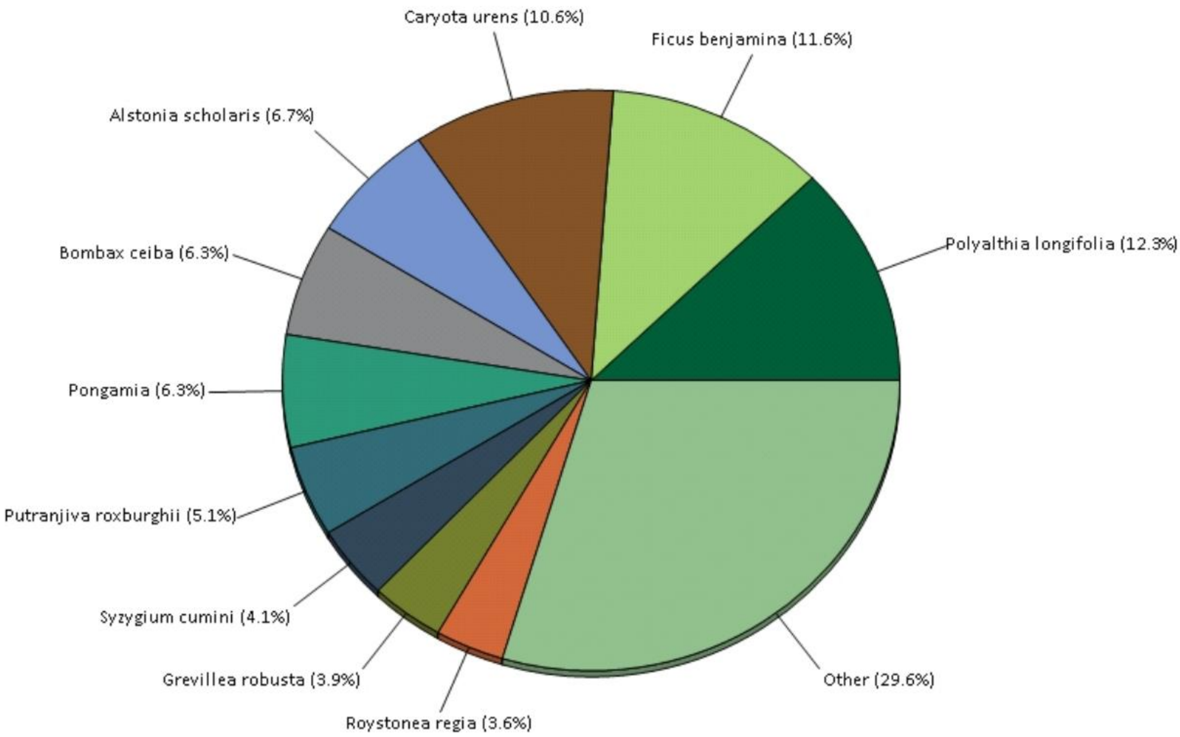

Figure 2: Tree species composition in District Park – Hauz Khas

For most species, there is a dominant size range (which can be described with the size of DBH). This shows that in recent years, different species were preferred when planting tree lines. The ten most common species with their DBH classification is given below and most of our analyses of the total trees in the park are related to the characterization and comparison of the populations of these species.

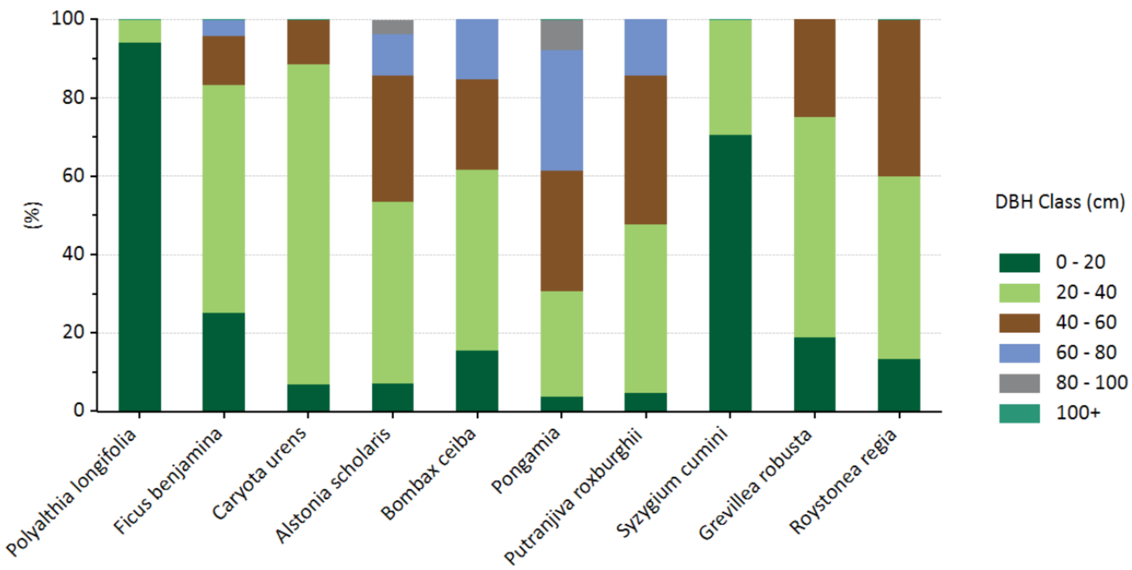

Figure 3: Species distribution in DBH class.

94.1% of *Polyalthia longifolia* lies in the DBH class of 0-20cm. *Ficus benjamina* has major 58.3% in the 20-40cm DBH class. 81.8% of *Caryota urens* lies in the DBH class of 20-40cm. *Alstonia scholaris* has 46.4% in the 20-40cm DBH class. *Bombax ceiba* has 46.2% in the 20-40cm DBH class. 30.8% of *Pongamia pinnata* lies in DBH class of 60-80cm.(Figure 3)

The trees lying in the DBH class 20-40cm are young trees and has immense potential to provide various ecosystem services in the upcoming years. This shows that in recent years, different species were preferred when planting tree lines. Trees lying in the DBH class 60-80cm and 80-100cm are old well-established trees contributing to the park’s major ecosystem services.

Table 4: Species-wise distribution of % of trees in DBH class

Species name	DBH Class (cm)				
	0-20	20-40	40-60	60-80	80-100
	%	%	%	%	%
Polyalthia longifolia	94.10	5.90	0.00	0.00	0.00
Ficus benjamina	25.00	58.30	12.50	4.20	0.00
Caryota urens	6.80	81.80	11.40	0.00	0.00
Alstonia scholaris	7.10	46.40	32.10	10.70	3.60
Bombax ceiba	15.40	46.20	23.10	15.40	0.00
Pongamia pinnata	3.80	26.90	30.80	30.80	7.70
Putranjiva roxburghii	4.80	42.90	38.10	14.30	0.00
Syzygium cumini	70.60	29.40	0.00	0.00	0.00
Grevillea robusta	18.80	56.30	25.00	0.00	0.00
Roystonea regia	13.30	46.70	40.00	0.00	0.00

1.2. Removal of key pollutants (PM2.5, CO, NO2, SO2 and O3) by trees:

Pollution removal by trees in District Park – Hauz Khas was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for PM10. It is estimated that trees remove 3.756 metric tons of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), particulate matter less than 10 microns and greater than 2.5 microns (PM10), and sulfur dioxide (SO2)) per year with an associated value of Rs551 million.

The removal of PM10 is significantly higher than all other pollutants throughout the year. Peaks are observed in March and April reaching nearly 400 kg, with another notable peak in October. Other Pollutants (CO, NO_2, O_3, PM2.5, SO_2) show much lower removal rates, generally below 50 kg per month. Their removal patterns are relatively stable with minor fluctuations, indicating less pronounced seasonal variation compared to PM10. The monthly removal of pollutants such as CO, NO2, O3, SO2, PM2.5, PM10 by the total number of trees in District Park – Hauz Khas are given below:

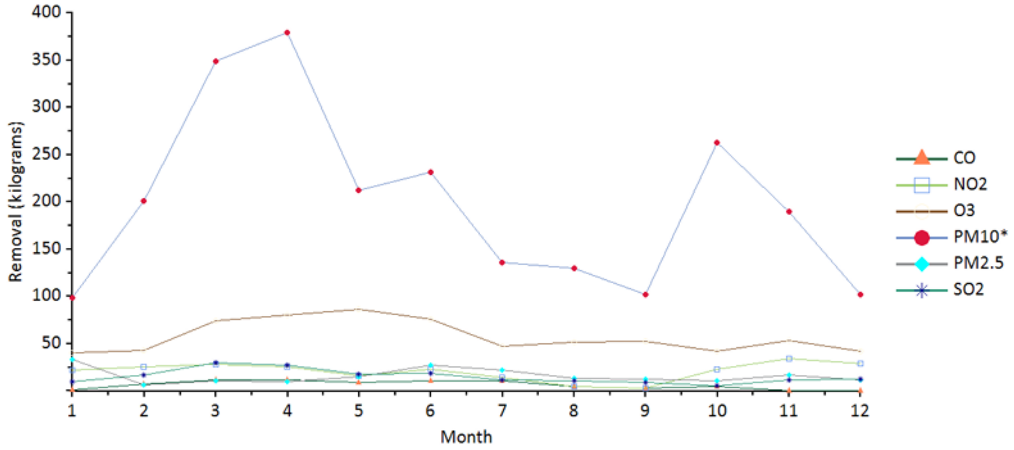

Figure 4: Pollution removal: Month-wise chart

Pollution removal value is calculated based on the prices of Rs93.68 per kilogram (CO), Rs2,306.74 per kilogram (O3), Rs2,306.74 per kilogram (NO2), Rs564.73 per kilogram (SO2), Rs1,540.11 per kilogram (PM2.5), Rs2,29,357.80 per kilogram (PM10).

Table 5: Month-wise pollutant removal (kgs) and their monetary value (Rs.)

Pollutant	Month	Removal (kilograms)	Value (Rs)
CO	January	0.64	60.30
	February	6.97	652.45
	March	11.13	1042.33
	April	11.24	1052.89
	May	8.43	789.28
	June	10.33	967.66
	July	10.05	941.49
	August	4.11	385.10
	September	2.53	237.00
	October	4.20	393.76
	November	0.32	29.82
	December	0.32	29.64
	Annual	**70.26**	**6581.73**
NO2	January	22.00	50754.12
	February	25.29	58328.10
	March	27.42	63259.63
	April	25.51	58838.63
	May	15.28	35257.30
	June	22.38	51615.10

	July	14.20	32746.33
	August	4.69	10828.40
	September	2.51	5778.83
	October	22.50	51889.30
	November	34.06	78569.71
	December	28.79	66409.08
	Annual	**244.62**	**5,64,274.52**
O3	January	40.09	92478.46
	February	42.32	97631.76
	March	73.62	1,69,820.41
	April	79.98	1,84,490.38
	May	86.32	1,99,117.34
	June	75.66	1,74,520.38
	July	47.11	1,08,679.20
	August	51.64	1,19,126.28
	September	51.84	1,19,574.11
	October	41.54	95824.05
	November	52.92	1,22,074.39
	December	41.55	95842.34
	Annual	**684.59**	**15,79,179.09**
PM10	January	98.30	2,25,44,625.87
	February	200.94	4,60,86,756.30
	March	348.38	7,99,02,851.88
	April	379.19	8,69,70,568.25
	May	212.17	4,86,63,851.57
	June	231.70	5,31,42,181.98
	July	135.74	3,11,33,522.45
	August	129.33	2,96,63,871.76
	September	101.82	2,33,54,074.62
	October	262.85	6,02,87,628.18
	November	189.93	4,35,61,702.91
	December	102.12	2,34,21,457.16
	Annual	**2,392.476**	**54,87,33,092.93**
PM2.5	January	33.42	51472.93
	February	6.24	9608.59
	March	10.38	15980.53
	April	9.46	14572.38
	May	14.94	23015.79
	June	26.72	41151.08
	July	21.71	33427.45
	August	13.38	20599.72
	September	12.18	18756.66
	October	10.60	16319.00
	November	16.53	25461.18

	December	10.98	16903.16
	Annual	**186.53**	**2,87,268.48**
SO2	January	9.92	5602.26
	February	16.75	9459.23
	March	29.62	16727.71
	April	27.31	15423.82
	May	17.23	9729.05
	June	18.16	10254.16
	July	11.38	6427.76
	August	10.06	5681.94
	September	8.52	4808.91
	October	5.39	3044.29
	November	11.13	6283.69
	December	11.94	6740.51
	Annual	**177.40**	**1,00,183.33**

Objective 2: Tree species composition and their pollution removal capacity

The below table presents the amount (g/yr) of six major air pollutants-CO, O_3, NO_2, SO_2, PM10, and PM2.5 removed by different tree species. The highest total removal is observed for PM10 (257,368.8), followed by PM2.5 (20,833.9), NO_2 (27,838.3), SO_2 (19,862.3), O_3 (7,649), and CO (7,862.6). This indicates that the collective tree species are most effective at removing particulate matter, especially PM10, from the air.

Table 6: Species-wise pollutant removal capacity (g/yr)

Species Name	CO	O3	NO2	SO2	PM10	PM2.5
Ailanthus excelsa	83	640.3	179	166.5	2322.5	140.9
Albizia lebbeck	133.2	1027.8	287.4	267.4	3728.4	226.2
Alstonia scholaris	622.1	7007.4	2782.3	1812.6	24012.5	2097
Artocarpus heterophyllus	123.8	1393	553.2	360.2	4773.6	417
Azadirachta indica	75.4	848.9	337.1	219.6	2909.1	254
Bauhinia racemosa	12.4	95.9	26.8	25	348	21.1
Bombax ceiba	712	5491.5	1535.7	1428.2	19920.2	1208.3
Callistemon viminalis	1.1	12.9	5.1	3.3	44.1	3.9
Caryota urens	116	1300.5	516.5	336.2	4457.3	389.3

Cassia fistula	238.3	1839	514.2	478.5	6669.7	404.6
Ceiba speciosa	53.8	414.6	115.9	107.8	1504	91.2
Citrus limon	1.2	13.6	5.4	3.5	46.4	4.1
Dalbergia sissoo	155.5	1199.2	335.3	312	4349.9	263.9
Delonix regia	19.5	150.3	42	39.1	545.3	33.1
Diospyros melanoxylon	0.2	2.7	1.1	0.7	9.2	0.8
Ehretia laevis	47.6	366.6	102.5	95.4	1329.8	80.6
Eucalyptus globulus	335.7	3778.7	1500.4	977.2	12948.3	1131
Ficus benghalensis	87.2	981.6	389.8	253.9	3363.7	293.8
Ficus benjamina	1000.3	11260.2	4471.1	2911.7	38586.8	3370.3
Ficus racemosa	372.9	4200.2	1667.8	1086.3	14393.1	1257.1
Ficus religiosa	326.6	2519.1	704.4	655.3	9138.6	554.2
Ficus virens	526	5923.5	2352.2	1532.2	20298.6	1772.7
Grevillea robusta	237.8	2680.8	1064.4	693.3	9186.7	802.3
Jacaranda mimosifolia	52.8	407.4	113.9	106	1478	89.7
Lagerstroemia speciosa ssp. Speciosa	38.6	298.2	83.4	77.6	1081.6	65.6
Leucaena leucocephala	12.3	138.7	55	35.9	475.1	41.5
Mimusops elengi	1.7	18.8	7.6	4.9	64.5	5.7
Moringa oleifera	38.8	299	83.6	77.8	1084.7	65.8
Morus alba	65.1	502.1	140.4	130.6	1821.3	110.5
Peltophorum pterocarpum	8.2	63.6	17.8	16.5	230.6	14
Phyllanthus emblica	102.8	793	221.7	206.3	2876.7	174.4
Pithecellobium dulce	59.8	460.6	128.8	119.8	1670.7	101.4
Plumeria obtusa	1.8	14.2	4	3.7	51.6	3.1
Polyalthia longifolia	48.1	542.6	215.8	140.2	1860.5	162.3
Pongamia	710.7	5483.2	1533	1426.3	19890.4	1206.2
Populus deltoides	39.2	302.4	84.6	78.7	1096.9	66.5
Prosopis juliflora	164.2	1266.1	354.1	329.3	4592.9	278.4
Pterygota alata	71.2	549.7	153.7	143.1	1993.9	121
Putranjiva roxburghii	695.8	7836	3111.7	2026.6	26852.4	2345.3
Roystonea regia	36.8	415.9	165.1	107.4	1425.8	124.7
Senna siamea	2.6	28.8	11.4	7.4	98.6	8.6

Syzygium cumini	168.5	1899.2	754.1	491.1	6507.4	568.3
Terminalia arjuna	12.1	93	26	24.2	337.2	20.5
Terminalia bellirica	216.3	1667.8	466.1	433.7	6049.7	366.9
Ziziphus mauritiana	37.4	420.9	167.1	108.9	1442.4	126
Total	7866.2	76649	27388.3	19862.3	2,67,868.8	20883.9

2.1. Removal of CO:

The top 10 tree species for carbon monoxide (CO) removal, measured in grams per year (g/yr): *Ficus benjamina* stands out as the most efficient species, removing 1000.3 g/yr of CO, which is substantially higher than any other species on the list. *Bombax ceiba* (712 g/yr), *Pongamia pinnata* (710.7 g/yr), and *Putranjiva roxburghii* (695.8 g/yr) also demonstrate strong CO removal capacities. The CO removal capacity gradually decreases from *Alstonia scholaris* (622.1 g/yr) and *Ficus virens* (526 g/yr) down to *Cassia fistula* (238.3 g/yr), indicating a moderate but noticeable difference in effectiveness among these species.

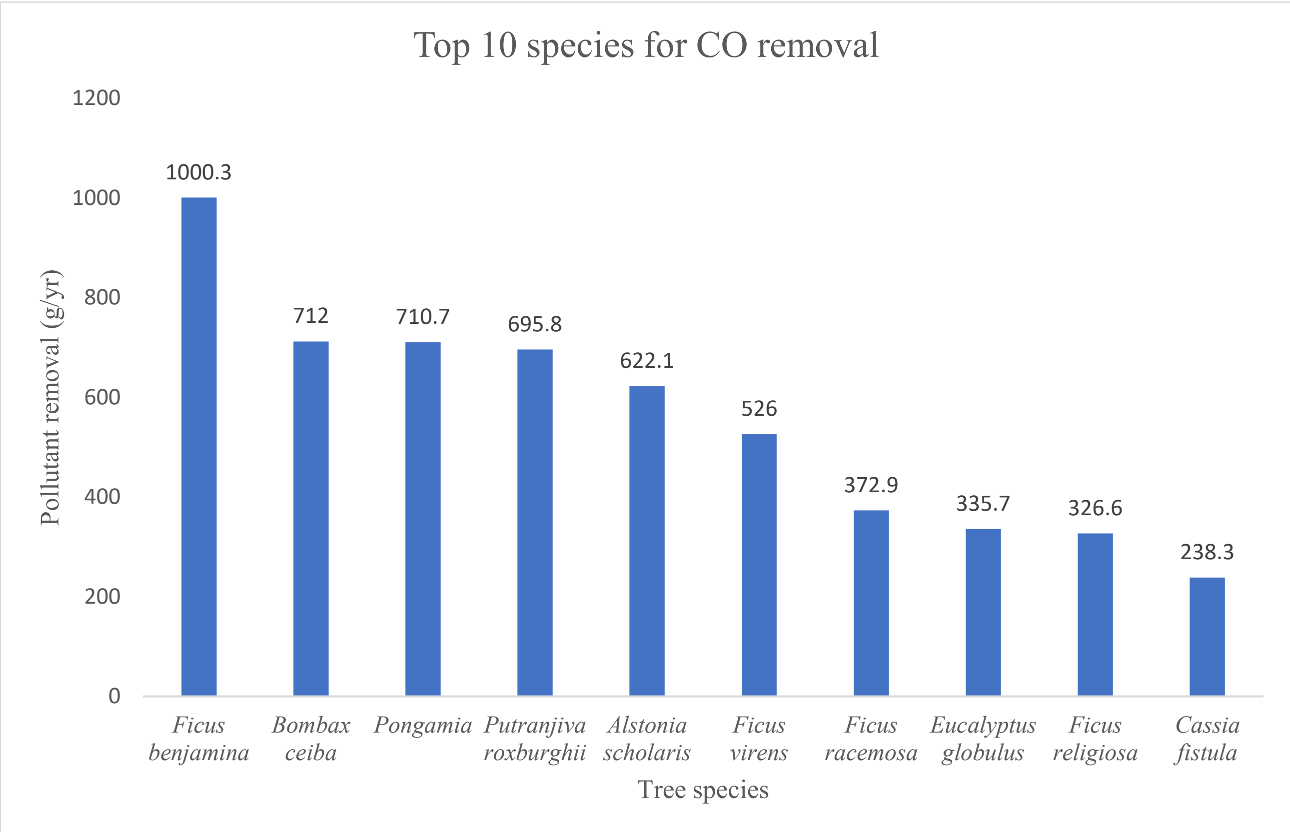

Figure 5: Top 10 species for CO removal

2.2. Removal of O3:

The top 10 tree species for ozone (O_3) removal, measured in grams per year (g/yr): *Ficus benjamina* removes by far the most ozone, at 11,260.2 g/yr. This is significantly higher than any other species on the list, indicating its exceptional ability to absorb or break down ozone pollution. *Putranjiva roxburghii* (7,836 g/yr) and *Alstonia scholaris* (7,007.4 g/yr) are also notable for their high ozone removal capacities, though they lag *Ficus benjamina* by a considerable margin. *Ficus virens* (5,923.5 g/yr), *Bombax ceiba* (5,491.5 g/yr), and *Pongamia pinnata* (5,483.2 g/yr) form a middle group with substantial but lesser removal rates. *Ficus racemosa* (4,200.2 g/yr) and *Eucalyptus globulus* (3,778.7 g/yr) show moderate ozone removal.*Grevillea robusta* (2,680.8 g/yr) and *Ficus religiosa* (2,519.1 g/yr) have the lowest removal rates among the top 10 but still contribute meaningfully.

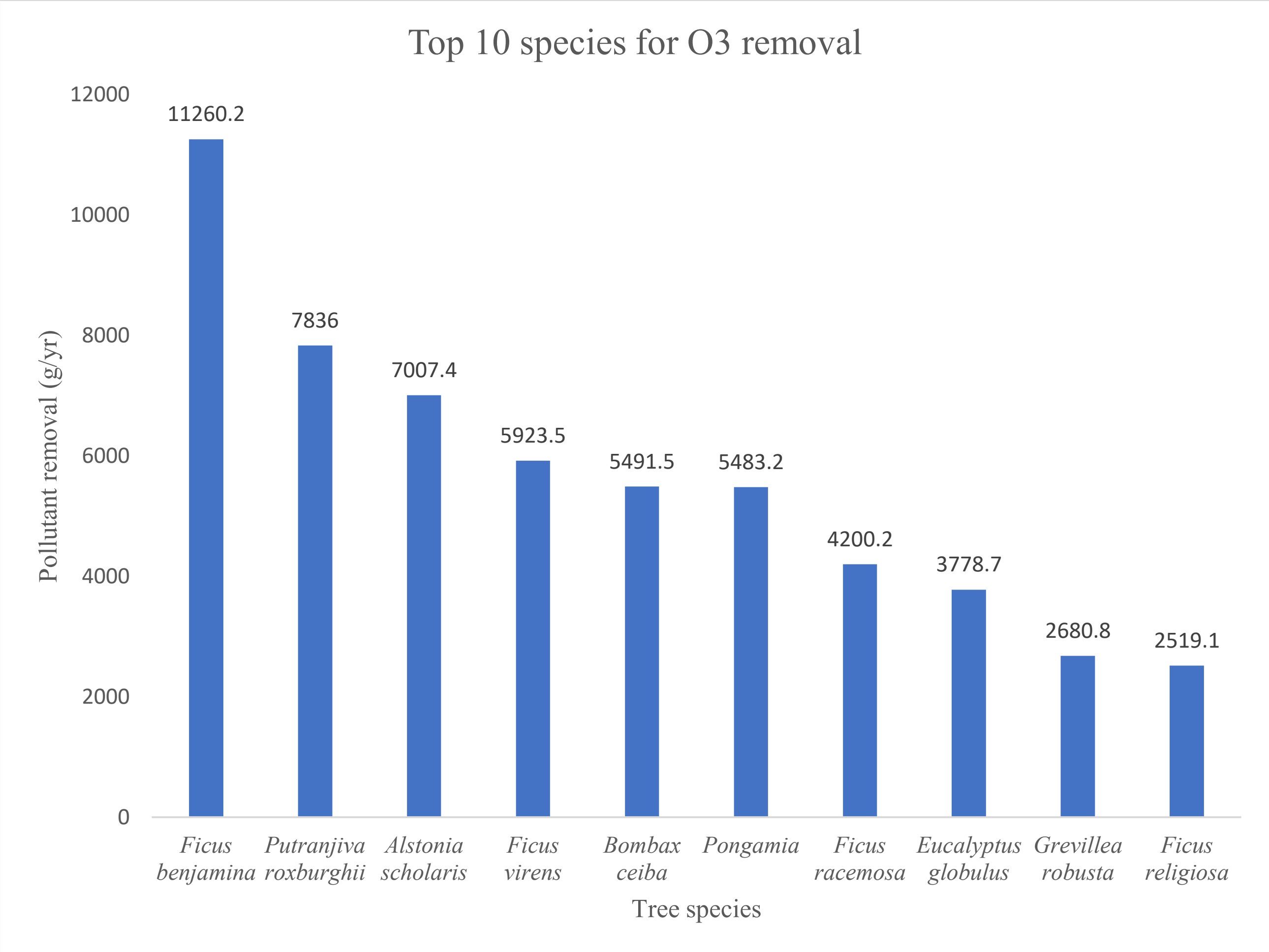

Figure 6: Top 10 species for O3 removal

2.3. Removal of SO2:

The top 10 tree species for sulfur dioxide (SO_2) removal, measured in grams per year (g/yr): *Ficus benjamina* removes the highest amount of SO_2, at 2911.7 g/yr. This is a significant lead over all other species, indicating its exceptional ability to absorb SO_2 from the atmosphere. *Putranjiva roxburghii* (2026.6 g/yr) and *Alstonia scholaris* (1812.6 g/yr) also show strong SO_2 removal capacity, though less than *Ficus benjamina*. *Ficus virens* (1532.2 g/yr), *Bombax ceiba* (1428.2 g/yr), and *Pongamia pinnata* (1426.3 g/yr) form a middle group with moderate SO_2 removal rates. *Ficus racemosa* (1086.3 g/yr) and *Eucalyptus globulus* (977.2 g/yr) contribute meaningfully but are less effective compared to the top species. *Grevillea robusta* (693.3 g/yr) and *Ficus religiosa* (655.3 g/yr) have the lowest removal rates among the top 10 but still play a role in SO_2 absorption.

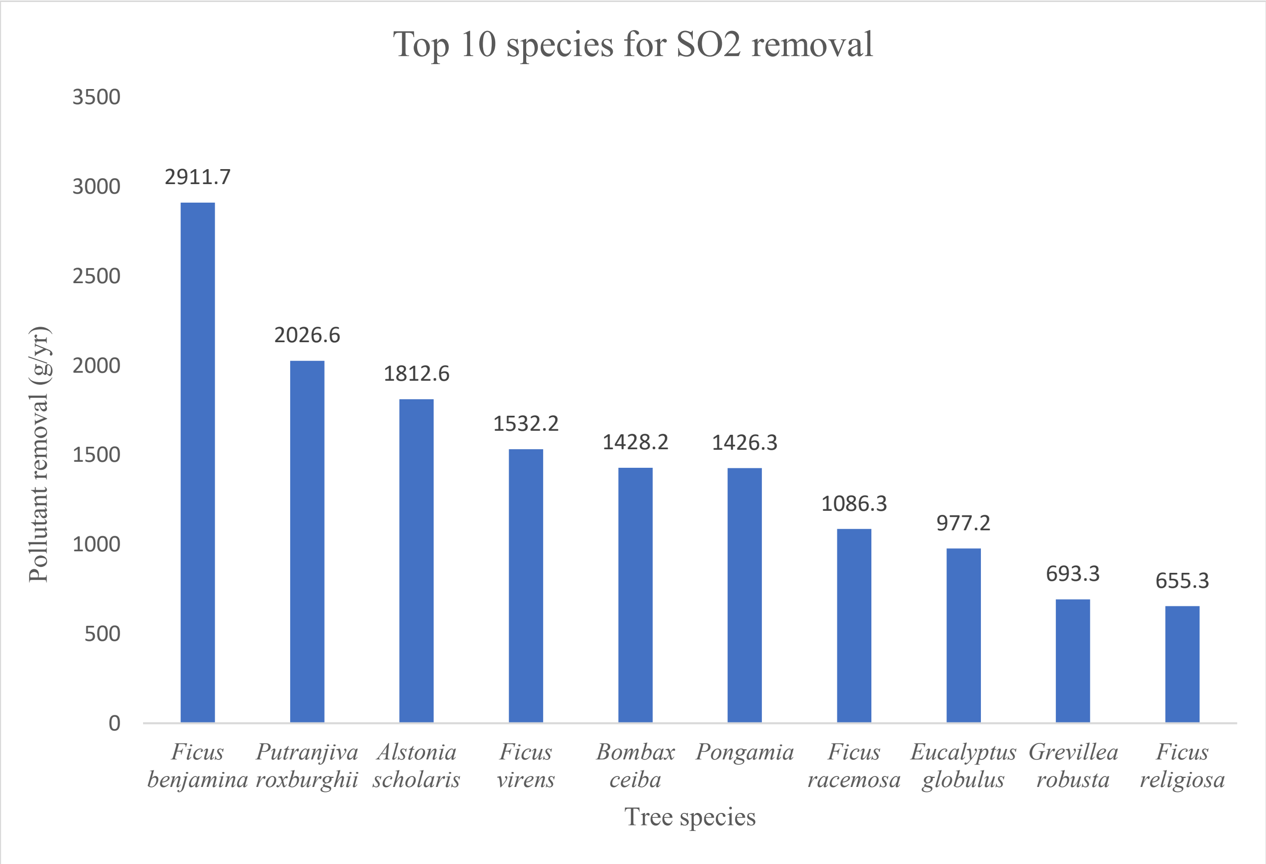

Figure 7: Top 10 species for SO2 removal

2.4. Removal of NO2:

The top 10 tree species for nitrogen dioxide (NO_2) removal, measured in grams per year (g/yr): *Ficus benjamina* stands out as the most effective species, removing 4471.1 g/yr of NO_2. This is significantly higher than any other species in the list. *Putranjiva roxburghii* (3111.7 g/yr) and *Alstonia scholaris* (2782.3 g/yr) also show strong NO_2 removal capacities. *Ficus virens* (2352.2 g/yr) and *Ficus racemosa* (1667.8 g/yr) are also notable contributors. *Bombax ceiba* (1535.7 g/yr), *Pongamia pinnata* (1533g/yr), and *Eucalyptus globulus* (1500.4 g/yr) have similar removal rates, forming a middle group. *Grevillea robusta* (1064.4 g/yr) and *Syzygium cumini* (754.1 g/yr) are the least effective among the top 10 but still provide meaningful NO_2 removal.

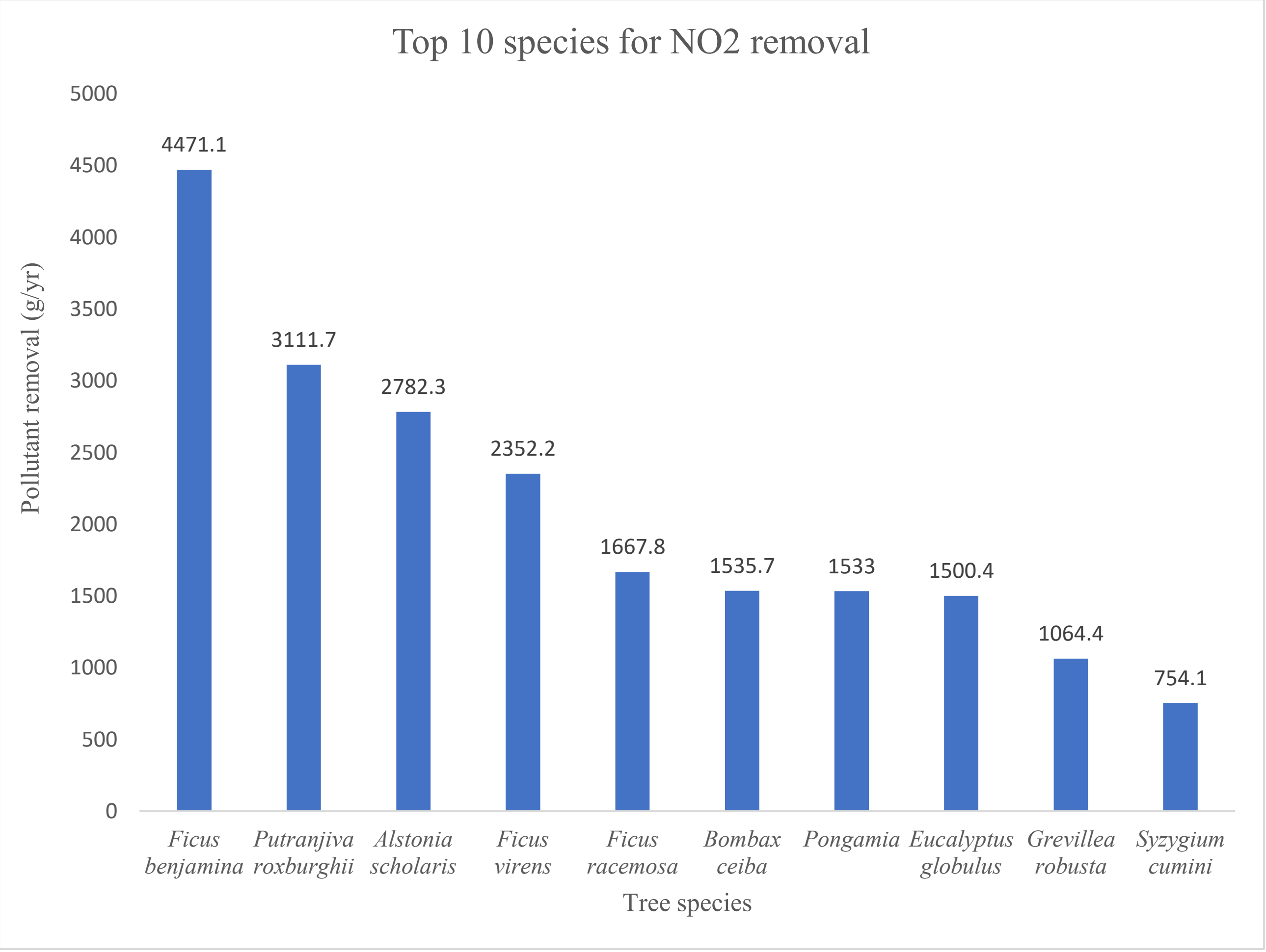

Figure 8: Top 10 species for NO2 removal

2.5. Removal of PM10:

The top 10 tree species for PM10 removal, measured in grams per year (g/yr): *Ficus benjamina* is the most effective species for PM10 removal, with a capacity of 38,556.8 g/yr, far surpassing the other species. *Putranjiva roxburghii* and *Alstonia scholaris* follow, removing 26,852.4 g/yr and 24,012.5 g/yr of PM10, respectively. The next group, including *Ficus virens, Bombax ceiba, and Pongamia pinnata*, removes between 19,890.4 and 20,296.8 g/yr. *Ficus racemosa and Eucalyptus globulus* show moderate removal capacities (14,393.1 g/yr and 12,943.3 g/yr). *Grevillea robusta* and *Ficus religiosa* have the lowest removal rates among the top 10, with 9,186.7 g/yr and 9,138.6 g/yr, respectively.

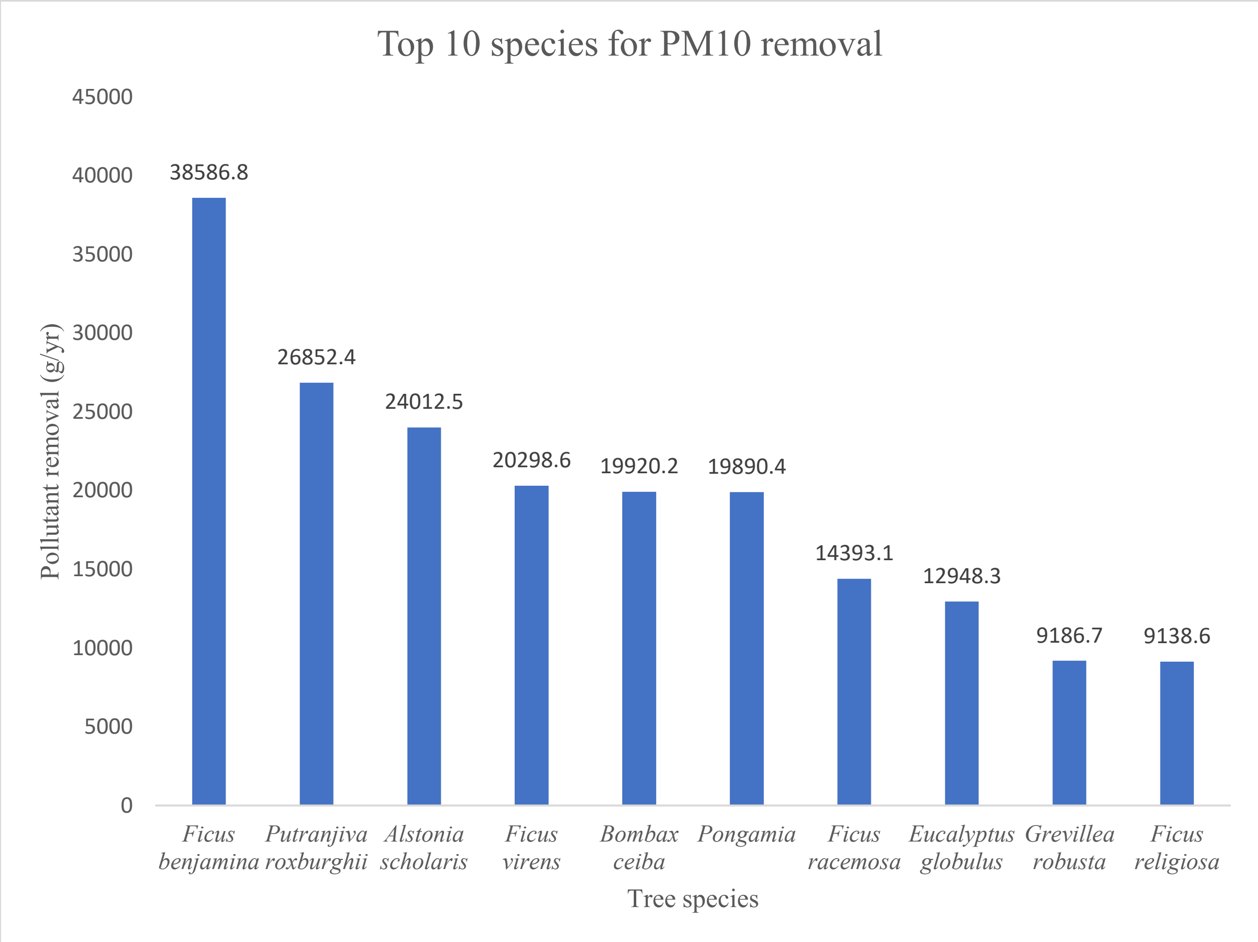

Figure 9: Top 10 species for PM10 removal

2.6. Removal of PM2.5:

The top 10 tree species for PM2.5 removal, measured in grams per year (g/yr): The data highlights significant variation in the ability of different tree species to remove fine particulate pollutants from the air. *Ficus benjamina* is the most effective species for PM2.5 removal, with a capacity of 3370.3 g/yr, which is considerably higher than the other species. *Putranjiva roxburghii* and *Alstonia scholaris* are the next best performers, removing 2345.3 g/yr and 2097 g/yr of PM2.5, respectively.

The removal capacity drops notably after the top three species, with *Ficus virens* at 1772.7 g/yr and *Ficus racemosa* at 1257.1 g/yr. The remaining species (*Bombax ceiba, Pongamia pinnata, Eucalyptus globulus, Grevillea robusta, and Syzygium cumini*) have removal capacities ranging from 1208.3 g/yr down to 568.3 g/yr. *Syzygium cumini* has the lowest PM2.5 removal among the top 10, at 568.3 g/yr.

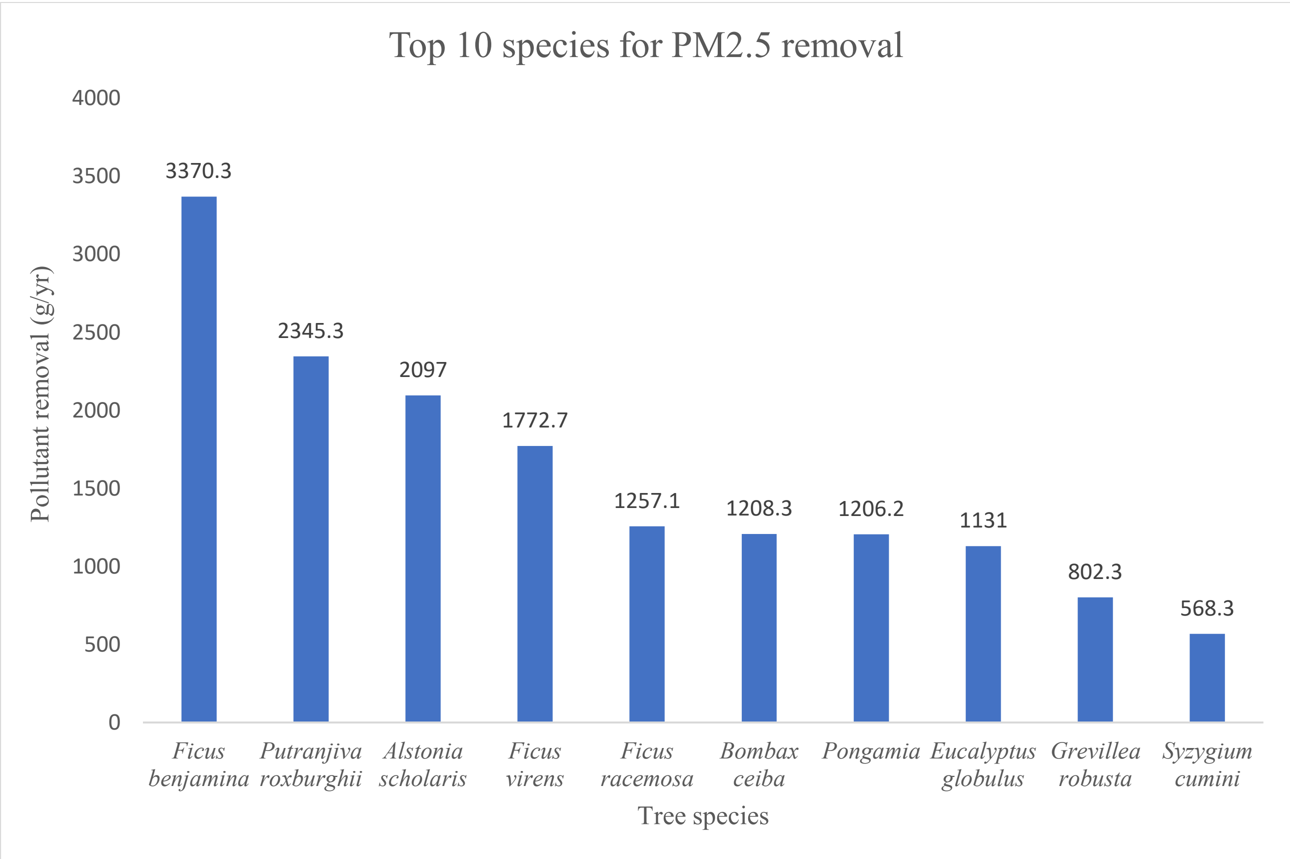

Figure 10: Top 10 species for PM2.5 removal

Objective 3: High-performing tree species:

3.1. Leaf area and biomass of trees:

The lists of different tree species along with their area coverage (m²/ha) and biomass (kg/ha) provides insight into the distribution and biomass contribution of each species within a given area.

Total area covered by all species is 33,915.70 m²/ha, and the total biomass is 3,365.00 kg/ha. *Alstonia scholaris* covers the largest area (2635.30 m²/ha) and has the highest biomass (391 kg/ha), indicating its dominance in both spread and mass. *Bombax ceiba* and *Eucalyptus globulus* also show significant biomass values (200.50 kg/ha and 184.00 kg/ha, respectively), even though their area coverage is less than *Alstonia scholaris*. Some species, like *Senna siamea* and *Callistemon viminalis*, have very small area coverage and low biomass, indicating they are minor components of the ecosystem. Ficus virens has a high area coverage (2,227.70 m²/ha) but a moderate biomass (174.00 kg/ha), suggesting it is widespread but not as massive as *Alstonia scholaris*. Several species, such as *Terminalia arjuna* and *Peltophorum*, have both low area and low biomass, contributing minimally to the overall density. *Alstonia scholaris* is the most dominant species in terms of both area and biomass, making it a key species in the ecosystem's structure and function.

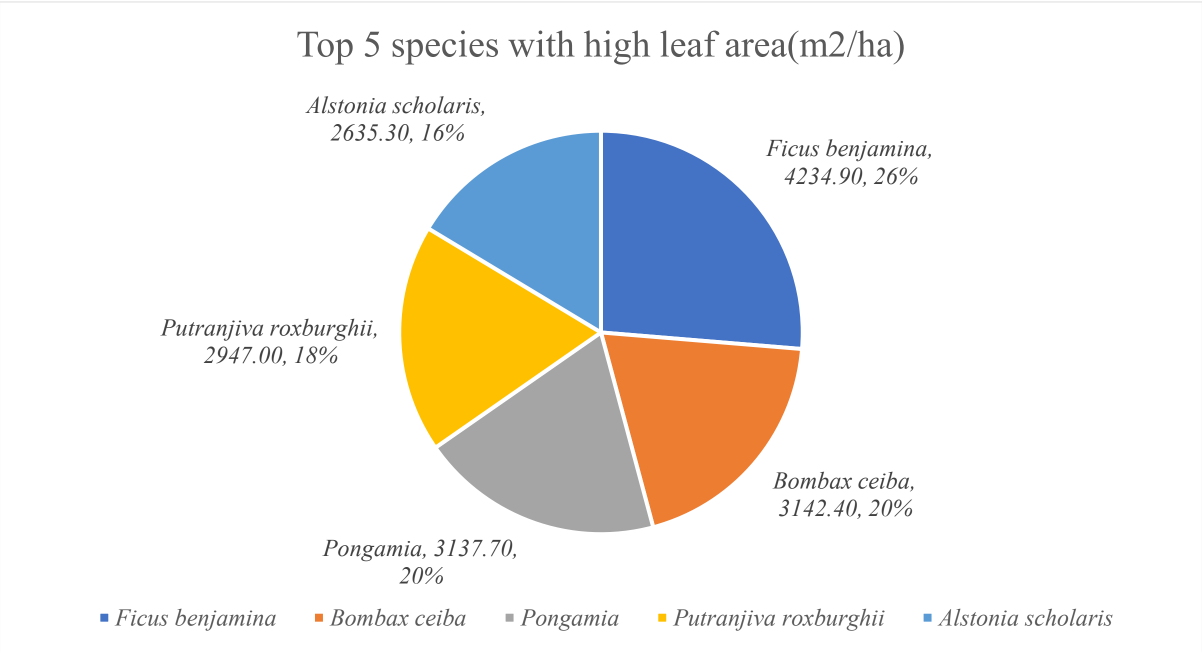

Figure 11: Top 5 species with High Leaf Area

Table 7: Tree species and their Leaf area, Biomass

Species	Leaf Area (m^2/ha)	Leaf Biomass (kg/ha)
Ficus benjamina	4234.90	331.60
Bombax ceiba	3142.40	200.50
Pongamia	3137.70	271.20
Putranjiva roxburghii	2947.00	223.90
Alstonia scholaris	2635.30	391.90
Ficus virens	2227.70	174.40
Ficus racemosa	1579.60	123.70
Ficus religiosa	1441.60	112.90
Eucalyptus globulus	1421.10	184.00
Cassia fistula	1052.10	273.40
Grevillea robusta	1008.20	122.60
Terminalia bellirica	954.30	123.50
Prosopis juliflora	724.50	62.60
Syzygium cumini	714.20	92.40
Dalbergia sissoo	686.20	59.30
Albizia lebbeck	588.20	25.60
Artocarpus heterophyllus	523.90	41.00
Caryota urens	489.20	82.10
Phyllanthus emblica	453.80	81.00
Ficus benghalensis	369.20	28.90
Ailanthus excelsa	366.40	56.40
Azadirachta indica	319.30	23.70
Pterygota alata	314.50	20.10
Morus alba	287.30	21.00
Pithecellobium dulce	263.60	22.80
Ceiba speciosa	237.30	13.50
Jacaranda mimosifolia	233.20	14.20
Ehretia laevis	209.80	41.50
Polyalthia longifolia	204.20	34.30
Populus deltoides	173.00	12.50

Moringa oleifera	171.10	11.50
Lagerstroemia speciosa ssp. Speciosa	170.60	22.10
Ziziphus mauritiana	158.30	7.00
Roystonea regia	156.50	26.20
Delonix regia	86.00	7.40
Bauhinia racemosa	54.90	4.70
Terminalia arjuna	53.20	6.90
Leucaena leucocephala	52.10	4.50
Peltophorum pterocarpum	36.40	3.10
Senna siamea	10.80	2.00
Plumeria obtusa	8.10	1.20
Mimusops elengi	7.10	0.50
Citrus limon	5.10	0.70
Callistemon viminalis	4.80	0.60
Diospyros melanoxylon	1.00	0.10

3.2. Crown health of trees by species:

The below table categorizes the crown health of tree species into Excellent, Good, Fair, Poor, Critical, Dying, and Dead (in percentage). The majority of the trees (93.30%) are in good health, and 2.40% are in fair health. Only a small percentage of trees fall into the Poor (0.70%), Dying (1.20%) and Dead (2.40%) categories. Most species, such as *Alstonia scholaris, Bombax ceiba,* and *Ficus benjamina*, have 100% of their individuals in Excellent health. Some species, like *Atrocarpus heterophyllus, Callistemon viminalis, Eucalyptus globulus, Ficus virens, Morus alba, Pongamia pinnata*, and *Syzygium cumini*, have individuals in poorer health categories, including Dead. Morus alba shows a significant percentage (33.3%) in the Dead category, indicating a problem with this species. *Plumeria obtusa* also has a notable percentage (50%) in the Dead category.

The overall health of the tree population is very good, with more than 95.70% of trees in Good or fair condition. Only a few species show signs of decline, with a small proportion of individuals in Poor, Critical, or Dead categories. The species with higher percentages in the

Dead or Poor categories may require further investigation or management intervention to determine the cause (such as disease, pests, or unsuitable site conditions). Crown Health defined by crown dieback percentage being: Excellent <= 0, Good <= 10, Fair <= 25, Poor <= 50, Critical <= 75, Dying <= 99, Dead <= 100.

Table 8: Tree species and their crown health

Species	**Crown Health (in %)**						
	Excellent	**Good**	**Fair**	**Poor**	**Critical**	**Dying**	**Dead**
Ailanthus excelsa		100.00					
Albizia lebbeck		100.00					
Alstonia scholaris		96.40		3.60			
Artocarpus heterophyllus		100.00					
Azadirachta indica		100.00					
Bauhinia racemosa		40.00					60.00
Bombax ceiba		100.00					
Callistemon viminalis		100.00					
Caryota urens		84.10	2.30	2.30			11.40
Cassia fistula		76.90	23.10				
Ceiba speciosa		100.00					
Citrus limon		100.00					
Dalbergia sissoo		60.00	40.00				
Delonix regia		100.00					
Diospyros melanoxylon		100.00					
Ehretia laevis		50.00	50.00				
Eucalyptus globulus		83.30					16.70
Ficus benjamina		100.00					
Ficus benghalensis		100.00					
Ficus racemosa		100.00					
Ficus religiosa		100.00					
Ficus virens		87.50				12.50	
Grevillea robusta		100.00					
Jacaranda mimosifolia		100.00					

Lagerstroemia speciosa ssp. Speciosa		100.00					
Leucaena leucocephala		100.00					
Mimusops elengi		100.00					
Morus alba		66.70				33.30	
Moringa oleifera		100.00					
Peltophorum pterocarpum		100.00					
Phyllanthus emblica		100.00					
Pithecellobium dulce		100.00					
Plumeria obtusa		50.00				50.00	
Populus deltoides		100.00					
Polyalthia longifolia		100.00					
Pongamia		100.00					
Prosopis juliflora		50.00	16.70	16.70		16.70	
Pterygota alata		100.00					
Putranjiva roxburghii		100.00					
Roystonea regia		100.00					
Senna siamea			100.00				
Syzygium cumini		94.10				5.90	
Terminalia arjuna		100.00					
Terminalia bellirica		100.00					
Ziziphus mauritiana			100.00				
Total		**93.30**	**2.40**	**0.70**		**1.20**	**2.40**

3.3. Importance value species-wise:

In District Park – Hauz Khas, the most dominant species in terms of leaf area are *Ficus benjamina, Bombax ceiba, and Pongamia*. The 5 species with the greatest importance values are listed below in the table 9. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 9: Top 5 Important Value species

Species	Percent Population	Percent Leaf Area	Importance Value
Ficus benjamina	11.6	12.5	24.1
Bombax ceiba	6.3	9.3	15.5
Pongamia	6.3	9.3	15.5
Putranjiva roxburghii	5.1	8.7	13.7
Alstonia scholaris	6.7	7.8	14.5

Table 10: Important Value of all tree species

Species	Percent Population	Percent Leaf Area	Importance Value
Ficus benjamina	11.60	12.50	24.10
Bombax ceiba	6.30	9.30	15.50
Pongamia	6.30	9.30	15.50
Alstonia scholaris	6.70	7.80	14.50
Putranjiva roxburghii	5.10	8.70	13.70
Polyalthia longifolia	12.30	0.60	12.90
Caryota urens	10.60	1.40	12.00
Ficus virens	1.90	6.60	8.50
Eucalyptus globulus	2.90	4.20	7.10
Grevillea robusta	3.90	3.00	6.80
Ficus racemosa	1.70	4.70	6.30
Cassia fistula	3.10	3.10	6.20
Syzygium cumini	4.10	2.10	6.20
Ficus religiosa	1.40	4.30	5.70
Terminalia bellirica	2.70	2.80	5.50
Roystonea regia	3.60	0.50	4.10
Prosopis juliflora	1.40	2.10	3.60
Dalbergia sissoo	1.20	2.00	3.20

Albizia lebbeck	1.00	1.70	2.70
Phyllanthus emblica	1.00	1.30	2.30
Artocarpus heterophyllus	0.50	1.50	2.00
Pterygota alata	1.00	0.90	1.90
Morus alba	0.70	0.80	1.60
Ailanthus excelsa	0.50	1.10	1.60
Azadirachta indica	0.50	0.90	1.40
Jacaranda mimosifolia	0.70	0.70	1.40
Bauhinia racemosa	1.20	0.20	1.40
Ficus benghalensis	0.20	1.10	1.30
Pithecellobium dulce	0.50	0.80	1.30
Ehretia laevis	0.50	0.60	1.10
Lagerstroemia speciosa ssp. Speciosa	0.50	0.50	1.00
Mimusops elengi	1.00	0.00	1.00
Ceiba speciosa	0.20	0.70	0.90
Populus deltoides	0.20	0.50	0.80
Moringa oleifera	0.20	0.50	0.70
Ziziphus mauritiana	0.20	0.50	0.70
Leucaena leucocephala	0.50	0.20	0.60
Plumeria obtusa	0.50	0.00	0.50
Delonix regia	0.20	0.30	0.50
Terminalia arjuna	0.20	0.20	0.40
Peltophorum pterocarpum	0.20	0.10	0.30
Senna siamea	0.20	0.00	0.30
Citrus limon	0.20	0.00	0.30
Callistemon viminalis	0.20	0.00	0.30
Diospyros melanoxylon	0.20	0.00	0.20

DISCUSSION:

The present study evaluated the air pollutant removal efficiency of trees in District Park, Hauz Khas, using the i-Tree Eco model, and provided a detailed assessment of the park's urban forest structure, species composition, and ecosystem service value. The findings reveal that the park's 3,707 trees remove approximately 3.756 metric tons of air pollutants annually, with particulate matter (PM10) accounting for the largest share. The economic valuation of this service, estimated at Rs551 million per year, underscores the substantial contribution of urban green spaces to air quality improvement and public health in Delhi.

The estimated annual removal of 3.756 metric tons of air pollutants by trees in District Park is consistent with findings from other urban forest studies, though the specific removal rates vary depending on local environmental conditions, species composition, and urban morphology. Nowak et al. (2006), in a seminal study of U.S. cities, reported that urban trees remove approximately 711,000 metric tons of air pollution annually nationwide, with removal rates ranging from 0.2 to 1.0 metric ton per hectare per year in city parks, depending on tree density and species mix. Similarly, Yang et al. (2005) found that Beijing's urban forest removed over 1,200 tons of pollutants annually, with PM10 constituting the largest fraction.

In the Indian context, Gupta et al. (2018) assessed several green spaces in Delhi and reported that urban trees could remove between 1.5 and 4.2 metric tons of air pollutants per year per park, depending on park size and tree cover. The removal rate observed in District Park, Hauz Khas, aligns well with these figures, especially considering the park's relatively high tree density (52.2% cover) and species diversity (45 species). This supports the assertion that well-managed urban forests can serve as effective natural filters for urban air pollution, particularly in megacities facing severe air quality challenges.

The study identified *Polyalthia longifolia*, *Ficus benjamina,* and *Caryota urens* as the most prevalent species in District Park. The dominance of these species is significant because previous research has shown that species-specific traits—such as leaf area, surface roughness, and canopy structure—strongly influence pollutant capture efficiency (Beckett et al., 2000; Baró et al., 2014). For example, Ficus species are known for their dense canopies and large leaf surface areas, which enhance their ability to intercept particulate matter and gaseous pollutants (Gupta et al., 2018).

Comparative studies in other cities have highlighted similar findings. In Barcelona, Baró et al. (2014) reported that broad-leaved species with high leaf area indices contributed disproportionately to air purification. The present study's identification of high-performing species in the Delhi context provides valuable guidance for future urban forestry and afforestation initiatives, emphasizing the need to prioritize species with proven pollution removal capacity.

The i-Tree Eco model's integration of DBH (diameter at breast height) class distribution allows for an assessment of how tree size and age affect pollutant removal. Larger, mature trees generally have greater leaf area and biomass, enabling them to remove more pollutants than younger, smaller trees (Nowak et al., 2008). In District Park, the presence of a balanced age structure—including both mature trees and younger cohorts—suggests that the park's urban forest is well-positioned to sustain high levels of ecosystem service provision over time.

This finding is consistent with studies in other urban contexts. Nowak et al. (2014) emphasized that maintaining a diverse age structure is critical for long-term urban forest health and function. In Toronto, Steenberg et al. (2017) demonstrated that parks with a mix of young and old trees provided more consistent air quality benefits and were more resilient to environmental stressors. The results from District Park reinforce the importance of strategic planting and maintenance to ensure continuity of ecosystem services.

The estimated economic value of Rs551 million per year for air pollutant removal in District Park is a striking illustration of the tangible benefits provided by urban forests. This valuation is in line with global studies that have sought to monetize the health and environmental benefits of urban vegetation. Nowak et al. (2014) estimated that U.S. urban trees provide annual air pollution removal services worth $3.8 billion, while Baró et al. (2014) valued the air quality benefits of Barcelona's urban forests at €1.12 million per year.

In India, such economic assessments are still emerging but are increasingly recognized as essential for informing policy and investment decisions (Kumar et al., 2019). By translating ecosystem services into monetary terms, the present study provides a compelling argument for prioritizing urban forestry in municipal budgets and development plans, particularly in cities like Delhi where the costs of air pollution are exceptionally high.

While the i-Tree Eco model is a robust and widely validated tool, certain limitations must be acknowledged. The model's accuracy depends on the quality and representativeness of field inventory data, as well as the availability of local meteorological and pollution data (Hirabayashi et al., 2012). In the present study, data were collected from 140 randomly selected plots, encompassing 415 trees, which were then extrapolated to the entire park. While this sampling approach is standard, it may introduce some uncertainty, particularly in highly heterogeneous landscapes.

Additionally, the model primarily accounts for dry deposition processes and does not fully capture the potential for pollutant resuspension or secondary emissions from vegetation (Nowak et al., 2006). Moreover, the benefits of urban trees extend beyond air pollution removal to include carbon sequestration, microclimate regulation, and biodiversity support—services that were not the primary focus of this study but are nonetheless critical for urban sustainability (Escobedo & Nowak, 2009; Singh et al., 2021)

CONCLUSION:

This study set out to evaluate the air pollutant removal efficiency of trees in District Park, Hauz Khas, South Delhi, using the i-Tree Eco model, with the broader aim of informing sustainable urban air quality management. The study's findings provide compelling evidence that urban forests are not only vital ecological assets but also powerful tools for mitigating the adverse impacts of air pollution in megacities like Delhi.

The park's urban forest, comprising an estimated 3,707 trees across 45 species, removes approximately 3.756 metric tons of air pollutants annually. Particulate matter (PM10) accounted for the largest share of removal, followed by other key pollutants such as CO, NO2, SO2, and O3. The economic value of this ecosystem service, estimated at Rs551 million per year, highlights the substantial public health and environmental benefits provided by the park's trees. Species composition played a critical role in determining pollution removal capacity, with *Polyalthia longifolia, Ficus benjamina, and Caryota urens* emerging as particularly effective species. The presence of a balanced age structure, encompassing both mature and younger trees, further enhanced the park's ability to deliver sustained ecosystem services.

The use of the i-Tree Eco model in this study represents a significant methodological advance for urban forestry research in India. By providing site-specific, quantitative, and economically robust estimates of ecosystem services, the model enables policymakers and urban planners to make informed decisions about species selection, park design, and resource allocation. This is particularly important in the context of rapid urbanization and declining green cover, where evidence-based strategies are essential for safeguarding urban environmental quality. The study's findings have direct implications for urban policy and management: While this study provides a robust foundation, further research is needed to deepen our understanding of urban forest ecosystem services in Delhi and other Indian cities. Longitudinal studies should be conducted to track changes in air pollution removal over time and assess the resilience of urban forests to climate change and other stressors. Integrating remote sensing, citizen science, and advanced modelling approaches can enhance data quality and spatial resolution. Additionally, future studies should explore the synergistic effects of urban green infrastructure on other ecosystem services—such as carbon sequestration, urban heat island mitigation, and stormwater management—to provide a more holistic assessment of urban sustainability.

In conclusion, the trees of District Park, Hauz Khas, provide a vital service by removing significant quantities of air pollutants and delivering substantial economic value to the city of

Delhi. The application of the i-Tree Eco model has demonstrated the power of advanced, site-specific assessment tools for quantifying and valuing urban ecosystem services. As Delhi continues to grapple with the challenges of rapid urbanization and deteriorating air quality, the preservation and enhancement of urban forests must be recognized as a cornerstone of sustainable urban development. The study's relevance extends beyond Delhi, offering a replicable framework for other Indian cities and global megacities facing similar environmental challenges. By investing in urban green infrastructure and leveraging scientific tools for ecosystem service assessment, cities can move towards cleaner air, healthier communities, and a more resilient urban future.

RECOMMENDATIONS:

This study's relevance in Delhi's current air quality scenario is multifaceted. It addresses a critical gap in pollution mitigation strategies by quantifying the role of urban forests—a nature-based solution aligned with the National Clean Air Programme's (NCAP) goals. Traditional mitigation measures—such as vehicular restrictions and industrial controls—are necessary but insufficient on their own. Nature-based solutions, particularly the strategic management of urban forests, offer a complementary and cost-effective approach to improving air quality, enhancing urban resilience, and supporting public well-being. With Delhi's PM2.5 levels consistently exceeding 500 $\mu g/m^3$ in winter, integrating tree-based interventions into policy (e.g., expanding green buffers along traffic corridors) could complement existing measures like the Graded Response Action Plan (GRAP). The identification of high-performing species like provides actionable insights for afforestation drives. For instance, prioritizing these species in Delhi's green policies could enhance long-term air quality resilience.

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