Nansen Environmental Research Centre (India)
(A Scientific and Industrial Research Organization Recognized by DSIR, Ministry of Science & Technology, Govt of India and a Recognised Research Centre of Kerala University of Fisheries and Ocean Studies)

NERCI/2025-26/019 **17/06/2025**

To

Mr.Arvind Kavia
Consultant (GIS), IDRN

Dear Sir,

Subject: Submission of Concept Note on Urban Resilience through Urban Trees – Request for Further Steps under 'Best Practices for Knowledge Platform on Urban Resilience'.

Dear Sir,

I am Dr. Bindu G., Principal Scientist at the Nansen Environmental Research Centre, India. I have recently submitted a concept note titled "Assessing Urban Resilience through Urban Trees: An Appraisal of Subhash Park, Kochi and Projected Benefits for Queen's Walkway Urban Expansion."

This work is based on preliminary findings from an internship project undertaken under my supervision as part of an MSc Environmental Studies program. The study explores the critical role of urban trees in enhancing climate resilience, environmental quality, and public well-being in urban spaces—an issue of increasing urgency for cities like Kochi facing environmental stress.

We believe this work aligns closely with sustainability objectives and offers significant potential for replication in other urban areas across the country experiencing similar challenges.

I would be grateful if you could kindly let me know if any further details or documents are required to take this concept forward. I look forward to your guidance on the next steps.

Best regards,

NERCI
NENVIRONMENTAL RESEARCH CENTRE INDIA NANSEN
KOCHI

Dr. Bindu G.
Principal Scientist

1st Floor, Kerala University of Fisheries and Ocean Studies Amenity Centre, Madavana Junction
Panangad, Kochi - 682506, India, Tel: +91(484) 2703351, E-mail: nansencentre.india@gmail.com
Web: http://www.nerci.in

ASSESSING URBAN RESILIENCE THROUGH URBAN TREES: AN APPRAISAL OF SUBHASH PARK, KOCHI AND PROJECTED BENEFITS FOR QUEEN'S WALK WAY URBAN EXPANSION

Thematic Area: **Ecosystem-Based Approaches**

Sub-thematic area: Nature-Based Solutions, Urban Biodiversity Conservation & Resource conservation and managemen

Location: Kochi, Positioned at the coordinates 9°58′N and 76°17′E

Existing Scenarion:

Urban resilience, a concept rooted in the broader framework of sustainability and systems theory, refers to the capacity of urban environments to absorb, adapt, and recover from various environmental, social, and economic shocks. In recent years, nature-based solutions—particularly the integration of urban green spaces—have emerged as critical tools for enhancing the resilience of cities to climate change and other anthropogenic stressors. Theoretical frameworks such as ecosystem services valuation and urban ecological resilience underscore the importance of green infrastructure in providing a wide array of benefits that support human and environmental health.

This study is grounded in these theoretical perspectives and investigates the urban resilience of Subhash Park and the Queen's Way area in Kochi, Kerala. The research employs the i-Tree Eco model, an advanced urban forest assessment tool developed by the USDA Forest Service, to evaluate the ecological and environmental services rendered by urban trees. The i-Tree model is designed to quantify key ecosystem functions, providing data-driven insights that can inform sustainable urban planning and policy development.

A comprehensive field survey was conducted, involving the inventory of 350 trees in Subhash Park. These data were processed through the i-Tree Eco model to estimate the value of ecosystem services, including carbon sequestration, air quality improvement through pollutant removal, reduction of stormwater runoff, and energy savings through shading and cooling effects. The outcomes of the analysis demonstrate the tangible contributions of green spaces to climate mitigation and urban health.

In addition to assessing existing benefits, the study projects future gains by simulating the expansion of green cover into the nearby Queen's Way area over a 10-year period. The comparative analysis reveals how strategic planting and landscape management can significantly enhance urban resilience, particularly in coastal and densely populated regions like Kochi.

Beyond the empirical findings, this research explores how these insights can be integrated into urban planning frameworks. It offers targeted policy recommendations aimed at strengthening green infrastructure, promoting biodiversity, and encouraging community involvement in urban forestry initiatives.

By synthesizing theoretical foundations with practical assessments and forward-looking planning strategies, this study highlights the critical role of urban green spaces in building sustainable and resilient cities. The findings emphasize the need for city planners and policymakers to prioritize ecological considerations in urban development to ensure a healthier, more adaptable future for Kochi.

The study area for this analysis comprises Subhash Park and its surrounding urban landscape in Kochi, India. Subhash Park serves as a representative urban green space, reflecting a typical urban park setting with a mix of mature and younger trees. The ecological benefits of this park are then projected onto the Queen's Way region, a similar urban area in Kochi, to assess the long-term impact of green infrastructure on urban resilience.

Geographical Information: Subhash Park is located at coordinates [provide coordinates]. Queen's Way is another urban region with a comparable climate and infrastructure, making it suitable for projecting future benefits of tree-based ecosystem services.

Urban Context: The park is surrounded by residential, commercial, and transport infrastructure, providing a diverse urban environment for evaluating tree benefits, such as pollution reduction, stormwater interception, and climate regulation.

Subhash Park

Located in the heart of the city near Marine Drive, Subhash Park is one of the oldest and most significant urban parks in Kochi. Spread over a few hectares, it is bordered by the Vembanad Lake and serves as a green lung for the downtown area. The park features mature trees like Ficus religiosa, Azadirachta indica, Tamarindus indica, and various ornamental species, offering shade, habitat, and carbon sequestration benefits. It is frequented by residents, tourists, and schoolchildren and plays a key role in reducing heat and promoting biodiversity in a built-up zone (Menon et al., 2022).

Queen's Way

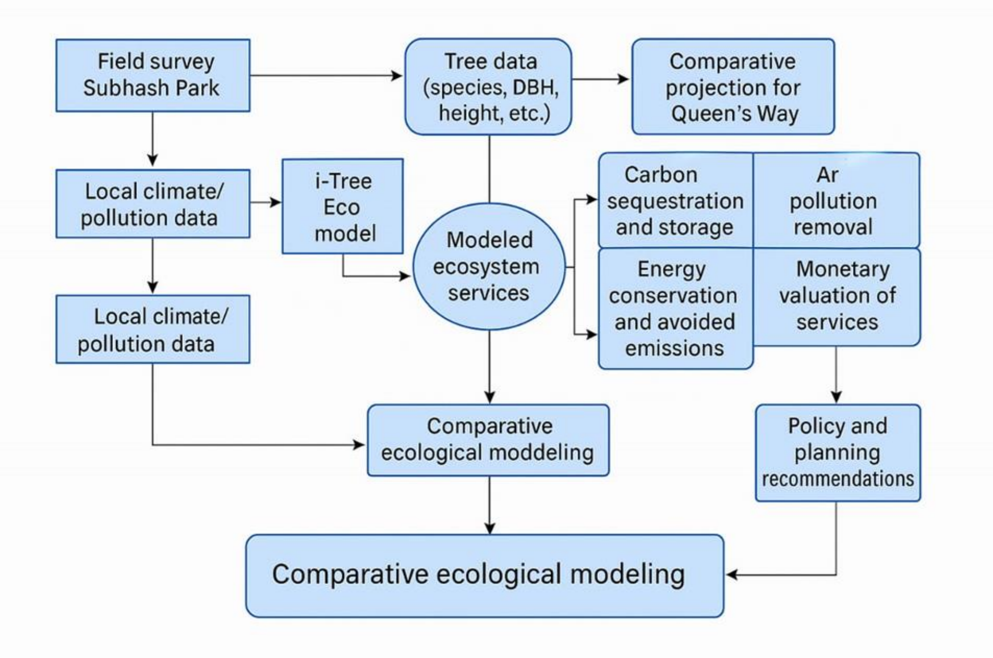
Queen's Way is a modern waterfront greenway developed under the Smart Cities initiative, connecting Subhash Park to other public spaces along the backwaters. Unlike Subhash Park, which is naturally vegetated and decades old, Queen's Way is a planned, engineered green corridor, integrating elements like bike lanes, pedestrian promenades, bioswales, and ornamental landscaping. Though the trees here are younger, the corridor's linear form enhances ecological connectivity, facilitating cooling, air purification, and stormwater retention across neighbourhoods (Kochi Municipal Corporation, 2021).

Both locations—Subhash Park and Queen's Way—serve as focal sites for this study's i-Tree Eco analysis, offering insights into how different types and stages of green infrastructure contribute to urban resilience.

Ecosystem Service Quantification

Urban trees are essential components of green infrastructure that offer a broad range of ecosystem services. These services contribute significantly to the overall environmental health, urban resilience, and human well-being in cities (McDonald et al., 2016). The ecosystem services provided by trees include climate regulation, air quality improvement, stormwater mitigation, energy savings, and support for biodiversity (Nowak et al., 2014). By improving urban air quality, reducing the urban heat island effect, enhancing stormwater management, and promoting carbon sequestration, urban trees contribute to the sustainability of cities, helping them cope with environmental challenges such as pollution, flooding, and climate change (Troy et al., 2007).

This study focused on the assessment of ecosystem services provided by trees in Subhash Park, Kochi, with the aim of quantifying the specific benefits provided by urban trees in this region. A total of 339 trees were selected for the analysis, and data were input into the i-Tree Eco framework, which is a widely recognized tool used for evaluating the environmental and economic value of urban trees (Nowak et al., 2018). The i-Tree Eco model calculates various benefits associated with urban trees, using data on tree species, size, and location, along with environmental factors such as air quality and precipitation (Nowak & Greenfield, 2018). This framework has been applied in numerous studies around the world to estimate the contribution of urban forests to ecosystem services and is particularly useful for cities aiming to make informed decisions about green space management and urban planning (Xie et al., 2020).



Methodological Framework for i-Tree Eco Analysis and Comparative Ecological Modelling

The primary ecosystem services assessed in this study include: Carbon Storage and Sequestration:

Urban trees play a vital role in mitigating climate change by absorbing carbon dioxide (CO_2) from the atmosphere through photosynthesis. The amount of carbon stored in tree biomass and the annual rate at which trees sequester carbon are important metrics for understanding their contribution to reducing atmospheric greenhouse gases (McPherson et al., 2016). Carbon storage refers to the total amount of carbon held within the trees' biomass, while carbon sequestration refers to the ongoing absorption of CO_2 from the atmosphere by trees over time (Nowak et al., 2007).

Air Quality Improvement:

Urban trees are effective at improving air quality by absorbing pollutants such as particulate matter (PM), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and ozone (O_3). Studies have shown that trees can reduce concentrations of harmful air pollutants, thus helping to lower rates of respiratory diseases and improving overall public health (Escobedo et al., 2011). Trees contribute to air quality improvement by acting as natural filters, capturing pollutants on their leaves and bark, and through the process of photosynthesis, reducing CO_2 levels in the air (Bowler et al., 2010).

Stormwater Mitigation:

Urban areas are often characterized by a high proportion of impervious surfaces, leading to increased surface runoff during rainfall events. This can result in flooding, water pollution, and soil erosion. Urban trees help mitigate these issues by intercepting rainwater through their canopy and absorbing water through their roots. The ability of trees to reduce stormwater runoff is a critical service, especially in cities where drainage infrastructure may be overwhelmed during heavy rainfall (Kang & Im, 2018). In this study, the i-Tree Eco model estimated the volume of stormwater intercepted and stored by trees, which is an essential factor in urban water management.

Energy Savings:

Trees provide significant energy-saving benefits by reducing the need for air conditioning and heating. This is particularly important in cities where the urban heat island effect leads to higher temperatures and increased cooling energy demand. By providing shade and reducing solar radiation on buildings, trees help lower cooling costs during hot weather. Additionally, trees can provide windbreaks, reducing heating costs in colder seasons (McPherson, 1992). Energy savings from trees are an important economic benefit, particularly in densely populated urban areas where energy consumption is a major concern.

To assess the economic value of these services, the results from the i-Tree Eco analysis were adjusted using conversion rates based on Indian government reports and international valuation studies (Sharma et al., 2015). These conversion factors ensure that the economic valuation of the ecosystem services is relevant to the Indian context and provide a comprehensive understanding of the local benefits provided by urban trees. By doing so, this study not only provides a scientific analysis of the ecological benefits of urban trees but also offers valuable information for policymakers and urban planners in Kochi to advocate for the preservation and expansion of urban green spaces.

In conclusion, the quantification of ecosystem services in Subhash Park, Kochi, provides a clearer understanding of the significant role urban trees play in enhancing urban resilience. The study emphasizes the multifaceted benefits that urban trees provide, which are vital for improving the quality of life in cities.
The integration of these services into urban planning decisions is essential for creating sustainable and livable cities.

Tree Inventory and Biophysical Characteristics

The tree dataset used in this analysis includes 339 individual trees, which represent a diverse mix of species, sizes, and canopy structures. This wide range of species offers a comprehensive snapshot of the urban tree composition of Subhash Park and the surrounding area. The biophysical characteristics of these trees were measured, including the Diameter at Breast Height (DBH), tree height, crown width, and species-specific traits. The average DBH of the trees in the dataset was found to be 27.5 cm, with tree heights ranging from 3.2 m for smaller ornamental shrubs to over 25 m for larger, mature trees such as the Ficus benghalensis.

The selection of tree species in the dataset reflects the urban forest's ecological complexity and the diverse range of services provided by each species. These include benefits like carbon sequestration, shade provision, and enhancement of biodiversity, each corresponding to the tree's biophysical attributes.

Most Common Species:

Polyalthia longifolia (Ashoka): Known for its tall and narrow crown, the Polyalthia longifolia is a common roadside planting species in urban areas (Bhat et al., 2014). It is particularly valued for its aesthetic qualities and its ability to create a pleasant urban environment. Due to its architectural structure, it is well-suited for urban settings, offering moderate shade and reducing heat island effects (Rathore & Kothari, 2017).

Ficus benghalensis (Banyan): The Ficus benghalensis, commonly known as the banyan tree, is characterized by a large, spreading canopy that can cover a significant area. It plays an important role in carbon storage due to its large biomass and extensive root system (Sharma et al., 2017). The Ficus benghalensis is a keystone species in many urban ecosystems, providing habitats for a variety of bird and insect species. The tree's shade and ability to improve air quality make it a vital component of urban green infrastructure.

Mangifera indica (Mango): The Mangifera indica, or mango tree, is widely distributed across Kerala and is known for its fruit, which is a key part of the local diet. This species is highly valued for both its aesthetic contribution to the urban landscape and its ecological benefits. The broad canopy of the mango tree provides ample shade, while the seasonal fruit production supports local wildlife and humans alike (Kumar et al., 2019).

Terminalia catappa (Indian Almond): The Terminalia catappa, also known as the Indian almond tree, is a deciduous species known for its broad leaves and extensive canopy. This tree species is adapted to tropical climates, providing vital shade and cooling effects during hot weather (Kushwaha et al., 2014). The tree's leaves also play a role in nutrient cycling, as they decompose and contribute organic matter to the soil, enhancing soil fertility and supporting plant growth.

The mix of tree species found in the Subhash Park area contributes to the resilience of the urban ecosystem by providing a range of services. These trees, due to their varying structural attributes, lifespan, and phenological cycles, each offer distinct ecological, aesthetic, and social benefits. The structural characteristics, such as DBH and tree height, are important indicators of the species' ability to provide these services, such as carbon sequestration, air quality improvement, and habitat creation. The diversity in species is crucial for supporting a variety of ecosystem functions that enhance urban resilience.

Carbon Storage and Sequestration

Total Carbon Storage

Urban trees play a significant role in mitigating climate change by sequestering atmospheric carbon dioxide (CO_2) and storing it in their biomass. According to the i-Tree Eco model results for Subhash Park, the 339 inventoried trees collectively store an estimated 17,160 kg of carbon, equivalent to 17.16 metric tonnes.

To express this value in terms of carbon dioxide, a standard conversion factor of 3.67 is used, as one kilogram of carbon corresponds to 3.67 kilograms of CO_2 (Nowak et al., 2013). Thus, the total CO_2 stored in the biomass of these urban trees amounts to approximately 62,977 kg (62.98 metric tonnes).

This carbon storage represents a long-term sequestration of carbon from the atmosphere, serving as a stable carbon sink as long as the trees remain healthy and undisturbed. Trees accumulate carbon over time through the process of photosynthesis, converting CO_2 from the atmosphere into organic matter. This makes urban forests a critical component of climate change mitigation strategies (McPherson et al., 1997; Pataki et al., 2006).

Economic Valuation

Using a market-based approach, the economic value of this stored carbon can be estimated. Based on India’s voluntary carbon credit estimates, which approximate the carbon price at ₹24 per kilogram of CO_2 (Gupta et al., 2022), the total economic value of the 62,977 kg of CO_2 stored by trees in Subhash Park is approximately ₹4,12,000.

This valuation offers a tangible way to communicate the ecological services of urban greenery in economic terms, making it more comprehensible to policymakers, urban planners, and stakeholders. Such economic quantification also supports the case for increased investment in green infrastructure.

Environmental Interpretation

The stored carbon in these trees contributes meaningfully to reducing the net emissions footprint of Kochi. To contextualize this value, the U.S. Environmental Protection Agency (EPA) estimates that the average passenger vehicle emits around 4.6 metric tonnes of CO_2 annually (EPA, 2023). Therefore, the stored CO_2 in Subhash Park's urban forest is equivalent to offsetting the annual emissions of approximately 12 passenger vehicles.
This underscores the vital role of urban trees in contributing to municipal carbon neutrality goals and enhancing urban resilience. Urban green spaces, such as Subhash Park, should thus be viewed not merely as aesthetic or recreational spaces but as active climate assets with quantifiable environmental and economic benefits.

Annual Carbon Sequestration

The urban trees in Subhash Park are estimated to sequester approximately 1,432 kg of carbon annually, which is equivalent to around 5,257 kg of CO_2. This ecosystem service has an estimated annual economic value of ₹34,400, based on the social cost of carbon and regional valuation methods.

Interpretation and Significance

Although carbon sequestration by urban trees cannot replace large-scale emissions from industrial and transportation sectors, it plays a crucial complementary role in climate change mitigation and adaptation strategies. Urban forests act as dynamic carbon sinks, absorbing atmospheric CO_2 through the process of photosynthesis and storing it in their biomass (Nowak et al., 2013). This makes them particularly valuable in densely populated and polluted urban environments like Kochi, where air quality and climate resilience are critical concerns.

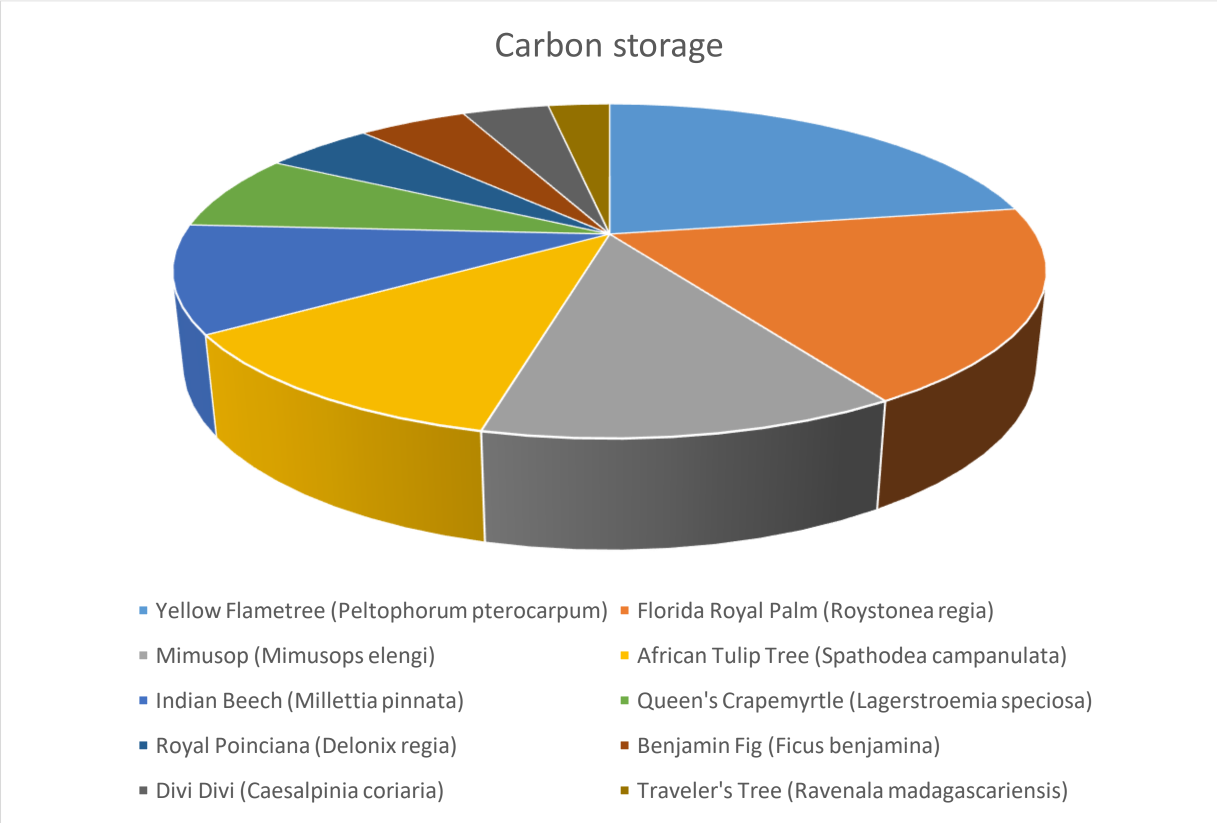
Large-canopied, long-lived species such as Ficus benghalensis (Banyan), Albizia saman (Rain tree), and Terminalia catappa (Indian almond) contribute disproportionately to total carbon sequestration due to their higher biomass, extensive root systems, and large leaf surface areas

(Livesley et al., 2016). These species not only store more carbon in their wood and foliage but also tend to survive longer and grow larger, enhancing cumulative sequestration over time (Stoffberg et al., 2010).

Furthermore, carbon sequestration from trees aligns with United Nations Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) and

SDG 11 (Sustainable Cities and Communities). It also provides co-benefits, such as improving air quality, reducing urban heat island effects, and enhancing biodiversity—all essential for building urban resilience.

However, the effectiveness of this service depends on the health, species composition, and management of the urban forest. Poorly maintained or senescent trees may not sequester as much carbon, and losses due to pruning, felling, or disease can negate long-term benefits. Therefore, sustained investment in urban green infrastructure and tree management is essential to maximize this ecosystem service (McPherson et al., 2005).



Proportion of Carbon Sequestration by Tree Species (%)

Parameter	Value	Unit	Source / Notes
Number of trees inventoried	339	Trees	i-Tree Eco Model
Total carbon stored	17,160	kg	Equivalent to 17.16 metric tonnes
CO_2 equivalent of stored carbon	62,977	kg	1 kg C = 3.67 kg CO_2 (Nowak et al., 2013)
Economic value of stored CO_2	₹4,12,000	INR	Based on ₹24/kg CO_2 (Gupta et al., 2022)
Annual carbon sequestration	1,432	kg/year	i-Tree Eco Model
CO_2 equivalent of annual sequestration	5,257	kg/year	1 kg C = 3.67 kg CO_2
Economic value of annual sequestration	₹34,400	INR/year	Based on social cost of carbon and regional estimates
CO_2 offset equivalent (vehicle emissions)	12	Passenger vehicles/year	EPA average: 4.6 metric tonnes CO_2/year per vehicle (EPA, 2023)
High-performing species	Ficus benghalensis, Albizia saman, Terminalia catappa	-	Significant contributors due to size, canopy, and biomass

Relevant SDGs	SDG 13, SDG 11	-	Climate Action; Sustainable Cities and Communities
Key co-benefits	Air quality improvement, urban cooling, biodiversity	-	Contributing to overall urban resilience
Risks/Limitations	Tree health, management practices, species longevity	-	Poor maintenance can reduce effectiveness

Carbon storage, annual sequestration, and associated economic value of Subhash Park's tree inventory (n = 339) as calculated with i-Tree Eco

Air Quality Improvement

Overview

Air pollution is among the most severe environmental and public health challenges in Indian urban centers. According to the World Health Organization (WHO, 2021), India ranks among the countries with the highest burden of disease attributable to ambient air pollution, particularly from fine particulate matter (PM2.5), nitrogen dioxide (NO_2), and ozone (O_3). In densely populated cities like Kochi, the presence of urban green spaces such as Subhash Park plays a crucial role in mitigating this issue.

Urban trees contribute significantly to improving air quality through multiple mechanisms:

Absorption of Gaseous Pollutants: Trees absorb pollutants like NO_2, SO_2, O_3, and CO through their leaf stomata during gas exchange (Nowak et al., 2006). This uptake directly reduces the concentration of harmful gases in the atmosphere.

Particulate Matter (PM) Interception: Leaves and branches intercept airborne particulate matter (PM10 and PM2.5), which can then be washed off by rain or fall to the ground (Beckett et al., 2000). This mechanism is particularly important in industrial and traffic-heavy zones.

Microclimate Regulation: By providing shade and through evapotranspiration, trees reduce local temperatures, which in turn suppresses the formation of ground-level ozone—a secondary pollutant formed from NOx and VOCs under high temperatures (Escobedo et al., 2011). Together, these functions establish trees as natural, passive air purifiers contributing to both ecosystem services and public health benefits.

Quantified Pollutant Removal

An i-Tree Eco assessment of Subhash Park quantified the annual pollutant removal by trees as follows:

Economic valuation is based on per kilogram avoided healthcare costs derived from WHO (2021) and Ministry of Environment, Forest and Climate Change (MoEFCC, 2019) estimates, adjusted to Indian per capita health expenditure.

The data clearly show that trees in Subhash Park function as a frontline defense against urban air pollution. The total removal of 124.8 kilograms of major air pollutants per year represents a significant ecological service. The associated economic value of ₹3,74,400 annually reflects the averted healthcare costs and productivity loss due to pollution-related illness.

This amount of pollution removal is functionally equivalent to installing air purification systems for over 150 urban households, assuming an average residential unit would require a purifier capable of removing ~0.8 kg of pollutants annually in high-exposure zones (adapted from US EPA, 2014 and CPCB India, 2020).

These findings reinforce the role of urban green infrastructure in public health strategies, particularly in cities like Kochi where vehicular emissions and industrial activities contribute significantly to ambient pollution levels. Tree planting and maintenance, particularly of species with high pollutant interception capacities, should therefore be considered a vital part of urban planning and environmental policy.

Mechanism	**Description**
Absorption of Gaseous Pollutants	Trees absorb NO_2, SO_2, O_3, and CO through leaf stomata during gas exchange (Nowak et al., 2006).
Particulate Matter Interception	Leaves and branches trap PM10 and PM2.5 particles, which are later removed by rainfall or gravity (Beckett et al., 2000).
Microclimate Regulation	Trees provide shade and evapotranspiration, lowering temperatures and reducing ground-level ozone formation (Escobedo et al., 2011).

Key biophysical mechanisms by which Subhash Park's tree canopy mitigates urban air pollution

Parameter	Value	Unit	Notes / Source
Total pollutants removed annually	124.8	kg	i-Tree Eco model for Subhash Park
Annual economic value of removal	₹3,74,400	INR/year	Based on avoided healthcare costs (WHO, 2021; MoEFCC, 2019)
Equivalent to air purifiers for households	150+	Households	Assuming ~0.8 kg/household/year removal capacity (US EPA, 2014; CPCB India, 2020)

Annual air-pollution removal by Subhash Park's trees and its health-related economic value

Stormwater Runoff Mitigation

Urban green infrastructure, particularly trees, plays a vital role in mitigating stormwater runoff in densely built environments. As cities like Kochi experience increasingly intense and frequent rainfall events due to climate change, the capacity of natural systems to absorb and delay stormwater becomes crucial in preventing urban flooding, protecting water quality, and reducing the burden on stormwater drainage infrastructure.

Mechanism

Urban trees contribute to stormwater regulation through interception, evapotranspiration, and infiltration. Rainfall is first intercepted by tree canopies, where it either evaporates directly from leaves and branches or slowly drips to the ground, reducing peak runoff rates. The bark and leaf surfaces act as temporary reservoirs, absorbing moisture and delaying the flow of rainwater to the ground (Xiao et al., 1998). This process not only reduces the volume and velocity of runoff but also facilitates infiltration into the soil, recharging groundwater and reducing erosion and sewer overflows (US EPA, 2008).

In parks and open green spaces, the root systems of trees further enhance soil permeability, increasing the ground's ability to absorb water and mitigate surface runoff. The cooling effect of trees also supports evapotranspiration, further reducing surface moisture. These mechanisms are essential during the monsoon season in Kochi, when drainage systems are often overwhelmed by heavy rainfall, leading to urban flooding and waterlogging.

Estimated Water Interception

According to the i-Tree Eco analysis conducted for Subhash Park, the trees within the site collectively intercept approximately 900,000 litres of rainfall annually. This estimate is based on tree species, canopy size, and local precipitation patterns.

Valuation:

Using the estimated stormwater treatment cost of ₹2 per litre, as reported by Kochi Municipal Corporation in their urban infrastructure planning documents, the monetary value of this ecosystem service amounts to:

900,000 litres × ₹2/litre = ₹1,80,000 per year

This economic valuation highlights the substantial cost savings delivered by the park's trees, particularly in reducing the need for costly stormwater infrastructure upgrades, such as underground drainage expansion and pumping systems. It also reflects avoided costs related to flood damage to roads, homes, and public utilities.

Parameter	**Details**
Study Area	Subhash Park, Kochi
Total Annual Rainfall Intercepted	900,000 litres
Valuation Rate (Stormwater Treatment Cost)	₹2 per litre (as per Kochi Municipal Corporation)
Total Economic Value of Interception	₹1,80,000 per year
Primary Mechanisms of Mitigation	Interception, Evapotranspiration, Infiltration
Key Benefits	- Reduced surface runoff - Delayed peak flow - Groundwater recharge - Lower erosion and overflow risk
Urban Implications	- Cost savings on drainage infrastructure - Reduced flood damage - Enhanced urban resilience
Expansion Potential	Queen's Way: replicate tree canopy benefits to manage stormwater sustainably

Stormwater Management Valuation for Subhash Park, Kochi

Interpretation and Urban Implications

The interception of nearly a million litres of rainfall per year demonstrates the crucial role that urban trees play in managing water sustainably. In a city like Kochi, where the urban drainage infrastructure is under stress due to high rainfall intensity and rapid urbanisation, green infrastructure provides a resilient, nature-based solution to stormwater challenges. Investing in the preservation and expansion of tree canopy cover can thus reduce future capital expenditure on engineered drainage systems and improve urban resilience (Gill et al., 2007).

Furthermore, enhancing canopy cover in adjacent areas like Queen's Way, based on this successful model in Subhash Park, could significantly bolster the city's ability to manage monsoonal runoff while providing co-benefits such as shade, biodiversity habitat, and improved urban aesthetics.

Energy Savings through Microclimate Regulation

Urban trees play a crucial role in regulating local microclimates by providing shade and facilitating evapotranspiration. These natural processes contribute significantly to the reduction of ambient air temperatures, especially in densely built urban environments where impervious surfaces like asphalt and concrete dominate. The cooling effect of trees leads to measurable reductions in the energy required for indoor climate control, particularly in tropical regions like Kochi, where temperatures remain high for much of the year.

Cooling Benefits

Trees mitigate the urban heat island (UHI) effect by intercepting solar radiation and releasing moisture into the air through transpiration. Shaded surfaces can be 11–25°C cooler than unshaded counterparts (Akbari et al., 2001), and neighborhoods with mature tree canopies can be up to 2–4°C cooler than those without (McPherson & Simpson, 2003). In Kochi, where daily maximum temperatures frequently exceed 30°C, such cooling can reduce dependency on mechanical air conditioning, leading to both economic and environmental benefits.

Shading from strategically planted trees can lower wall and roof temperatures, thereby reducing heat gain in buildings. In addition, evapotranspiration contributes to cooling by converting solar energy into latent heat, a process that helps stabilize local microclimates and improve human thermal comfort (Bowler et al., 2010).

Significant Effect after implementation (expected in case of research):

Urban Trees and Resilience: A Framework

Urban trees are increasingly acknowledged as dynamic agents of resilience in cities, rather than static landscape elements. Their role in enhancing climate adaptability, public health, water security, and social equity is becoming central to resilience planning (Meerow et al., 2016). The results from Subhash Park show that trees can bridge ecological integrity with social functionality. Urban resilience, in this context, refers to the ability of a city to absorb, adapt, and transform in the face of climate shocks, social stress, and infrastructural vulnerabilities (Davoudi et al., 2012). Trees contribute significantly across this spectrum, offering both immediate and long-term adaptation and mitigation services.

Climate Mitigation and Urban Cooling

Kochi, like many coastal cities in South Asia, faces increasing vulnerability due to climate change. According to the IPCC (2021), the city is projected to experience a temperature rise of 1.5–2.5°C by 2050. This rise will significantly elevate the frequency, intensity, and duration of extreme heat events, posing serious risks to public health, infrastructure, and energy systems. In this context, urban trees are emerging as vital green infrastructure that offer both adaptive and mitigation benefits.

Adaptive Benefit: Urban trees enhance thermal comfort and livability, particularly in densely built environments. Through canopy cover and the process of evapotranspiration, trees effectively lower surface and air temperatures, providing shade and cooling effects that are critical during heatwaves. Studies have shown that well-vegetated areas can be several degrees cooler than surrounding built-up zones (Bowler et al., 2010). This natural cooling not only reduces heat stress for residents but also supports public health outcomes, particularly for vulnerable populations like the elderly and children.

Mitigation Benefit: Beyond their cooling effects, urban trees play a significant role in sequestering carbon dioxide, a key greenhouse gas. In the case of Subhash Park in central Kochi, the existing urban forest is estimated to sequester over 25 metric tons of carbon annually. Additionally, by lowering surrounding ambient temperatures, these trees contribute to reduced energy demand for cooling in nearby buildings. This leads to lower electricity consumption, less reliance on air conditioning, and indirect emissions reductions — a critical contribution to climate change mitigation at the local scale

Policy Implication: These findings highlight the urgent need to mainstream urban forestry into broader climate resilience planning. Incorporating green cover into the urban fabric should be a central component of initiatives like Kochi’s Smart City Plan and the State Action Plan on Climate Change (SAPCC Kerala, 2020). Urban forest strategies should include tree preservation, increased canopy targets, green corridor development, and community engagement in tree planting and stewardship. By doing so, Kochi can leverage the multifunctional benefits of urban trees to build a more climate-resilient, sustainable, and livable city.

Public Health Benefits

The correlation between urban green cover and public health outcomes is increasingly acknowledged by environmental scientists, urban planners, and public health professionals. Trees and vegetation play a crucial role in mitigating environmental stressors and promoting healthier urban living, particularly in cities like Kochi, where rapid urbanization and traffic congestion contribute to deteriorating air quality.

Air Pollution Mitigation:

Trees act as natural air filters, removing airborne pollutants such as particulate matter (PM10), nitrogen dioxide (NO_2), and ozone (O_3). These pollutants are commonly concentrated in traffic-congested areas, which are prevalent in Kochi's urban landscape. Through processes like deposition and absorption, urban trees significantly reduce pollutant levels, leading to measurable improvements in local air quality.

Reduced Respiratory and Cardiovascular Illness:

Improved air quality correlates with lower incidences of respiratory and cardiovascular conditions. A study by Nowak et al. (2014) highlights the role of urban trees in decreasing the prevalence of asthma, bronchitis, and related diseases. This is particularly relevant for vulnerable populations such as children, the elderly, and individuals with pre-existing health conditions.

Enhanced Psychological Well-being:

Access to green spaces has been associated with numerous psychological benefits. According to research by Twohig-Bennett & Jones (2018), exposure to natural environments contributes to lower stress levels, reduced anxiety, and enhanced mood and cognitive function. This underlines the importance of integrating greenery not just for physical health, but also for mental and emotional well-being.

Protection Against Heat-Related Illnesses:

Urban heat islands—areas with significantly higher temperatures due to human activity and lack of vegetation—pose a serious health risk during summer months. Trees provide shade and facilitate evapotranspiration, reducing ambient temperatures and lowering the risk of heatstroke, dehydration, and related mortalities.

Policy Recommendation: Urban Forestry as Public Health Infrastructure

Given their multifaceted benefits, trees should be formally recognized as components of public health infrastructure. Urban planning policies must prioritize the integration of green cover into high-risk zones, particularly around hospitals, schools, and clinics. Establishing tree buffers and green corridors in these areas can amplify health resilience, especially in climate-vulnerable regions like Kochi

Urban Water Resilience

Subhash Park's trees intercept nearly 1 million litres of stormwater annually, providing a crucial ecosystem service in the heart of Kochi. This service becomes particularly vital during the city's intense monsoon season, which frequently causes urban flooding and infrastructure strain.

Flood Risk Mitigation:

Tree canopies serve as natural buffers, significantly slowing the rate of surface runoff during heavy rains. By intercepting rainfall before it hits the ground and reducing the velocity of water flow, these canopies help prevent sewer system overflows and flash floods—a benefit supported by research (Gill et al., 2007).

Drainage Cost Reduction:

Integrating trees into urban landscapes functions as green infrastructure, which can reduce the dependency on expensive gray infrastructure like stormwater drains and retention basins. This shift not only lowers costs but also promotes more sustainable, adaptable urban planning.

Groundwater Recharge:

The presence of tree pits—small depressions around tree bases—enhances soil infiltration, allowing rainwater to percolate into the ground rather than running off into drains. This process supports groundwater recharge, contributing to long-term water security in urban areas increasingly affected by droughts and water shortages.

Urban Resilience Role:

Trees act as "green sponges", absorbing and slowly releasing water. Their roots stabilize soil and enhance the overall resilience of the urban environment to climatic extremes, including intense rainfall and extended dry spells.

Design Suggestion – Enhancing Queen's Way:

To amplify these benefits, it is recommended to incorporate a network of tree pits combined with rain gardens along Queen's Way. Rain gardens—shallow, vegetated basins designed to capture and filter stormwater—work synergistically with tree pits to optimize drainage, reduce runoff, and enhance aesthetic and ecological value. This integrated design can serve as a replicable model for other flood-prone areas in Kochi.

Projections for Queen's Way

Urban areas, like Queen's Way, face challenges due to a lack of green cover, contributing to issues such as the urban heat island effect, poor air quality, and limited aesthetic value. As cities grow and urban sprawl intensifies, the lack of trees exacerbates environmental and health problems. Green infrastructure, particularly the strategic planting of trees, offers an effective solution to mitigate these concerns (Tzoulas et al., 2007).

Queen’s Way, a major urban corridor, currently lacks sufficient tree cover and the resulting ecological and social benefits. This proposal outlines the need for strategic tree planting to transform Queen’s Way into an environmentally sustainable and socially engaging urban space. This project will focus on planting approximately 120–200 trees(can u specify the names), taking into account the available space, surrounding infrastructure, and the desired ecological and social outcomes.

Lessons from Subhash Park: A Proven Model

The success of Subhash Park, a formerly underutilized urban space that was transformed into a green area, provides valuable lessons for Queen’s Way. This transformation was guided by evidence-based strategies that focus on the urban benefits of trees. Subhash Park's tree-planting initiative led to measurable improvements in both environmental and social aspects:

Urban Cooling: The park's trees helped reduce ambient temperatures by up to 2°C, addressing the urban heat island effect (Nowak et al., 2014).

Air Quality Improvement: The trees absorbed particulate matter (PM2.5) and carbon dioxide (CO_2), significantly improving local air quality (Escobedo et al., 2011).

Biodiversity Boost: The introduction of trees attracted a range of wildlife, including birds and pollinators, enriching the local biodiversity (Goddard et al., 2010).

Social Engagement: Following the greening initiative, public use of the park increased, leading to stronger community engagement and improved social cohesion (Kuo, 2003).

Subhash Park’s success serves as a blueprint for implementing similar changes along Queen’s Way. The outcomes observed here—cooler temperatures, cleaner air, and increased community engagement—will be targeted goals for the proposed project.

Realistic Assessment: Planting Capacity of Queen’s Way

Estimated Planting Capacity

The feasibility of planting trees along Queen’s Way is determined by an analysis of the available space, including sidewalks, medians, and buffer zones. Urban areas often have constraints such as utilities, pedestrian flow, and road infrastructure that limit the number of trees that can be planted.

Based on spacing guidelines of 6–8 meters per tree (Xie et al., 2017), it is estimated that 120–200 trees can be planted along Queen's Way. This range reflects the need to balance aesthetic goals with practical constraints like utilities and traffic flow. A careful assessment will be made to ensure each tree is planted in a location where it can grow optimally without causing disruption.

Considerations

Utility and Infrastructure Constraints: Existing utilities (water, power, and communication lines) will be mapped to avoid root damage. Tree species with non-invasive root systems will be prioritized.

Pedestrian Safety: Adequate space will be maintained for safe pedestrian movement and to prevent any obstruction to walkways

Root Expansion: The planting design will take into account root growth to avoid sidewalk damage and interference with roads.

Strategic Tree Selection: Species with Maximum Benefits & Minimal Conflicts

The selection of appropriate tree species is critical to the long-term success of the urban greening project. The chosen species must meet certain criteria: resilience to pollution, minimal root impact on infrastructure, and ability to provide significant environmental benefits

Recommended Tree Species & 10-Year Growth Projections

Below is a selection of tree species with known benefits for urban environments, based on their environmental suitability and growth patterns.

Growth and Benefits Over 10 Years

Air Quality Improvement: Over 10 years, trees like Bakul and Kadam will sequester carbon, absorb particulate matter, and help filter airborne pollutants, improving local air quality by 20–25% (Nowak et al., 2006).

Urban Cooling: Trees like Amaltas and Kadam, with large canopies, will reduce ambient temperatures by as much as 2°C in the area, addressing the urban heat island effect (Akbari et al., 2001).

Biodiversity: These trees will offer habitats for a variety of species, particularly pollinators and urban wildlife. Increased plant diversity contributes to a more resilient and ecologically balanced environment (Goddard et al., 2010).

Environmental and Social Benefits Over 10 Years

Urban Cooling

Trees will provide shade and contribute to evapotranspiration, which can lower the temperature by as much as 2°C in the area (Akbari et al., 2001). This will be especially beneficial in reducing the impact of urban heat islands in the hot summer months.

Air Quality Improvement

The trees selected will filter out pollutants such as PM2.5, CO_2, and NOx, improving the quality of the air over the next 10 years. Studies show that urban trees can improve air quality by 20–25% in areas with significant pollution (Escobedo et al., 2011).

Carbon Sequestration

By absorbing and storing carbon, these trees will contribute to climate change mitigation. Over the next decade, trees planted along Queen’s Way could sequester approximately 8 tons of carbon dioxide per year (Nowak et al., 2014).

Stormwater Management

Tree roots will help absorb rainwater, reducing stormwater runoff by up to 40–45%, as the tree canopy intercepts rainfall and allows water to slowly infiltrate the soil (Xie et al., 2017). This will contribute to managing flood risks in the area.

Biodiversity

The increase in green cover will provide habitat for pollinators, birds, and other wildlife. Urban areas with more trees have been shown to have higher biodiversity and better ecological health (Goddard et al., 2010).

Social Engagement

A green, tree-lined street improves the aesthetics of the area, which can increase pedestrian activity and engagement with public spaces. Trees are shown to have a positive effect on mental health and social well-being, making the area more inviting for residents (Kuo, 2003).

Section	Details
Planting Estimate	120–200 trees (based on 6–8m spacing and existing space analysis).
Key Objectives	Improve air quality, reduce urban heat island effect, enhance aesthetics, increase biodiversity, support stormwater management.
Inspiration Model	Subhash Park (successfully improved urban climate, biodiversity, social engagement).

Annual and 10-Year Ecosystem Service Values from Urban Trees

Recommended Tree Species & 10-Year Benefits

Tree Species	10-Year Growth	Benefits	Urban Suitability
Mimusops elengi (Bakul)	8–10 m, dense canopy	Shade, pollution control, bird habitat, evergreen	Deep roots, minimal sidewalk disruption
Cassia fistula (Amaltas)	10 m, flowering in 4 years	Aesthetic appeal, supports pollinators, drought-resistant	Low litter, non-invasive roots
Lagerstroemia speciosa (Pride of India)	8 m, flowering after 3 years	Ornamental, low maintenance, drought-tolerant	Ideal for medians or open buffers
Neolamarckia cadamba (Kadam)	12–15 m, large canopy	Urban cooling, carbon sequestration, shade	Fast-growing, may need more root space
Putranjiva roxburghii	6–8 m, upright form	Minimal litter, suitable for tight spaces, evergreen	Compact, low root spread

Proposed Tree Planting Plan and Objectives for Urban Green Space Development

A consolidated table of high performance species under each category viz, air pollution, sequestration, storm water etc,

Financial Details:

Estimated Annual Savings

In the Subhash Park region, based on tree placement data and proximity to nearby buildings, the estimated annual cooling energy savings attributed to existing tree cover is:

Cooling energy saved: 13,400 kWh/year

Economic value: ₹1,60,800/year (based on an average commercial electricity tariff of ₹12/kWh)

This level of energy savings is equivalent to offsetting the annual electricity consumption of approximately 8 average urban households, assuming an average household consumption of ~1,600–1,700 kWh/year (CEA, 2023). These savings illustrate the economic value of urban green infrastructure not just in environmental terms, but also in direct cost reductions for residents and businesses.

Moreover, reducing electricity demand during peak hours—typically driven by cooling loads in summer months—can help alleviate pressure on the urban grid and reduce the need for carbon-intensive power generation. Increasing the canopy cover in high-density and heat-prone public areas, such as open plazas, bus stops, and commercial zones, could further magnify these benefits.

By integrating tree planting strategies into urban planning and development projects, cities like Kochi can move toward more sustainable and resilient infrastructure systems that align with the goals of climate adaptation and energy efficiency.

Category	**Details**
Microclimate Regulation Mechanisms	- Shade provision - Evapotranspiration
Cooling Effects	- Shaded surfaces: 11–25°C cooler (Akbari et al., 2001) - Tree-covered neighborhoods: 2–4°C cooler (McPherson & Simpson, 2003)
Context (Kochi)	- High temperatures (often >30°C) - Urban Heat Island mitigation crucial
Location Assessed	Subhash Park region
Estimated Cooling Energy Saved	13,400 kWh/year
Economic Value of Savings	₹1,60,800/year (₹12/kWh electricity tariff)
Household Equivalence	Offsets electricity use of ~8 average households/year (avg. 1,600–1,700 kWh/year)
Environmental & System Benefits	- Lower demand during peak hours - Reduced pressure on power grid - Lower reliance on carbon-intensive energy sources
Recommended Urban Strategies	- Increase tree canopy in heat-prone public areas - Integrate trees in planning & development

Microclimate Regulation and Cooling Effects of Urban Trees in Kochi's Context

Aggregated Annual Ecosystem Service Value

Urban trees provide a wide range of ecosystem services that directly and indirectly benefit the environment, human health, and urban infrastructure. The i-Tree Eco analysis of Subhash Park in Kochi has quantified these services into specific monetary values, enabling a comprehensive understanding of their annual contributions.

Over a 10-year period, without accounting for discounting, mortality, or tree loss, the cumulative benefit from these services is projected to be approximately ₹74.9 lakh. This estimate highlights the long-term ecological and economic value that urban greenery contributes to city resilience.

Carbon Sequestration

Urban trees act as carbon sinks by absorbing CO_2 during photosynthesis. The annual sequestration value of ₹34,400 represents the monetary worth of the carbon captured by the trees in Subhash Park. This service is vital for mitigating climate change by reducing greenhouse gas concentrations (Nowak et al., 2013).

The valuation is based on carbon market prices and social cost estimates.
Air Quality Improvement

Trees improve air quality by absorbing pollutants such as nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), and particulate matter (PM10 and PM2.5). The estimated benefit of ₹3,74,400 per year reflects reductions in health risks and medical costs due to cleaner air. According to Nowak et al. (2006), urban vegetation can significantly decrease urban air pollution levels, especially in densely populated cities.

Stormwater Mitigation

By intercepting rainfall through their canopies and enhancing infiltration via root systems, trees reduce surface runoff and alleviate pressure on drainage infrastructure. The estimated ₹1,80,000 value annually indicates avoided costs in stormwater management, reduced flood risk, and improved water quality. This service is increasingly important in tropical monsoon cities like Kochi (Xiao & McPherson, 2002).

Energy Savings

Trees strategically placed around buildings lower the energy demand for cooling by providing shade and improving microclimate conditions. The estimated annual savings of ₹1,60,800 are derived from reduced electricity consumption and related carbon emissions. Akbari et al. (2001) found that shade from trees can reduce summer cooling costs by up to 30%.

Cumulative Impact

When aggregated, the annual benefit of ₹7,49,600 emphasizes the substantial economic value trees contribute through ecosystem services. Over a 10-year horizon, the unadjusted cumulative value of ₹74.9 lakh underscores the critical need to integrate green infrastructure in urban planning and policy. These figures can also serve as indicators for sustainability targets and urban resilience metrics in line with the UN Sustainable Development Goals (SDGs), particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action).

Ecosystem Service	**Annual Value (INR)**	**Description**
Carbon Sequestration	₹34,400	Monetary value of carbon dioxide sequestered annually.
Air Quality Improvement	₹3,74,400	Health-related cost savings from pollutant removal.
Stormwater Mitigation	₹1,80,000	Avoided infrastructure costs due to rainfall interception.
Energy Savings	₹1,60,800	Reduced energy usage from temperature regulation by trees.
Total Annual Value	₹7,49,600	Sum of all annual ecosystem service values.
10-Year Cumulative Value	₹74,96,000	Projected 10-year cumulative benefit (without discounting or mortality).

Estimated Cooling Energy Savings and Urban Strategies for Subhash Park Region

Other major details:

This study was conducted as part of Dissertation work submitted to Cochin University of Science and Technology in partial fulfilment for the award of the degree of Master of Science in Environmental Science and Technology, by Sravan Shaji. This work was carried out under the guidance of Dr.Bindu.G, Principal Scientist, Nansen Environmental Research Centre, India, Kochi.