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Urban forestry: A multi-mechanism framework

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Abstract

The Net objective of urbanization is causing cities to expand and develop haphazardly, which is widening and distancing the people and the environment and also depleting natural resources. Hence, one of the possible resources is the urban forests which are becoming more widely recognized as a crucial element in urban development. According to Jeong and Park, urban woods are crucial for maintaining ecosystem services that benefit both urban biodiversity and city dwellers. The study investigates the several ways that sustainable urban forestry might improve ecological balance and urban living circumstances. In improving the livability, environmental sustainability, and resilience of urban settlements, the trees and woods play an increasingly important role. In order to satisfy the demands of both the urban forest and its inhabitants, this article addresses the necessity of urban forestry, its current condition, its relevance, and other aspects pertaining to strategic sustainable planning in India.

Keywords: Urban Forestry; Sustainable Development Goals (SDGS); Nature-Based Solutions (NBS); Urban Development

1. Introduction

Cities across the world are expanding rapidly, often at the cost of their natural ecosystems. As urban areas grow, green spaces are frequently replaced by built infrastructure, leading to environmental degradation, biodiversity loss, and increased climate vulnerability. This transformation has intensified the ecological footprint of cities, while simultaneously reducing their capacity to absorb environmental shocks. As a result, urban environments are increasingly characterized by declining air quality, rising temperatures, and reduced resilience to climate-related disturbances.

The rapid conversion of natural landscapes into urban fabric reflects broader patterns of deforestation, land-use change, and ecosystem fragmentation. These processes not only disrupt ecological balance but also weaken the essential services that natural systems provide, such as air purification, temperature regulation, and stormwater management. In the absence of adequate green infrastructure, cities face compounded environmental and public health challenges, further exacerbating the risks associated with climate change.

In this context, urban forest has emerged as a critical strategy for mitigating environmental stress while enhancing the livability of urban areas. Urban forests comprising street trees, parks, and peri-urban green networks—play a vital role in restoring ecological functions within cities. They contribute to biodiversity conservation, improve microclimatic conditions, and support human well-being by fostering stronger connections between people and nature. To address these challenges, integrated approaches such as Nature-based Solutions (NbS) and Green Infrastructure (GI) have gained prominence within contemporary urban planning discourse (Escobedo et al., 2011). These frameworks advocate for the incorporation of natural systems into urban development as multifunctional assets capable of addressing environmental, social, and economic concerns simultaneously. NbS, in particular, offers a holistic pathway by aligning

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ecological processes with urban resilience strategies (Fang and others, 2024). Complementing these approaches, various strategies aligned with the Sustainable Development Goals (SDGs) further reinforce the need for sustainable and inclusive urban transformation.

Urban forestry has therefore become a central theme in global discussions on sustainable urban development. Its significance extends beyond visual enhancement, positioning it as a key component of ecological infrastructure that supports biodiversity, climate adaptation, and overall urban resilience. Ensuring equitable access to the benefits provided by urban forests remains essential for fostering inclusive and sustainable cities ("A Worldwide View of Urban Forests," 2023)

1.1. Need for the study

The need for this study arises from the growing mismatch between rapid urban expansion and the declining integration of ecological systems within city landscapes. As natural areas continue to be fragmented or replaced by built environments, the capacity of cities to sustain environmental quality, biodiversity, and human well-being is increasingly compromised. Although concepts such as urban forestry, Nature-based Solutions (NbS), and Green Infrastructure (GI) have gained recognition in planning discourse, their implementation often remains fragmented, lacking context-specific strategies and institutional coordination. In many cities, particularly in rapidly urbanizing regions, urban forestry is still treated as an aesthetic or supplementary component rather than as a critical layer of urban infrastructure. This gap highlights the absence of a comprehensive framework that connects ecological functions with spatial planning, governance mechanisms, and community engagement. Furthermore, the weakening relationship between urban populations and natural systems underscores the need to re-establish urban forests as accessible, functional, and inclusive spaces. Therefore, this study is essential to critically examine existing challenges, identify structural and governance gaps, and develop an integrated approach to urban forestry that enhances ecological resilience while supporting sustainable and equitable urban development.

2. Methodology

The methodology adopted for this study integrates literature review, spatial analysis, and conceptual framework development to examine the role of urban forestry in strengthening ecological resilience and sustainable urban development. The research begins with a comprehensive review of scholarly literature, international guidelines, and policy documents related to urban forestry, nature-based solutions, green infrastructure, and ecosystem services. This review establishes the theoretical foundation of the study and identifies key indicators such as canopy cover, accessibility to green spaces, biodiversity support, and environmental health benefits that are widely used in evaluating urban forest systems. To understand the existing ecological conditions, the study employs spatial analysis using secondary data sources including satellite imagery, planning reports, and municipal datasets. Geographic Information System (GIS) techniques are used to analyse land use and land cover patterns, distribution of vegetation, and the relationship between built environments and green infrastructure. This analysis helps identify areas experiencing vegetation loss, urban heat stress, and unequal access to green spaces, thereby providing an evidence-based understanding of the environmental impacts of rapid urbanization. The research also examines different categories of urban forests such as peri-urban forests, city parks, pocket parks, street trees, and other vegetated open spaces. This classification helps in understanding the diversity of urban green systems and their ecological and social contributions, including climate regulation, air purification, biodiversity conservation, and recreational benefits. Additionally, the study situates urban forestry within the broader historical context of environmental transformation driven by rapid industrialization and urban expansion. To evaluate spatial equity and accessibility of green infrastructure, the methodology incorporates the 3-30-300 rule as a planning benchmark. This guideline assesses whether residents can visually access trees from their homes, whether neighbourhoods maintain adequate canopy cover, and whether public green spaces are located within walkable distances. These indicators help evaluate the distribution and accessibility of urban green spaces across the city. Based on the diagnostic findings and theoretical insights, the study develops an Urban Forestry Multi-Mechanism Framework that integrates ecological, social, and governance dimensions of urban forest planning. The framework considers factors such as plant diversity, spatial distribution of green spaces, disaster mitigation potential, public health benefits, measurable green space indicators, and policy mechanisms that support implementation. Through this structured approach, the methodology moves from environmental assessment to conceptual development, ultimately providing a basis for planning strategies that promote resilient, inclusive, and sustainable urban forestry systems.

3. Main urban forest types

3.1. Peri-urban forests and woodlands

Forests and woodlands surrounding towns and cities that can provide goods and services such as wood, fibre, fruit, other non-wood forest products, clean water, recreation and tourism.

3.2. City parks and urban forests (>0.5 ha).

Large urban or district parks with a variety of land cover and at least partly equipped with facilities for leisure and recreation.

3.3. Pocket parks and gardens with trees (<0.5 ha).

Small district parks equipped with facilities for recreation/ leisure, and private gardens and green spaces.

3.4. Trees on streets or in public squares.

Linear tree populations, small groups of trees, and individual trees in squares and parking lots and on streets, etc.

3.5. Other green spaces with trees.

For example, urban agricultural plots, sports grounds, vacant lands, lawns, river banks, open fields, cemeteries and botanical gardens.

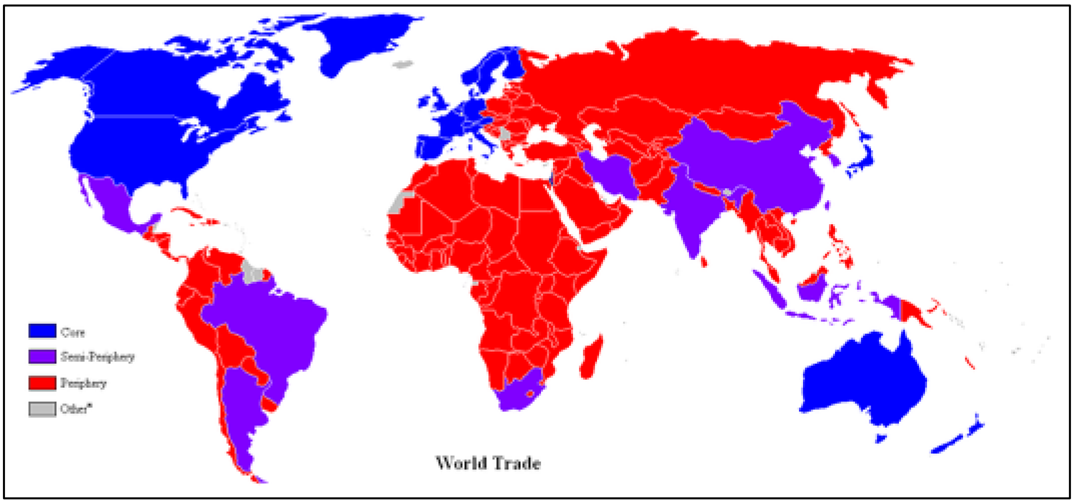
Source: FAO (Food and Agriculture Organization of the United Nations)

Figure 1 Main Urban Forest Types

4. The industrialization of nature: a modern history

4.1. The Great Acceleration

- Timeline: Mid-20th century, primarily after World War II.
- Key characteristics: Rapid industrialization, population growth, and urbanization.
- Impact on urban forests: Increased demand for resources, land conversion for urban development, and pollution contributed to the decline of many urban forests.



Source: based on a list in Christopher Chase-Dunn, Yukio Kawano and Benjamin Brewer, Trade Globalization since 1795, American Sociological Review, 2000 February, Vol. 65)

Figure 2 The Great Acceleration- World Trade Map

Trade Map, Late 20th Century This map shows the "core" industrialized nations of the northern hemisphere, and the "periphery" nations of the tropics and south dependent on subsistence agriculture and natural resource extraction. This unequal relationship is the product of hundreds of years of trade and economic globalization

4.2. The Green Revolution

Timeline: Mid-20th century, primarily in developing countries.

Key characteristics: Development and adoption of high-yielding crop varieties, improved agricultural practices, and increased use of fertilizers and pesticides.

Impact on urban forests: While the Green Revolution increased food production, it also led to deforestation, land degradation, and water pollution, which can have negative consequences for urban forests.

The Green Evolution

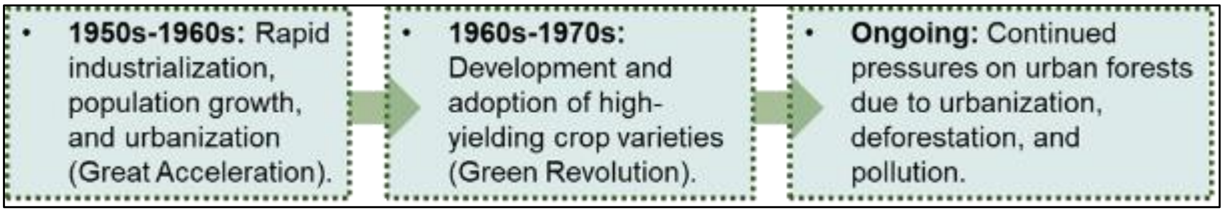


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Figure 3 The Green Evolution Chronology Timeline

5. 3-30-300 rule concept

5.1. 3 TREES: Trees from every home

Prove to provide health benefits

5.2. 30 %: Tree Canopy cover in every neighbourhood

Increase cooling and support rain water management.

5.3. 300 Metres: From the nearest public park or green spaces.

Benefits for physical and well-being as well as habitats for biodiversity.

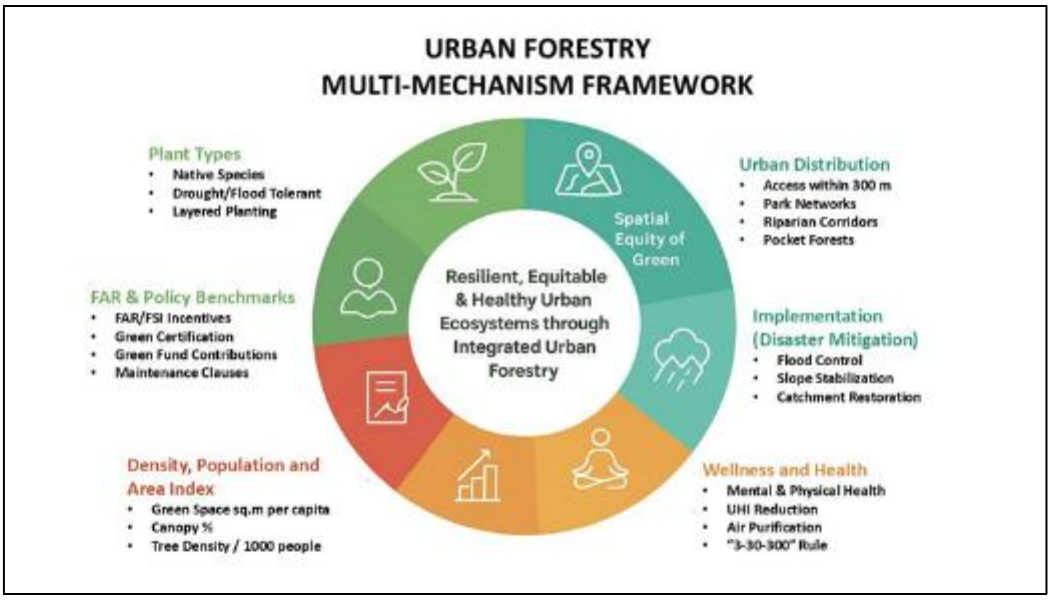
Source: (Konijnendijk, 2021), NBSI (Nature-Based Solutions)

Figure 4 The 3-30-300 Rule Concept Diagram

6. Urban forestry multi-mechanism framework

The findings point to a city that is rapidly urbanizing, losing tree cover and wetlands, heating up, and becoming more flood- and landslide-prone, so the core outcome is that Guwahati needs an integrated, conservation-led urban forestry program embedded in planning and policy rather than scattered plantations.

The urban forestry multi-mechanism framework integrates Ecology, People, and Policy for Sustainable Urban Environments.



Source: Author

Figure 5 Urban Forestry Multi-Mechanism Framework

The "multi-mechanism" framework visualized in the diagram represents six interacting dimensions (or "wedges") that together determine how an urban forestry system performs in terms of climate resilience, livability, and social equity.

Each mechanism corresponds to a functional pillar, and all are interlinked to form a holistic urban-ecosystem management cycle.

- It links land, water, and biodiversity conservation with urban form to rebuild Guwahati's ecological resilience.
- It centres community health and cultural landscapes so that trees, hills, and wetlands directly support people's daily lives.
- It embeds clear planning regulations and incentives so that every new project contributes to canopy, access to green, and risk reduction.
- It uses measurable standards such as canopy cover, green-space access, and tree density to track progress across all wards.
- It prioritizes vulnerable, heat-stressed, and flood-prone neighbourhoods to ensure an equitable distribution of urban nature.

6.1. Plant Types (Ecological Foundation)

This segment defines what kinds of trees and vegetation should constitute an urban forest.

Table 1 Plant Types (Ecological Foundation)

Key focus	Description
Native and endemic species	Prefer locally adapted flora to strengthen ecological integrity and pollinator networks (Alvey 2006).
Climate-resilient species	Select drought- and flood-tolerant trees suitable for hill slopes (Gillner et al. 2013; Esperon-Rodriguez et al. 2022).
Layered vegetation structure	Combine canopy, understory, shrub, and ground-cover layers for soil stabilization and microclimatic buffering.
Ecosystem service yield	Trees provide shade, carbon sequestration, and storm-water infiltration (Nowak et al. 2006; Dimoudi and Nikolopoulou 2003).

A diverse, multi-layered tree palette enhances resilience to pests, temperature extremes, and hydrological stress — the biophysical heart of the framework.

6.2. Spatial Equity of Green (Accessibility Mechanism)

Focuses on where green spaces are located and who can access them.

- Implements the 3–30–300 Rule (Jeong and Park 2024; WHO 2021):
    - Each person should see three trees from their home.
    - Each neighborhood should have ≥ 30 % canopy cover.
    - Each resident should be ≤ 300 m from a green space.
- Promotes green connectivity through linked parks, river corridors, and street-tree avenues.
- Integrates pocket forests or Miyawaki clusters within dense cores for micro-scale biodiversity.
- Ensures equitable distribution of green assets across income and gender lines (Kabisch et al. 2015).

Spatial equity ensures that ecosystem and health benefits are inclusive, not concentrated in high-income zones. It operationalizes the "right to green" as part of urban governance (Ordóñez et al. 2019).

6.3. Implementation / Disaster-Mitigation Mechanism

Represents the functional use of urban forestry as nature-based infrastructure for climate-risk reduction.

Table 2 Implementation / Disaster-Mitigation Mechanism

Application	Function	Example Tools
Slope stabilization	Deep-rooted native trees bind soil and prevent landslides (Shuya and Neogi 2024).	Vetiver grass, Ficus spp.
Rainwater and flood regulation	Riparian vegetation slows runoff, enhances infiltration (Datta and Dash 2023).	Bioswales, vegetated detention basins
Heat and wind buffering	Trees reduce surface temperature by 2–4 °C (Armson et al. 2012; Bowler et al. 2010).	Urban canopy corridors
Pollution interception	Leaf surface traps $PM_{2.5}$ and absorbs NO_2, O_3 (Nowak et al. 2006).	Broad-leaf evergreen species

Forests act as natural disaster-management systems, lowering both physical risks (erosion, flooding) and social vulnerability.

6.4. Wellness and Health Mechanism

Centers on human benefits — physical, mental, and social well-being.

- Exposure to green space reduces stress hormones and enhances cognitive restoration (Kabisch et al. 2015).
- Urban parks increase physical activity and social cohesion (Georgi and Dimitriou 2010).
- Tree shade reduces heat-related illnesses in dense settlements (Armson et al. 2012).
- Clean air and lower noise levels improve respiratory and cardiovascular health (Escobedo et al. 2011).
- Interaction with nature enhances sense of belonging and environmental stewardship.

Links ecosystem health to human health converting urban forestry into a public-health asset.

6.5. Density, Population and Area Index (Quantitative Mechanism)

Quantifies how much green infrastructure a city possesses relative to its population and built density.

Table 3 Density, Population and Area Index (Quantitative Mechanism)

Indicator	Benchmark	Purpose
Per-capita green space	≥ 9 m^2/person (WHO guideline)	Evaluate liveability
Canopy coverage	≥ 30 % neighborhood canopy	Urban-heat reduction
Tree density	≥ 1000 trees / km^2	Maintain ecological continuity
Forest cover ratio	20–25 % citywide (Shuya and Neogi 2024)	Policy planning baseline

These indices translate ecological aspirations into measurable planning metrics, guiding zoning and performance monitoring.

6.6. FAR and Policy Benchmark Mechanism (Governance and Finance)

Connects urban forestry with planning regulations, fiscal tools, and institutional frameworks.

- FAR/FSI incentives for developments incorporating on-site greening or vertical gardens.
- Urban Green Fund contributions: developers finance city-level tree-maintenance budgets.
- Mandatory landscape ratio in building bylaws (e.g., 15–20 % soft-surface area).
- Certification and monitoring: adopt SFI Urban and Community Forest Standard principles (SFI 2021).
- Data transparency: integrate i-Tree or GIS dashboards for canopy tracking (Doick 2019).

Transforms urban forestry from a voluntary aesthetic act into a regulated and funded planning instrument, ensuring accountability and continuity.

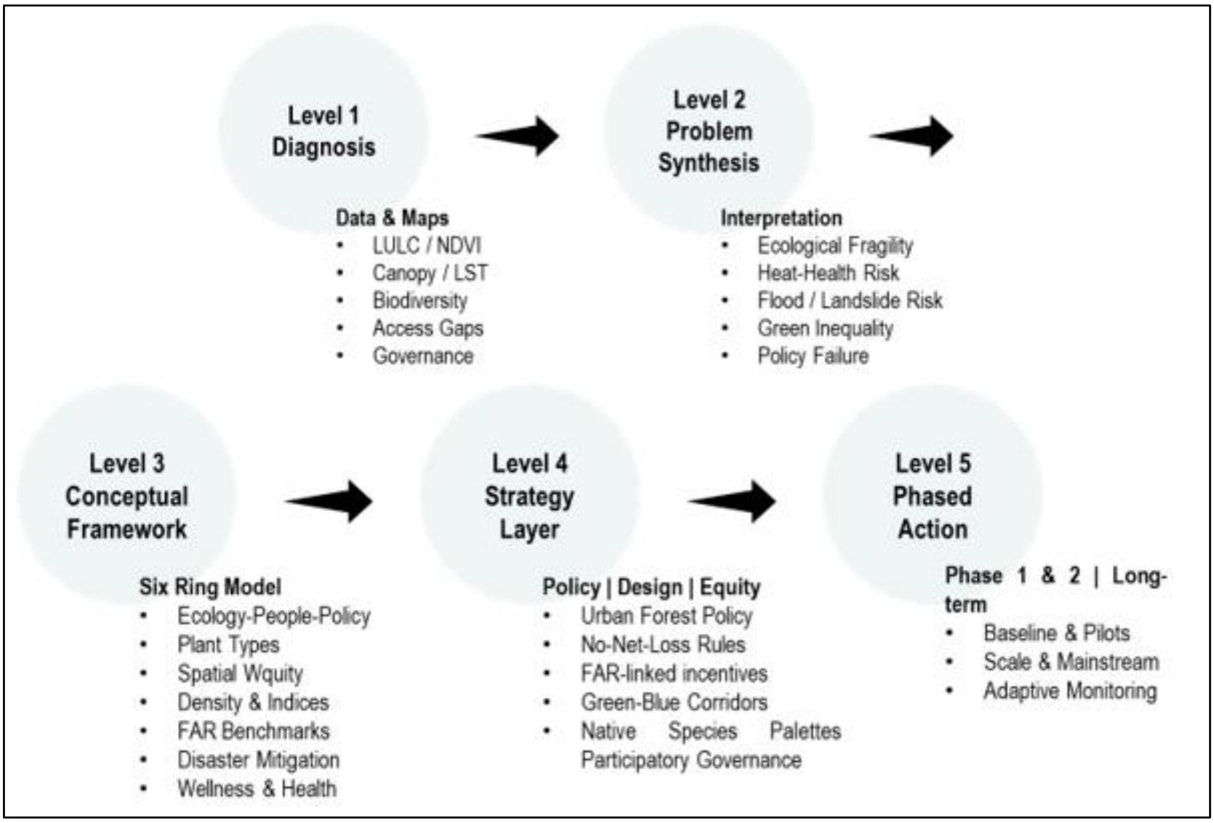
7. Analysis

7.1. Outcome levels for the framework

The Urban Forestry Multi-Mechanism Framework is translated into five outcome levels, ensuring a clear path from analysis to implementation.

Each level answers a distinct research question and contributes a specific type of knowledge, together forming a methodological spine for the study.

The outcome of this study moves from diagnosis (Levels 1–2), to conceptual structuring (Level 3), to spatial–policy strategies (Level 4), and finally to phased implementation (Level 5), each supported by peer-reviewed urban forestry literature.



Source: Author

Figure 6 Outcome levels for the framework

7.2. Table Representation of the Components and Outcomes

The study is structured through a systematic progression from diagnosis to implementation, translating empirical observations into actionable urban forestry strategies. At the first level, diagnostic findings establish clear evidence base of urban environmental conditions using measurable indicators such as land-use change, canopy structure, urban heat, biodiversity, and access to green spaces. Existing literature demonstrates that tools like GIS mapping, canopy assessment, and microclimate analysis effectively reveal patterns of forest loss, fragmented vegetation structure, heat concentration, and unequal access to green infrastructure. In the context of Guwahati, these methods highlight critical issues such as declining layered canopies, heat hotspots linked to vegetation loss, lack of shaded public spaces, fragmented biodiversity patches, and institutional gaps in urban forestry governance. (Dimoudi and Nikolopoulou, 2003; Fang et al., 2024; Georgi and Dimitriou, 2010; Nowak et al., 2006)

Building on this, the second level synthesizes these findings into broader urban challenges. The study identifies ecological fragility, heat-related health risks, flood and landslide vulnerability, biodiversity loss, spatial inequity, and governance failure as key interconnected problems. Theoretical insights from literature frame urban forestry not merely as beautification but as essential climate infrastructure, emphasizing its role in regulating temperature, stabilizing slopes, enhancing hydrological systems, and improving public health. It also reveals that fragmented governance and policy disconnect significantly hinder effective implementation, thereby justifying the need for integrated, multi-scalar planning and institutional reform. (Gillner et al., 2013b, 2013a; Hsieh et al., 2016a)

The third level translates these problems into a coherent conceptual framework grounded in contemporary urban forestry theory, ecosystem services, and Nature-based Solutions. Here, urban forestry is positioned as a form of green infrastructure that operates across multiple scales—from plot to ward to city. The framework integrates ecological, social, and policy dimensions through measurable indicators, equity-based planning principles such as the 3-30-300 rule, and climate-responsive species selection. It emphasizes the need for a harmonized approach linking people, ecology, and governance systems while embedding monitoring mechanisms to track performance and outcomes. (Barona et al., 2020; Escobedo et al., 2011, 2019; Jeong and Park, 2024)

At the fourth level, the framework is operationalized into a strategy layer comprising policy, spatial design, and implementation mechanisms. Policy strategies focus on establishing dedicated urban forestry institutions, enforcing protection and compensation measures, incentivizing private sector participation through FAR-linked benefits, and ensuring sustainable financing through mechanisms like an Urban Forest Fund. Spatial design strategies prioritize the development of green-blue corridors, street-level cooling through shaded avenues, topography-sensitive interventions for slope stability, and native species planting to enhance resilience. Implementation strategies further stress disaster risk reduction, equity-first interventions targeting vulnerable areas, and participatory governance models to strengthen community ownership and long-term stewardship. (Alvey, 2006; Armson et al., 2012; Barona et al., 2020; Bowler et al., 2010; Escobedo et al., 2011, 2019)

Finally, the phased action plan ensures that the proposed strategies are feasible, adaptive, and measurable over time. It begins with baseline assessments and pilot projects to establish data-driven foundations, followed by scaling and mainstreaming through policy integration and institutional alignment. In the long term, adaptive management is emphasized through continuous monitoring, periodic evaluation, and recalibration of strategies to ensure ecological stability and sustained urban resilience. Together, this structured approach bridges the gap between research, policy, and practice, offering a comprehensive roadmap for integrating urban forestry into sustainable city planning. (Hernández et al., 2004; Hsieh et al., 2016b; Lin et al., 2019; Pinto et al., 2022)

8. Conclusion

The pressure of urbanization can be met by the framework, in cities where urbanization has increasingly placed pressure on natural ecosystems, leading to the loss of green spaces, rising temperatures, and declining environmental quality. The highlights and the importance of urban forestry as a strategic component is proved as per the researches and findings. By examining ecological conditions, spatial distribution of green infrastructure, and existing planning challenges, the research emphasizes the critical role that trees and urban green systems play in regulating microclimates, supporting biodiversity, and improving public health. The study proposes an Urban Forestry Multi-Mechanism Framework that integrates ecological, social, spatial, and governance dimensions of urban forest planning. By combining measurable indicators such as canopy cover, accessibility to green spaces, and climate-resilient vegetation with planning benchmarks like the 3-30-300 rule, the framework provides a structured approach for strengthening ecological resilience and ensuring equitable access to urban greenery.

Ultimately, integrating urban forestry within planning policies and development strategies can help cities address environmental challenges while improving overall urban livability

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