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Tree diversity, growth performance and phytosociological assessment of urban forests in Raipur and Naya Raipur smart city, Chhattisgarh, India

Animesh Shukla, SC Tiwari and Garima TiwariDOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i7m.6046>**Abstract**

Urban forests are essential for conserving biodiversity, mitigating climate change, and enhancing environmental quality in rapidly urbanizing regions. This study inventoried tree species and assessed their growth performance and ecological diversity in Raipur and Naya Raipur (Atal Nagar) Smart City, Chhattisgarh, India. Systematic field surveys were conducted across roadside plantations, parks, institutional campuses, and other urban green spaces to record tree species, height, girth at breast height (GBH), diameter at breast height (DBH), and basal area. Phytosociological parameters, including density, frequency, relative density, relative frequency, relative dominance, and Importance Value Index (IVI), were estimated using standard ecological methods. Species diversity was evaluated using the Shannon-Wiener Diversity Index, Simpson's Dominance Index, Pielou's Evenness Index, and Menhinick's Richness Index. A total of 60 tree species belonging to 26 families were recorded, reflecting high floristic diversity. *Azadirachta indica* exhibited the highest ecological importance (IVI = 31.89), followed by *Dalbergia sissoo*, *Pongamia pinnata*, and *Albizia lebbbeck*. In contrast, *Dalbergia sissoo* recorded the highest GBH, whereas *Azadirachta indica* showed the greatest basal area. The diversity indices, Shannon-Wiener (3.8234), Simpson's Dominance (0.0286), Pielou's Evenness (0.9338), and Menhinick's Richness (1.6615), indicated a diverse, balanced, and ecologically stable urban tree community. The study provides a comprehensive baseline database to support biodiversity conservation, urban forest management, green infrastructure planning, and evidence-based strategies for developing sustainable and climate-resilient cities under the Smart Cities Mission.

Keywords: Urban forestry, tree diversity, phytosociology, importance value index, shannon diversity index, urban biodiversity, raipur, smart city, ecological sustainability

Introduction

Urbanization is rapidly transforming natural ecosystems worldwide, resulting in habitat fragmentation, biodiversity loss, environmental degradation, and increased greenhouse gas emissions. As cities expand, urban forests have become an essential component of sustainable urban development due to their ability to provide ecological, economic, and social benefits (Ostoic & van den Bosch, 2015) ^[1]. Urban forests, which include roadside plantations, parks, institutional campuses, residential green spaces, and peri-urban forests, contribute significantly to climate regulation, air pollution mitigation, biodiversity conservation, stormwater management, and human well-being (Tiwari et al., 2022) ^[2].

The ecological sustainability of urban forests largely depends on their tree species composition, structural diversity, and growth performance. Diverse urban forests are generally more resilient to environmental stresses, pests, diseases, and climate change while providing enhanced ecosystem services such as carbon sequestration, temperature regulation, and habitat support for wildlife (Morgenroth et al., 2016; Xie et al., 2024) ^[3,4]. Therefore, assessment of tree diversity has become a critical component of urban forest management and planning.

Tree species inventories provide baseline information on species richness, abundance, distribution, health status, and structural characteristics. Such inventories facilitate the evaluation of ecosystem services and support evidence-based conservation and management strategies. Quantitative assessment of vegetation communities is commonly conducted using phytosociological parameters such as density, frequency, Dominance, relative density, relative frequency, relative dominance, and Importance Value Index (IVI).

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In addition, diversity indices including the Shannon-Wiener Diversity Index, Simpson's Dominance Index, Pielou's Evenness Index, and Menhinick's Richness Index are widely used to assess species richness, evenness, and community structure. Growth performance of urban trees, measured through parameters such as diameter at breast height (DBH), girth at breast height (GBH), tree height, basal area, and stem volume, provides valuable information regarding tree health, productivity, biomass accumulation, and carbon storage potential (Nowak & Crane, 2002) ^[5]. These measurements are essential for understanding urban forest structure and estimating ecosystem services provided by trees. In India, rapid urban expansion has considerably altered urban vegetation patterns, leading to increased environmental challenges such as air pollution, urban heat island effects, and loss of biodiversity (Sharma *et al.*, 2025, Tiwari *et al.*, 2023) ^[6]. Urban forests have therefore gained importance as nature-based solutions for improving environmental quality and enhancing urban resilience (Maitry *et al.*, 2023; Bherwani *et al.*, 2024) ^[7-9]. Raipur Smart City, one of the fastest-growing cities in Central India, has experienced significant industrial and infrastructural development, resulting in increasing pressure on urban green spaces. Despite the ecological importance of urban trees in the city, comprehensive information regarding tree species composition, diversity, and growth performance remains limited (Humane *et al.*, 2025) ^[10].

Therefore, the present study was undertaken to inventory the tree species and assess their growth performance and diversity indices in the Raipur Smart City area. The study aims to generate baseline information on species richness, vegetation structure, and ecological significance of urban trees, which will support sustainable urban forestry, biodiversity conservation, climate-resilient urban planning, and future assessments of carbon sequestration potential.

Materials and Methods

The present study was carried out between March to July 2025 in the interconnected urban ecosystems of Raipur and Naya Raipur (officially Atal Nagar), Chhattisgarh, India, located between 21° 14' - 21° 17' N latitude and 81° 38' - 81° 47' E longitude (Fig. 1). Together, these zones form a complex urban-to-peri-urban gradient at an average regional elevation of 298-300 meters above mean sea level. Raipur operates as a high-density administrative and commercial core with fragmented green spaces, whereas Naya Raipur, located 15-20 km southeast, is a planned satellite smart city featuring extensive, continuous institutional greenbelts. The modern landscape transitions from intensive commercial and residential concrete matrices to developing industrial fringes and structured avenue plantations dominated by species like Neem (*Azadirachta indica*), Karanj (*Pongamia pinnata*), Amaltas (*Cassia fistula*), and Arjun (*Terminalia arjuna*).

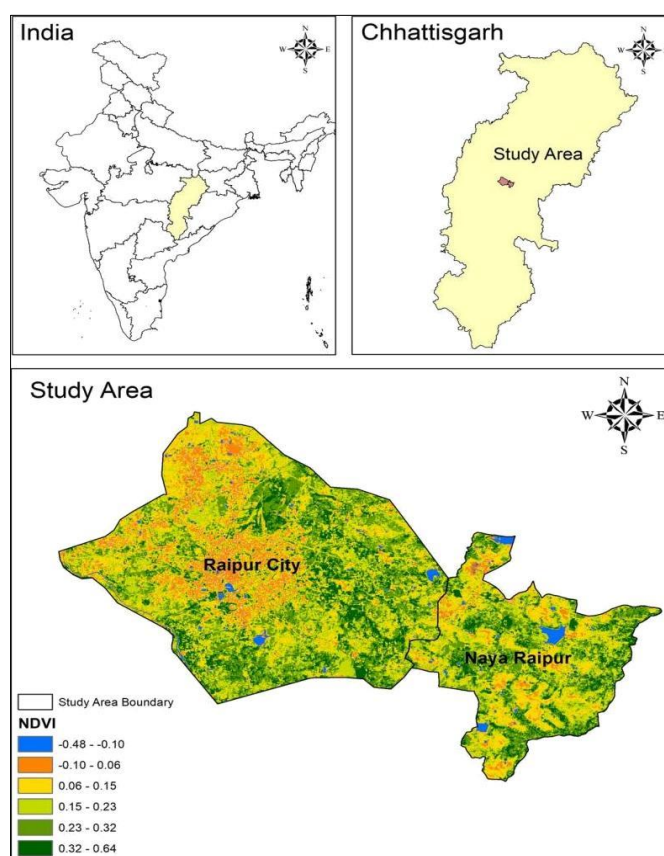


Fig 1: Map of the study site

Topographically situated in the fertile Chhattisgarh Basin within the Mahanadi River catchment, the area exhibits a gently undulating terrain. The region experiences a sub-humid Tropical Wet and Dry climate (Köppen: Aw), characterized by hot summers exceeding 45 °C with pronounced urban heat

island effects, mild dry winters, and an average annual rainfall of 1,200-1,400 mm primarily delivered by the southwest monsoon (June-September). The underlying soil is a tropical red-and-yellow complex dominated structurally by Alfisols and Inceptisols. These are locally classified into the moderately

retentive *Matasi* (sandy/clay loam) and nutrient-depleted *Bhata* (lateritic gravelly) soil series, which historically supported a native Tropical Dry Deciduous Forest ecosystem rich in Sal (*Shorea robusta*) and Teak (*Tectona grandis*).

Tree Inventory and Growth Assessment

Following the establishment of the sampling plots using a stratified random sampling approach, a systematic field survey was carried out during the study period to document the tree flora across the major urban land-use categories of Raipur and Naya Raipur, including roadside plantations, public parks, institutional campuses, residential areas, and other urban green spaces. Within each of the 120 quadrats (31.62m×31.62m), all tree individuals were enumerated and identified to species level using standard regional floras, taxonomic literature, and expert consultation wherever necessary. For each recorded individual, the species name, family, and abundance were documented. To assess the growth performance and structural attributes of the urban tree population, dendrometric parameters including tree height, girth at breast height (GBH; measured at 1.37 m above ground level), and diameter at breast height (DBH) were recorded following standard forestry measurement protocols (Maitry *et al.*, 2025) [11]. The basal area of each tree was subsequently computed from the DBH measurements to characterize stand structure and provide the quantitative data required for subsequent analyses of species composition, growth performance, and diversity within the urban forest ecosystem.

Phytosociological Analysis

The phytosociological parameters, including frequency, density, abundance, basal area, relative frequency (RF), relative density (RD), relative dominance (RDo), and Importance Value Index (IVI), were computed following the standard methods described by Curtis and McIntosh (1950) [12] and Misra (1968) [13] using the following formulae:

Frequency(%)

$$= \frac{\text{Number of quadrats in which the species occurred}}{\text{Total number of quadrats sampled}} \times 100$$

Density

$$= \frac{\text{Total number of individuals of a species}}{\text{Total sampled area (ha)}}$$

Abundance

$$= \frac{\text{Total number of individuals of a species}}{\text{Number of quadrats in which the species occurred}}$$

$$\text{Basal Area} = \frac{\pi D^2}{4} [D$$

$$= \text{Diameter at Breast Height (DBH, m)}]$$

Since the field measurements were recorded as GBH (cm), the diameter was first calculated as:

$$D = \frac{GBH}{\pi}$$

$$RF = \frac{\text{Frequency of a species}}{\sum \text{Frequency of all species}} \times 100$$

$$RD = \frac{\text{Density of a species}}{\sum \text{Density of all species}} \times 100$$

$$RDo = \frac{\text{Basal area of a species}}{\sum \text{Basal area of all species}} \times 100$$

$$IVI = RF + RD + RDo$$

Diversity Analysis

Tree diversity was evaluated using standard ecological indices, including the Shannon-Wiener Diversity Index (Shannon & Weaver, 1963) [14], Simpson's Dominance Index (Simpson, 1949) [15], Pielou's Evenness Index (Pielou, 1966) [16], and Menhinick's Species Richness Index (Menhinick, 1964) [17]. These indices were used to assess species richness, diversity, dominance, and evenness of the urban tree community.

Statistical Analysis

The collected data were compiled and analyzed using Microsoft Excel and standard ecological formulae. Descriptive statistical analyses were performed to summarize tree species composition, growth performance, and diversity indices. In addition, Pearson correlation matrix among the different phytosociological parameters was carried out using Origin software to examine the underlying relationships among the variables. The calculated ecological parameters were subsequently interpreted to evaluate the structure, diversity, and ecological stability of the urban forest ecosystem.

Results and Discussion

Tree Species Composition and Diversity

The floristic survey conducted in the urban landscapes of Raipur and Naya Raipur Smart City recorded a total of 60 tree species belonging to 26 families, indicating high taxonomic diversity within the urban forest ecosystem (Table 1). The heterogeneous species composition observed in the study area can be attributed to the mosaic of urban habitats and varying environmental conditions that collectively influence species establishment and persistence. Such diversity enhances ecosystem stability and improves the capacity of urban forests to provide ecosystem services, including carbon sequestration, biodiversity conservation, climate regulation, and air pollution mitigation (Nizamani *et al.*, 2021; Nagendra & Gopal, 2010) [18, 19]. Among the inventoried species, *Azadirachta indica* recorded the highest abundance (88 individuals), followed by *Pongamia pinnata* (84), *Albizia lebbeck* (77), and *Dalbergia sissoo* (71). These species also exhibited higher frequency, density, basal area, and Importance Value Index (IVI), indicating their ecological dominance and adaptability under urban environmental conditions.

Table 1: Species Composition, Growth Performance and Phytosociological Characteristics of Urban Tree Species in Raipur and Naya Raipur Smart City

Species	Family	Total Individual s	Species Present in No. of Quadrate s	Frequenc y Percent	Densit y Trees (ha)	Abundanc e	Mean Heigh t (m)	Mean GBH (cm)	Basa l Area (m ² ha)	Relative Frequenc y Percent	Relativ e Density Percent	Relative Dominanc e Percent	IVI
<i>Azadirachta indica</i>	Meliaceae	88	71	59.17	7.33	1.24	15.7	101.6	0.602	9.07	6.75	16.07	31.89
<i>Alstonia scholaris</i>	Apocynaceae	40	26	21.67	3.33	1.54	10.67	44.5	0.053	3.32	3.07	1.4	7.79
<i>Ailanthus excelsa</i>	Simaroubaceae	30	19	15.83	2.5	1.58	11.61	71.86	0.103	2.43	2.3	2.74	7.47
<i>Dalbergia sissoo</i>	Fabaceae	71	45	37.5	5.92	1.58	14.33	111.93	0.59	5.75	5.44	15.74	26.93
<i>Tectona grandis</i>	Lamiaceae	21	13	10.83	1.75	1.62	9.1	53.69	0.04	1.66	1.61	1.07	4.34
<i>Mangifera indica</i>	Anacardiaceae	41	28	23.33	3.42	1.46	9.75	67.53	0.124	3.58	3.14	3.31	10.03
<i>Albizia lebbeck</i>	Fabaceae	77	61	50.83	6.42	1.26	11.4	69.53	0.247	7.79	5.9	6.59	20.28
<i>Ficus religiosa</i>	Moraceae	52	45	37.5	4.33	1.16	13.65	73.53	0.186	5.75	3.99	4.97	14.71
<i>Ficus benghalensis</i>	Moraceae	26	14	11.67	2.17	1.86	13.69	83.45	0.12	1.79	1.99	3.2	6.98
<i>Terminalia arjuna</i>	Combretaceae	37	26	21.67	3.08	1.42	8.1	50.39	0.062	3.32	2.84	1.66	7.82
<i>Syzygium cumini</i>	Myrtaceae	34	20	16.67	2.83	1.7	8.73	62.28	0.087	2.55	2.61	2.33	7.49
<i>Pongamia pinnata</i>	Fabaceae	84	63	52.5	7	1.33	12.35	74.11	0.306	8.05	6.44	8.16	22.65
<i>Delonix regia</i>	Fabaceae	23	12	10	1.92	1.92	10.55	49.36	0.037	1.53	1.76	0.99	4.29
<i>Cassia fistula</i>	Fabaceae	23	16	13.33	1.92	1.44	8.19	77.9	0.093	2.04	1.76	2.47	6.28
<i>Tamarindus indica</i>	Fabaceae	31	16	13.33	2.58	1.94	10.37	81.7	0.137	2.04	2.38	3.66	8.08
<i>Butea monosperma</i>	Fabaceae	20	13	10.83	1.67	1.54	7.18	27.04	0.01	1.66	1.53	0.26	3.45
<i>Acacia nilotica</i>	Fabaceae	12	4	3.33	1	3	8.33	37.21	0.011	0.51	0.92	0.29	1.73
<i>Acacia auriculiformis</i>	Fabaceae	17	6	5	1.42	2.83	7.78	32.44	0.012	0.77	1.3	0.32	2.39
<i>Samanea saman</i>	Fabaceae	11	4	3.33	0.92	2.75	10.63	33.94	0.008	0.51	0.84	0.22	1.58
<i>Terminalia catappa</i>	Combretaceae	15	8	6.67	1.25	1.88	10.24	57.81	0.033	1.02	1.15	0.89	3.06
<i>Bauhinia variegata</i>	Fabaceae	5	3	2.5	0.42	1.67	9.64	66.68	0.015	0.38	0.38	0.39	1.16
<i>Shorea robusta</i>	Dipterocarpaceae	13	8	6.67	1.08	1.62	11.18	53.05	0.024	1.02	1	0.65	2.67
<i>Lagerstroemia speciosa</i>	Lythraceae	6	3	2.5	0.5	2	6.38	38.99	0.006	0.38	0.46	0.16	1
<i>Hardwickia binata</i>	Fabaceae	9	5	4.17	0.75	1.8	9.55	37.36	0.008	0.64	0.69	0.22	1.55
<i>Polyalthia longifolia</i>	Annonaceae	7	3	2.5	0.58	2.33	8.3	68.73	0.022	0.38	0.54	0.58	1.5
<i>Peltophorum pterocarpum</i>	Fabaceae	7	3	2.5	0.58	2.33	10.33	35.62	0.006	0.38	0.54	0.16	1.08
<i>Gmelina arborea</i>	Lamiaceae	18	9	7.5	1.5	2	9.14	44.24	0.023	1.15	1.38	0.62	3.15
<i>Neolamarckia cadamba</i>	Rubiaceae	14	8	6.67	1.17	1.75	6.65	26.41	0.006	1.02	1.07	0.17	2.27
<i>Ficus virens</i>	Moraceae	11	4	3.33	0.92	2.75	7.89	47.89	0.017	0.51	0.84	0.45	1.8
<i>Artocarpus heterophyllus</i>	Moraceae	9	5	4.17	0.75	1.8	9.63	49.29	0.015	0.64	0.69	0.39	1.72
<i>Bombax ceiba</i>	Malvaceae	8	3	2.5	0.67	2.67	6.46	38.04	0.008	0.38	0.61	0.2	1.2
<i>Eucalyptus tereticornis</i>	Myrtaceae	6	3	2.5	0.5	2	10.85	53.5	0.011	0.38	0.46	0.3	1.15

<i>Casuarina equisetifolia</i>	Casuarinaceae	10	5	4.17	0.83	2	11.3	39.6	0.01	0.64	0.77	0.28	1.68
<i>Ceiba pentandra</i>	Malvaceae	11	5	4.17	0.92	2.2	6.66	35.26	0.009	0.64	0.84	0.24	1.72
<i>Acacia catechu</i>	Fabaceae	24	13	10.83	2	1.85	11.16	25.31	0.01	1.66	1.84	0.27	3.77
<i>Terminalia chebula</i>	Combretaceae	12	6	5	1	2	8.5	34.99	0.01	0.77	0.92	0.26	1.95
<i>Moringa oleifera</i>	Moringaceae	23	10	8.33	1.92	2.3	8.03	67.43	0.069	1.28	1.76	1.85	4.89
<i>Leucaena leucocephala</i>	Fabaceae	13	8	6.67	1.08	1.62	8.18	68.73	0.041	1.02	1	1.09	3.11
<i>Spathodea campanulata</i>	Bignoniaceae	24	12	10	2	2	7.51	47.38	0.036	1.53	1.84	0.95	4.33
<i>Mitragyna parvifolia</i>	Rubiaceae	21	12	10	1.75	1.75	7.71	26.66	0.01	1.53	1.61	0.26	3.41
<i>Madhuca longifolia</i>	Sapotaceae	21	9	7.5	1.75	2.33	9.02	27.32	0.01	1.15	1.61	0.28	3.04
<i>Manilkara hexandra</i>	Sapotaceae	9	3	2.5	0.75	3	9.81	55.63	0.018	0.38	0.69	0.49	1.57
<i>Holoptelea integrifolia</i>	Ulmaceae	16	7	5.83	1.33	2.29	11.91	35.89	0.014	0.89	1.23	0.36	2.49
<i>Diospyros melanoxylon</i>	Ebenaceae	8	3	2.5	0.67	2.67	10.57	35.69	0.007	0.38	0.61	0.18	1.18
<i>Prosopis juliflora</i>	Fabaceae	10	4	3.33	0.83	2.5	9.79	53.51	0.019	0.51	0.77	0.51	1.78
<i>Putranjiva roxburghii</i>	Putranjivaceae	15	8	6.67	1.25	1.88	6.54	62.59	0.039	1.02	1.15	1.04	3.21
<i>Senna siamea</i>	Fabaceae	10	4	3.33	0.83	2.5	11.15	39.67	0.01	0.51	0.77	0.28	1.56
<i>Albizia procera</i>	Fabaceae	8	3	2.5	0.67	2.67	10.27	61.43	0.02	0.38	0.61	0.53	1.53
<i>Terminalia bellirica</i>	Combretaceae	24	15	12.5	2	1.6	7.05	56.09	0.05	1.92	1.84	1.34	5.09
<i>Phyllanthus emblica</i>	Phyllanthaceae	11	5	4.17	0.92	2.2	11.03	55.41	0.022	0.64	0.84	0.6	2.08
<i>Schleichera oleosa</i>	Sapindaceae	22	14	11.67	1.83	1.57	9.25	56.31	0.046	1.79	1.69	1.23	4.71
<i>Melia azedarach</i>	Meliaceae	11	5	4.17	0.92	2.2	11.89	48.25	0.017	0.64	0.84	0.45	1.94
<i>Cleistanthus collinus</i>	Phyllanthaceae	21	9	7.5	1.75	2.33	11.98	68.44	0.065	1.15	1.61	1.74	4.5
<i>Cordia dichotoma</i>	Boraginaceae	9	3	2.5	0.75	3	11.3	33.49	0.007	0.38	0.69	0.18	1.25
<i>Aegle marmelos</i>	Rutaceae	13	7	5.83	1.08	1.86	10.2	63.1	0.034	0.89	1	0.92	2.81
<i>Limonia acidissima</i>	Rutaceae	24	14	11.67	2	1.71	10.68	53.89	0.046	1.79	1.84	1.23	4.86
<i>Ziziphus mauritiana</i>	Rhamnaceae	15	6	5	1.25	2.5	6.97	65.43	0.043	0.77	1.15	1.14	3.05
<i>Lannea coromandelica</i>	Anacardiaceae	24	14	11.67	2	1.71	6.06	29.57	0.014	1.79	1.84	0.37	4
<i>Bauhinia malabarica</i>	Fabaceae	7	3	2.5	0.58	2.33	6.03	32.24	0.005	0.38	0.54	0.13	1.05
<i>Ficus racemosa</i>	Moraceae	22	9	7.5	1.83	2.44	10.15	54.34	0.043	1.15	1.69	1.15	3.99
		1304											

The *Azadirachta indica* recorded the highest IVI (31.89), followed by *Dalbergia sissoo* (26.93), *Pongamia pinnata* (22.65), *Albizia lebbeck* (20.28), and *Ficus religiosa* (14.71). According to Maitry *et al.*, (2023)^[9], higher IVI values indicate greater ecological significance due to the combined contribution of density, frequency, and dominance. Similar dominance of *Azadirachta indica* and *Pongamia pinnata* has been reported in urban forests because of their adaptability, rapid growth, and tolerance to pollution and drought (Rai, 2016)

[20]. Species such as *Lagerstroemia speciosa*, *Bauhinia variegata*, *Bombax ceiba*, *Bauhinia malabarica*, and *Peltophorum pterocarpum* recorded comparatively lower IVI values (<2.0), indicating restricted occurrence and relatively poor representation in the study area. Their lower abundance may be associated with species-specific ecological requirements, plantation preferences, or limited adaptability under highly urbanized conditions (Galle *et al.*, 2021)^[21].

Growth performance of tree species

Marked variation was observed in growth characteristics among the recorded tree species. Mean tree height varied from approximately 6.03 to 15.70 m, whereas mean girth at breast height (GBH) ranged from 25.31 to 111.93 cm, demonstrating considerable interspecific variation in growth performance. Among all species, *Dalbergia sissoo* recorded the highest mean GBH (111.93 cm), followed by *Azadirachta indica* (101.60 cm), *Ficus benghalensis* (83.45 cm), and *Tamarindus indica* (81.70 cm). Likewise, *Azadirachta indica* exhibited the highest basal area (0.602 m² ha⁻¹), followed by *Dalbergia sissoo* (0.590 m² ha⁻¹), *Pongamia pinnata* (0.306 m² ha⁻¹), and *Albizia*

lebbek (0.247 m² ha⁻¹). These species contribute substantially to above-ground biomass accumulation and long-term carbon storage because basal area is directly related to tree biomass and productivity (Thakur *et al.*, 2019) [22]. The superior growth performance of these species may be attributed to their high adaptability to tropical climatic conditions, tolerance to urban pollution, efficient nutrient utilization, and drought resistance (Yadav *et al.*, 2024) [23]. Similar findings have been reported by Behera *et al.*, (2022) [24], who observed that *Azadirachta indica*, *Dalbergia sissoo*, and *Albizia lebbek* possess excellent biomass production and carbon sequestration potential under Indian urban conditions.

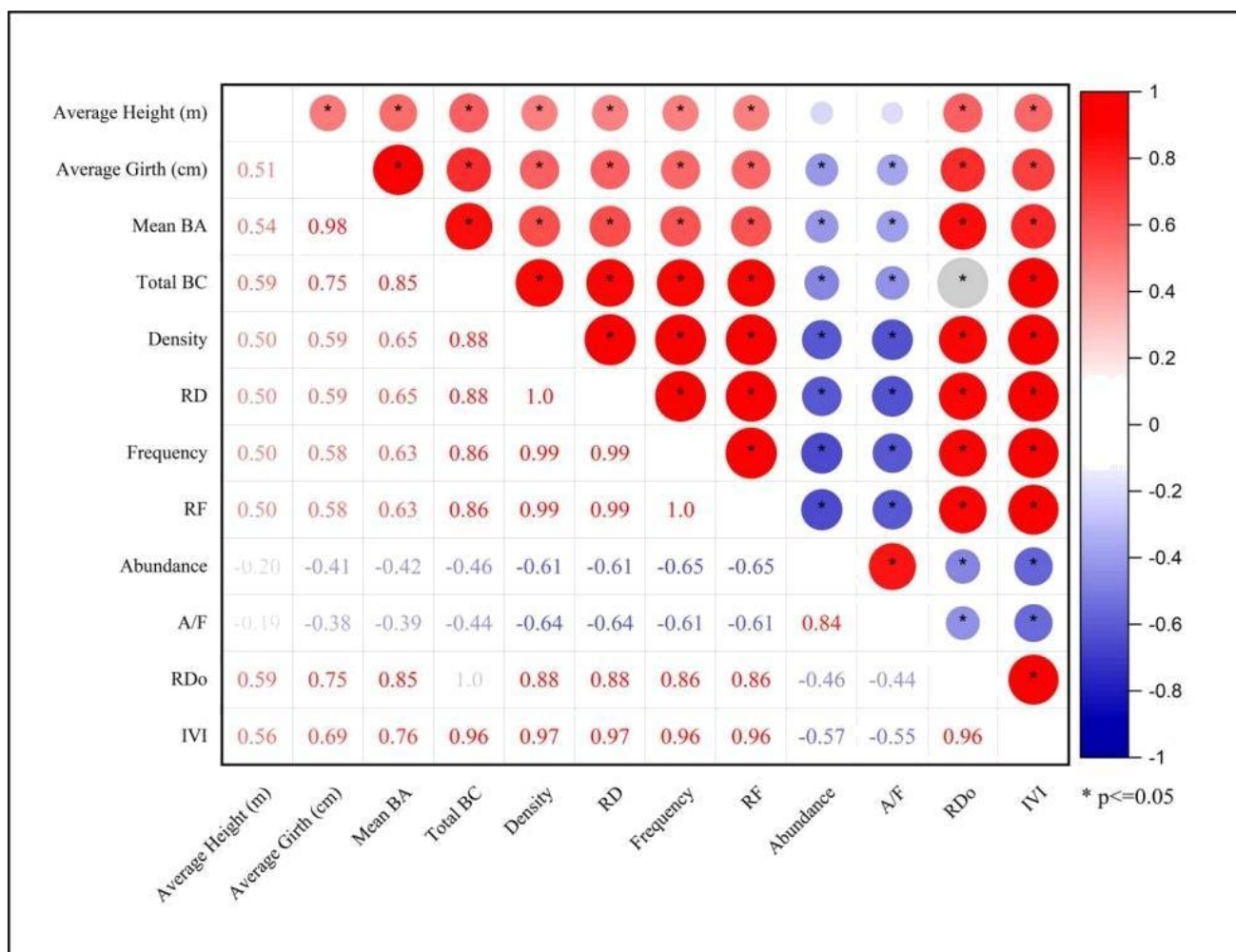


Fig 2: Pearson correlation between different phytosociological parameters

The correlogram shows Pearson correlations among twelve phytosociological parameters, with circle size/colour indicating strength and direction, and asterisks marking significance ($p \leq 0.05$). Growth and structural attributes including height, girth, basal area, density, frequency, and dominance are strongly, significantly, and positively intercorrelated ($r = 0.50$ – 0.98), with pairs like density-relative density (RD), frequency-relative frequency (RF), and total basal cover (BC)-relative dominance (RDo) approaching unity since relative measures are mathematically derived from their absolute counterparts. IVI, as the sum of RD, RF, and RDo, correlates very highly with these variables ($r = 0.96$ – 0.97), confirming its role as an integrative dominance index (Negi *et al.*, 2022) [25]. Conversely, abundance and A/F are negatively correlated with dominance-

related parameters ($r = -0.42$ to -0.65) despite being positively correlated with each other ($r = 0.84$), reflecting that clumped distribution does not equate to structural dominance, echoing findings that basal area, density, and diversity, while generally linked, can diverge under disturbance (Sagar & Singh, 2006) [26]. Height alone shows weak, nonsignificant links with abundance and A/F.

Diversity Indices

The calculated ecological diversity indices revealed that the urban forests of Raipur Smart City possess a diverse and ecologically stable tree community (Table 2). Based on the total abundance data ($n=1304$) across all 60 species, here are the calculated values:

Table 2: Diversity Indices of the Tree Community in the Study Area

Diversity Index	Formula Used	Calculated Value
Shannon-Weiner Index (H')	$-\sum p_i \ln(p_i)$	3.8234
Simpson Dominance Index (D)	$\sum p_i^2$	0.0286
Evenness Index (J')	$(H')/(\ln(S))$	0.9338
Richness Index (D_{mn})	$(S)/(\sqrt{N})$	1.6615

{Where: $p_i = n_i / N$; n_i = Number of individuals of the i^{th} species; N = Total number of individuals; S = Total number of species}

The Shannon-Wiener Diversity Index (H') was 3.8234, indicating high species diversity and a structurally stable ecosystem. This index values greater than 3.0 generally characterize mature and heterogeneous vegetation communities with high ecological stability. Similar high diversity values have been reported for well-managed urban forests across the world (Naidu and Kumar, 2016) [27]. The Simpson Dominance Index (D) was 0.0286, indicating very low dominance by any single species. Low Simpson values reflect balanced species composition and lower ecological vulnerability to pest outbreaks, diseases, or environmental disturbances (Kumar, 2025) [28]. Such findings suggest that no single species monopolizes the urban vegetation of Raipur Smart City. The Pielou's Evenness Index (J') was 0.9338, indicating a remarkably uniform distribution of individuals among the recorded species. High evenness values close to one are generally associated with stable ecosystems where species are evenly represented (Joshi and Garkoti 2025) [29]. The Menhinick Richness Index was 1.6615, demonstrating relatively high species richness after standardizing for sample size (Joshi and Dhyani, 2019) [30]. The richness observed in the present investigation reflects the success of urban greening initiatives and plantation programmes implemented within the Smart City area.

Ecological implications

The dominance of *Azadirachta indica*, *Dalbergia sissoo*, *Pongamia pinnata*, *Albizia lebbeck*, and *Ficus religiosa* demonstrates that these species are highly suitable for urban afforestation and green infrastructure development because of their superior growth performance, ecological importance, and greater biomass accumulation. Simultaneously, the presence of numerous indigenous and moderately abundant species contributes to maintaining biodiversity and ecosystem stability (Xess *et al.*, 2026) [4]. The present findings indicate that the urban forests of Raipur Smart City constitute a diverse and well-structured ecosystem capable of delivering important ecosystem services, including carbon sequestration, air pollution mitigation, urban heat island reduction, biodiversity conservation, and climate resilience. Therefore, continued protection of existing green spaces, coupled with enrichment planting of native tree species, will further strengthen the ecological sustainability of the city's urban landscape.

Conclusion

The present study provides a comprehensive assessment of the tree diversity, growth performance, and phytosociological characteristics of the urban forests in the study area. The inventory revealed a rich and heterogeneous assemblage of tree species distributed across various urban green spaces, reflecting the ecological significance of urban forests in sustaining biodiversity within a rapidly urbanizing landscape. Phytosociological analysis identified clear differences in the ecological importance and distribution of individual species,

highlighting the dominance of a few well-adapted species while demonstrating the substantial contribution of several others to the overall community structure. Variations in growth attributes among species further indicated differences in their adaptability, growth potential, and structural contribution to the urban forest ecosystem. The observed composition and structure of the urban tree community indicate a resilient and functionally stable ecosystem capable of supporting biodiversity conservation and sustaining key ecosystem services. Maintaining such diverse urban forests will be essential for enhancing ecological resilience and environmental sustainability in the context of ongoing urbanization.

The findings emphasize the importance of conserving and promoting diverse native and well-adapted tree species to enhance the ecological sustainability of urban landscapes. The comprehensive database generated through this study provides valuable baseline information for urban forest planning, species selection, biodiversity conservation, and long-term ecological monitoring. Furthermore, the study contributes to evidence-based decision-making for the development and management of green infrastructure, supporting climate change mitigation, environmental quality improvement, and the creation of sustainable and resilient urban ecosystems under the Smart Cities Mission. Future urban greening initiatives should prioritize species diversity and ecological suitability to ensure the continued delivery of ecosystem services and strengthen the long-term resilience of urban forests.

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