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Evaluating urban tree diversity and the "10-20-30" rule of urban forestry in Ilorin metropolis, Nigeria

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ABSTRACT

Urban forests comprising trees in streets, parks, and other urban settings, provide essential ecological, economic, and social benefits. The "10-20-30" rule of urban forestry is a guideline to promote tree species diversity and enhance the resilience of urban forests. This study therefore evaluates urban tree diversity in Ilorin metropolis, Nigeria, with a focus on adherence to the "10-20-30" rule. This research employed a systematic survey of urban tree species across various central areas in Ilorin covering about 20% of Ilorin's landmass. Tree species were identified to species level. Data were analyzed using descriptive statistics, Shannon-Wiener's index, and Margalef's index to assess diversity and species richness. The results revealed high species diversity, with the Fabaceae family being the most represented. Notable species include *Albizia lebbeck*, *Ficus macrocarpa*, and *Polyalthia longifolia*. The Shannon-Wiener index of 3.88 and Margalef's index of 10.5 indicate significant species diversity and richness. The study confirmed compliance with the "10-20-30" rule, as no single species (*Polyalthia longifolia* = 8.40%, *Azadirachta indica* = 6.36%, *Ficus macrocarpa* = 5.80%), genus (Ficus = 14.85%, Terminalia = 8.84%, Polyalthia = 8.40%) or family (Fabaceae = 21.71%, Moraceae = 15.01%, Annonaceae = 11.35%) exceeded the thresholds. These findings highlight the importance of diverse urban forests in enhancing urban resilience and sustainability, offering valuable insights for policymakers and urban planners to improve urban forestry management in developing cities. To enhance urban resilience and sustainable forestry in Ilorin metropolis, it is crucial to maintain adherence to the "10-20-30" rule by fostering species, genus, and family diversity. Conservation efforts should prioritize diverse species like *Albizia lebbeck*, *Ficus macrocarpa*, and *Polyalthia longifolia*, while policymakers and urban planners should integrate these findings into actionable strategies.

Keywords: "10-20-30" rule of urban forestry; fabaceae; species; genus; species diversity

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INTRODUCTION

According to Nowak (2016), urban forests are defined by their proximity to human populations and include all trees within urban lands, which encompass trees along streets, in residential lots, parks, and other urban settings. Urban forestry plays a crucial role in enhancing the quality of life in metropolitan areas by providing a wide array of ecological, economic, and social benefits (Martyka and Figurska-Dudek, 2023). They provide a wide range of ecosystem services such as mitigating air pollution, providing fruits and wood, reducing urban heat island effects, improving mental health, and enhancing the aesthetic appeal of urban landscapes (MEA, 2005; Alemu, 2016; Vollenweider *et al*., 2021; Amusa *et al*., 2022). However, the sustainability and resilience of urban forests heavily depend on the diversity of tree species within these ecosystems (Nitoslawski *et al*., 2016).

The "10-20-30" rule of urban forestry, proposed by Frank Santamour, serves as a guideline to ensure the tree species diversity of urban forests (Santamour, 1990). The rule advocates that no more than 10% of the urban tree population should belong to a single species, no more than 20% to a single genus, and no more than 30% to a single family. This rule aims to mitigate the risks associated with monocultures, such as susceptibility to pests, diseases, and climatic events, thereby promoting resilient and sustainable urban forests (Avolio, 2023). Although the rule does not rely on empirical data (Kendal *et al*., 2014), it has however gained widespread recognition and adoption, likely contributing positively to the structure and diversity of urban forests (Konijnendijk, 2023).

Ilorin metropolis is presently experiencing significant urbanization pressures, especially due to the commencement of the “Ilorin City Master Plan 2042” project that was launched by the state government in 2022. The master plan, as pronounced, will boost the economy of the state, provide utility infrastructure, and accommodate future growth, among others (Dar, 2022). Although it was also noted that the plan will further protect the environment and mitigate the effect of climate change, however, ongoing developments show otherwise. As urban development intensifies, the diversity and composition of urban trees are increasingly compromised (Nock *et al*., 2013). Evaluating the urban tree diversity in Ilorin through the lens of the "10-20-30" rule provides critical insights into the current state of the metropolis’ urban forest and highlights areas for improvement in urban forestry management practices. This evaluation not only aids in understanding the existing tree diversity but also serves as a foundation for strategic planning and policymaking to enhance urban resilience and sustainability.

By conducting a survey of urban tree species, genera, and families within the study area, this research aims to identify the dominant species, evaluate the diversity index, and highlight potential risks associated with the current tree population structure. It also seeks to determine the extent to which the urban forests in the study area align with the "10-20-30" rule. This research, therefore, contributes to the broader discourse on urban forestry management in developing cities, offering practical insights for policymakers, urban planners, and environmentalists dedicated to preserving and enhancing urban green spaces.

MATERIALS AND METHODS

Study Area

The research was conducted in Ilorin metropolis, Kwara State, Nigeria (Figure 1). Ilorin is situated between latitudes 08°26′237″ and 08°31′267″ N, and between longitudes

04°30′02″ and 04°33′77″ E. Positioned in Nigeria's North-central geopolitical zone, Ilorin encompasses three main Local Government Areas: Ilorin East, Ilorin South, and Ilorin West. According to the 2006 National Population Census, Ilorin had a population of 777,667 with an annual growth rate of around 3% (NPC, 2006) which takes the 2024 projected population to about 1,323,926. Rainfall in Ilorin varies from 1000 mm to 1500 mm annually, peaking in September and early October. The temperature ranges from 33 ºC to 35 ºC between November and January, and from 34 ºC to 37 ºC between February and April (Ahmed, 2008; Ajadi *et al*., 2016). Ilorin's tropical savanna climate features distinct wet and dry seasons, with the wet season from April to October and the dry season from November to March, including harmattan winds during peak dry months.

Data Collection

Tree species data were collected from central areas, covering about 20% of Ilorin's landmass. These areas included Irewolede (New Yidi Road), Asadam, Taiwo, Murtala Mohammed Way, Offa Garage, Ahmadu Bello Way, Fate, Tanke, Gaa Akanbi, Sawmill, Adewole, Olohunsogo, Kwara Polytechnic campus, Kwara State College of Education campus, and the University of Ilorin campus.

A systematic sampling method was used in the study. It involved the identification of road networks and houses within the central districts that had trees. From these, every nth road and house was selected at regular intervals, ensuring an even distribution across the area. The starting point was chosen randomly to avoid bias, and the intervals were determined based on the total number of eligible roads and houses. This approach ensured that the sample was representative of the entire district while being practical and methodical. To ensure accurate identification, an experienced taxonomist was employed, and all trees were identified down to the species level.

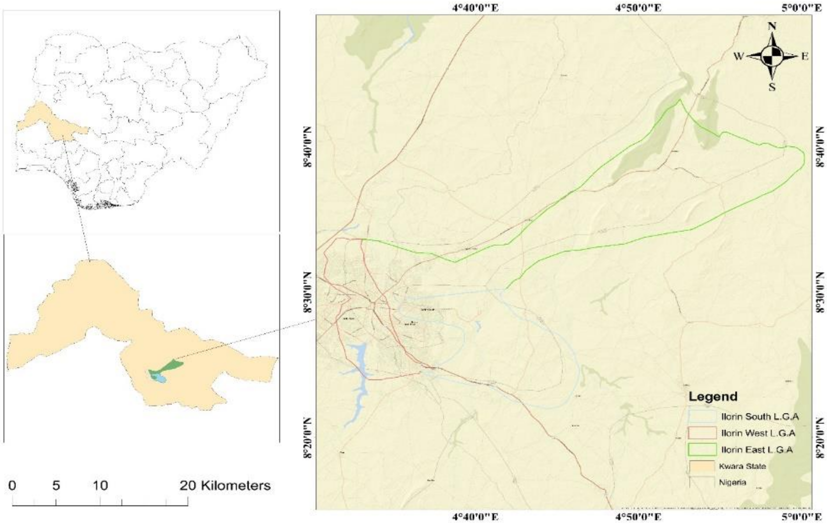

Figure 1: Map of Ilorin metropolis (inset: map of Nigeria showing Kwara State and map of Kwara State showing Ilorin metropolis)

Data Analysis

Data were analyzed using descriptive statistics such as frequency, percentage, and charts. Tree species diversity was calculated using Shannon-Wiener's index of diversity (Price, 1997), and the species richness was calculated using Margalef's index (Margalef, 1958).

Shannon-Wiener's index = $-\sum_{t=1}^{s} PiIn(Pi) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$

Where S = total number of species in the area; P_i = proportion of 'S' made up of the *i*th species, and *ln* = natural logarithm.

Margalef's index (d) = $\frac{S}{\sqrt{N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

Where S = the number of tree species encountered and N = the total number of individuals of all the tree species in the area.

RESULTS AND DISCUSSION

Of the 23 taxonomic families, Fabaceae family was the most represented (Figure 2), with numerous species and high frequencies. For instance, *Albizia lebbeck* exhibits a relatively significant occurrence of 79 (2.4%), indicating its prevalence or ecological dominance (Table 1). Other notable Fabaceae members include *Acacia polycantha* with a frequency of 16 (0.5%), *Leucena leucocephala* (62, 1.92%), and *Daniella oliveri* (62, 1.9%). The results suggest a wide distribution and possibly favourable environmental conditions for Fabaceae species. The Meliaceae family is highlighted by *Azadirachta indica*, which had the highest individual species frequency of 205 (6.3%), highlighting its ecological or economic importance (Table 1). Other Meliaceae species like *Khaya senegalensis* and *Cedrela odorata* showed moderate frequencies of 32 (1.0%) and 23 (0.7%), respectively. The Anacardiaceae family was prominently represented by *Mangifera indica* (89, 2.8%) and *Anacardium occidentale* (78, 2.4%), reflecting their substantial presence, potentially due to their economic and nutritional value. The Moraceae family includes species with a wide range of frequencies, from *Ficus carica* (2, 0.1%) to *Ficus macrocarpa* (187, 5.8%), indicating varying levels of distribution and possibly ecological adaptability. Other significant Moraceae members include *Ficus benjamina* (39, 0.01%) and *Ficus mucoso* (73, 2.3%). In the Combretaceae family, *Terminalia mantaly* stands out with a frequency of 164 (5.1%), suggesting its significant presence, possibly due to its adaptability and fast growth which makes it a widely planted species for shade in Ilorin. *Annoigeissus leocarpus* (56, 1.7%) and *Terminalia catappa* (110, 3.4%) further emphasize the family's notable presence. Several species showed lower frequencies, such as *Ceiba pentadra* (2, 0.1%) from the Malvaceae family and *Bombax constratum* (4, 0.12%) from the Bombacaceae family, possibly indicating limited distribution or specific habitat requirements. High-frequency species such as *Polyalthia longifolia* (271, 8.4%) from the Annonaceae family and *Blighia sapida* (132, 4.1%) from the Sapindaceae family are indicative of their ecological prominence or specific advantageous traits that support their prevalence.

Table 1: Tree species composition in Ilorin metropolis

Tree species	Family	Frequency
Acacia auriculiformis	Fabaceae	12
Acacia nilotica	Fabaceae	6
Acacia polycantha	Fabaceae	16
Acacia senegalensis	Fabaceae	5
Adansonia digitata	Malvaceae	30
Afezelia africana	Fabaceae	7
Albizia coriaria	Fabaceae	32
Albizia lebbeck	Fabaceae	79
Abizia zygia	Fabaceae	43
Anacardium occidentale	Anacardiaceae	78
Annoigeissus leocarpus	Combretaceae	56
Annona senegalensis	Annonaceae	8
Annona muricata	Annonaceae	87
Anthocliesta djalonensis	Loganiaceae	5
Anthocliesta nobilis	Gentianaceae	6
Atrocarpus altilis	Moraceae	5
Azadirachta indica	Meliaceae	205
Blighia sapida	Sapindaceae	132
Bridelia ferruginea	Euphorbiaceae	18
Burkea Africana	Fabaceae	6
Butea superba	Fabaceae	9
Bombax constratum	Bombacaceae	4
Buhienia veriegata	Fabaceae	10
Calotropis procera	Gentianaceae	11
Cassia fistula	Fabaceae	48
Casuarina equisetifolia	Casuarinaceae	9
Cedrela odorata	Meliaceae	23
Ceiba pentadra	Malvaceae	2
Cocos nucifera	Arecaceae	22
Combretum molle	Combretaceae	16
Crescentia cujete	Bignoniaceae	6
Croton gratissimus	Euphorbiaceae	4
Dalbergia latifolia	Fabaceae	8
Daniella oliveri	Fabaceae	62
Delonix regia	Fabaceae	6
Detarium microcarpum	Fabaceae	29
Erythrina senegalensis	Fabaceae	62
Erythrina sigmoidea	Fabaceae	18
Eucalyptus camadalensis	Myrtaceae	62
Eucalyptus citrodora	Myrtaceae	60
Eucalyptus toreliana	Myrtaceae	12
Ficus benjamina	Moraceae	39
Ficus carica	Moraceae	2
Ficus capensis	Moraceae	5
Ficus exasperate	Moraceae	37

Ficus macrophylla	Moraceae	69
Ficus macrocarpa	Moraceae	187
Ficus mucoso	Moraceae	73
Ficus sur	Moraceae	4
Ficus sycomorous	Moraceae	29
Ficus thoningii	Moraceae	34
Gmelina arborea	Lamiaceae	81
Gliricidia sepium	Fabaceae	13
Hildegardia barteri	Malvaceae	7
Hura crepitans	Euphorbiaceae	12
Khaya grandifoliola	Meliaceae	6
Khaya senegalensis	Meliaceae	32
Kigelia africana	Bignoniaceae	6
Lannea acida	Anacardiaceae	11
Lannea barteri	Anacardiaceae	21
Leucena leucocephala	Fabaceae	62
Mangifera indica	Anacardiaceae	89
Millieta thonningii	Fabaceae	3
Newbouldia laevis	Bignoniaceae	22
Nuclear latifolia	Rubiaceae	9
Parinari polyandra	Chrysobalanceae	71
Parkia biglobosa	Fabaceae	66
piliostigma thonningii	Fabaceae	38
Plumeria alba	Apocyanaceae	23
Polyalthia longifolia	Annonaceae	271
Prosopsis africana	Fabaceae	17
Pterocarpus erinaceus	Fabaceae	5
Roystonea regia	Arecaceae	45
Senna siamea	Fabaceae	38
Securidaca longepedunculata	Polygalaceae	4
Spathodea campanulate	Bignoniaceae	16
Spondias mombin	Anacardiaceae	32
Sterculia setigera	sterculiaceae	12
Strychnos spinosa	loganiaceae	2
Tectona grandis	Lamiaceae	44
Terminalia catappa	Combretaceae	110
Terminalia mantaly	Combretaceae	164
Terminalia glaucescens	Combretaceae	11
Vitellaria paradoxa	Sapindaceae	43
Vitex doniana	Lamiaceae	35
Ziziphus abyssinica	Rhamnaceae	6
TOTAL		3225

The high frequency and diversity of species within certain families like Fabaceae and Moraceae suggest a rich biodiversity. As noted by Vasiliev (2022), biodiversity is crucial for maintaining ecosystem stability, resilience, and functionality. The Fabacea have been reported in several studies (e.g. Iheyen *et al*., 2009; Moshood *et al*., 2023) to be the dominant species possibly due to their seed dispersal mechanism by wind. Additionally, species with high frequencies, such as *Azadirachta indica* and *Polyalthia longifolia*, indicate dominant or keystone species that play significant roles in their ecosystems. Their dominance could influence the structure and composition of the plant community and affect other species' survival and distribution as posited by Stavert *et al*. (2019). Furthermore, the varied frequencies across species suggest different habitat preferences and ecological niches. Costa-Pereira *et al*. (2018) and Fournier *et al*. (2020) also corroborated that species with lower frequencies may occupy more specialized or restricted niches, while those with higher frequencies could be more adaptable to a range of environmental conditions. It is also possible that the least occurring species could have been affected by human activities such as logging and the erection of buildings as opined by Moshood *et al*. (2023).

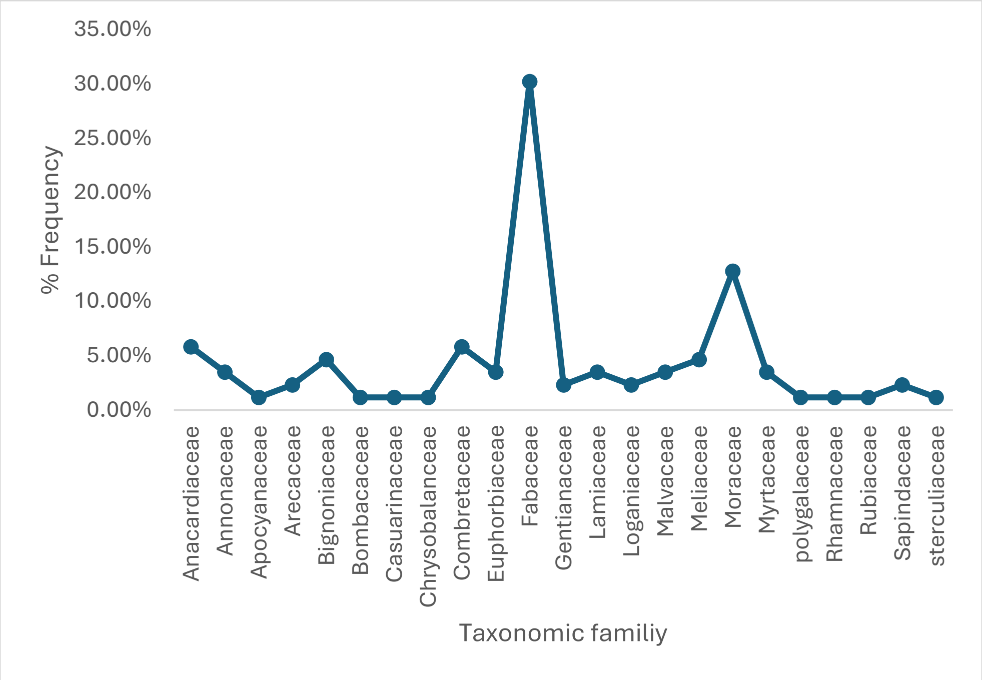

Figure 2: Representative taxonomic families in the study area

The Shannon-Wiener index for the study area was 3.88, while the Margalef was 10.52. (Table 2) The Shannon-Wiener value of 3.88 suggests that the study area has a wide variety of species and that the individuals are relatively evenly distributed. The Shannon-Wiener Index theoretically ranges from 0 to positive infinity. However, in practice, particularly in tropical vegetation, values are generally below 10. According to Magurran (2004), the value for the Shannon-Wiener Index can vary between 0 and 7, where a range of 0-2 signifies low diversity, 2-3 indicates moderate diversity, and values above 3 denote high diversity. The result is higher than what was reported for Abuja (3.56), Minna (3.08), and Port Harcourt (3.39) but lower than the 3.99 reported for Ibadan (Agbelade *et al*., 2016a; Agbelade *et al*., 2016b; Agbelade and Onyekwelu, 2020).

Table 2: Shannon-Wienner and Margalef indices result in Ilorin metropolis

S/N	Indices	Value
1	Shannon-Wiener Index of Diversity	3.88
2	Margalef Index of Species Richness	10.52

As noted by Isbell *et al.* (2015), high biodiversity is often associated with greater ecosystem stability and resilience. Diverse ecosystems can better withstand environmental stresses and are more resilient to disturbances such as climate change, disease, and habitat loss. Heydari *et al.* (2020) opined that a high Shannon-Wiener Index implies complex interactions among species, which can enhance ecosystem functions such as nutrient cycling, pollination, and soil formation. A value of 10.5 for Margalef's index indicates a high level of species richness. This suggests that the study area supports a large number of different species. Richness is an important aspect of biodiversity because it contributes to the functional diversity and overall health of the ecosystem. Zhang (2023) also stated that high species richness often reflects diverse habitats within the study area, providing various niches and conditions that support different species.

Concerning the 10-20-30 rule, the study showed that no individual species was higher than 10% of the tree population, no genus was more than 20% of the population and no family was more than 30% of the population (Figure 3). *Polyalthia longifolia* was the highest-occurring species and covered 8.40% of the population, followed by *Azadirachta indica* (6.36%) and *Ficus macrocarpa* (5.80%). Studies including Parkar *et al*. (2020) have observed that *Polyalthia longifolia* is often chosen for urban planting due to its ornamental appeal and ability to thrive in urban settings. Similarly, Mishra *et al.* (2019) noted that *Azadirachta indica* is valued for its medicinal properties and resilience to urban stressors. Also, *Ficus macrocarpa* further exemplifies the importance of the Ficus genus. As per the genus, Ficus, Terminalia and Polyalthia covered 14.85%, 8.84% and 8.40% respectively. Percival *et al*. (2006) had earlier noted that the Ficus genus is known for its adaptability to urban environments and provides substantial shade and aesthetic value. As for the taxonomic family, Fabaceae, Moraceae and Annonaceae covered 21.71%, 15.01% and 11.35% respectively.

The diversity among these families suggests a well-balanced urban forest structure that supports various ecological functions and mitigates the risk of diseases and pests impacting the entire tree population as noted by Kendal *et al*. (2014) and Nitoslawski *et al*. (2016). The findings showed adherence to the 10-20-30 rules and a balanced distribution across different families, genera, and species, promoting biodiversity and reducing the risk of widespread disease or pest outbreaks. In a study in Raleigh, North Carolina, Irwin (2023) reported that only one species (out of 226 total) which comprised 11.54% broke the 10% rule. No single genus violates the 20% rule, and no family was close to violating the 30% rule.

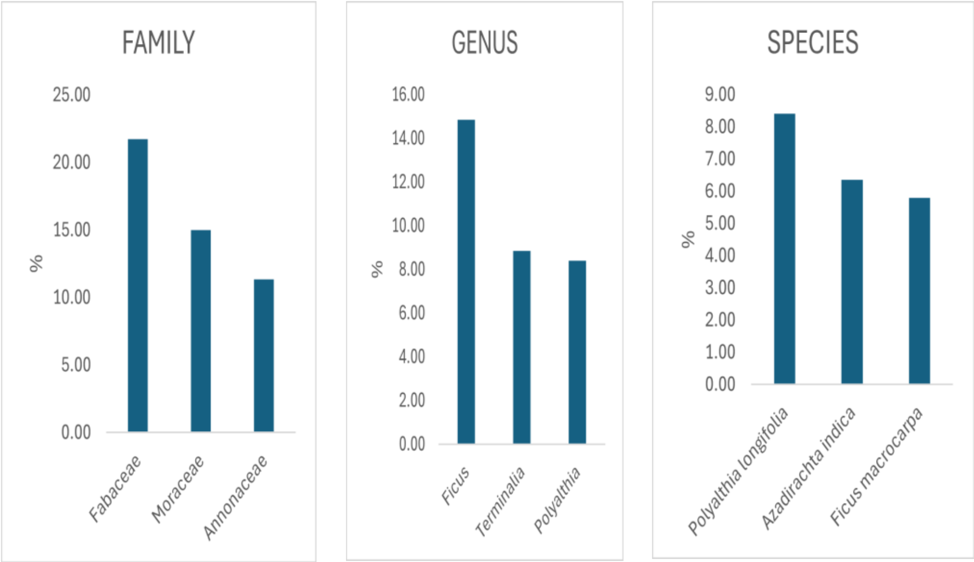

Figure 3: Distribution of three highest-occurring urban trees by species, genus, and family, according to the 10-20-30 rule

CONCLUSION

The assessment of tree species composition in the Ilorin metropolis shows a rich diversity with the Fabaceae emerging as a dominant family alongside other notable families like Moraceae and Annonaceae. These families showcase a diverse array of species, each contributing distinctively to the ecological landscape. The prevalence of high-frequency species shows their ecological importance and contribution to their ecosystems. Their presence not only influences the structure and composition of plant communities but also plays a vital role in supporting various ecosystem functions. Furthermore, the calculated Shannon-Wiener and Margalef indices reflect a high level of species diversity and richness in the study area. The adherence to the 10-20-30 rule of urban forestry indicates a well-balanced distribution of species, genera, and families, mitigating the risks associated with widespread disease or pest outbreaks. This balanced urban forest structure not only enhances aesthetic appeal but also ensures ecological sustainability and the provision of essential ecosystem services. It is pertinent to maintain adherence to the "10-20-30" rule by encouraging species, genus, and family diversity in urban forests in Ilorin metropolis. It is also important to emphasize the conservation of diverse species like *Albizia lebbeck*, *Ficus macrocarpa*, and *Polyalthia longifolia*. Finally, policymakers and planners should utilize these insights to strengthen urban resilience and sustainable forestry in Ilorin metropolis.

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