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COMPARATIVE EVALUATION OF SIMPSON'S AND SHANNON-WIENER'S INDICES FOR ASSESSING TREE SPECIES DIVERSITY IN ILORIN METROPOLIS, NORTH-CENTRAL NIGERIA

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Abstract
Assessing tree species diversity is paramount for understanding ecosystem dynamics and guiding conservation efforts. In urban landscapes like Ilorin metropolis, where human activities exert significant pressure on ecosystems, accurate assessments of tree diversity are crucial for sustainable urban planning and conservation strategies. This study conducted a comparative analysis of Simpson's and Shannon-Wiener's indices to evaluate tree species diversity within Ilorin Metropolis, Nigeria. Data on tree species were gathered from the central areas of Ilorin. Data collection was from road networks and houses with trees using a systematic method. Data was analysed with descriptive and inferential statistics (t-test and correlation analysis). Tree species diversity was assessed using Shannon-Wiener's and Simpson's diversity index. The study identified 3225 individual trees belonging to 86 species and 23 taxonomic families. The most common species was Polyalthia longifolia (8.40%), while Ceiba pentadra, Ficus carica, and Strychnos spinosa (0.06% each) were the least common. The Simpson's and Shannon-Wiener indices for the study area were 0.97 and 3.88, respectively. The results further revealed that Simpson's had a mean, a standard error of the mean and a standard deviation of 0.00035, 0.00011 and 0.00098, respectively. In contrast, Shannon-Wiener's had a mean, a standard error of the mean and a standard deviation of 0.045, 0.0045 and 0.041, respectively. The correlation coefficient between the indices was 0.83, while the t-test showed a significant relationship (t =10.189; p-value = 0.000). The study concludes that both diversity indices were highly suitable for assessing tree species diversity in the study area, but Simpson's diversity is more suitable.

Key Words: *Comparative evaluation, Shannon-Wiener's diversity index, Simpson's diversity index, Ilorin Metropolis*

Introduction

Nigeria is characterised by diverse ecosystems ranging from tropical rainforests to savannas. It harbours a rich array of tree species, contributing to the country's ecological, social, and economic structure (Agbelade and Onyekwelu, 2020). However, rapid urbanisation, land-use changes, and anthropogenic pressures have posed significant threats to tree species diversity and ecosystem integrity in urban areas like the Ilorin Metropolis (Ohwo and Abotutu, 2015; Agbelade *et al*., 2016; Agbelade and Onyekwelu, 2020). Understanding the patterns and drivers of tree species diversity within urban environments is imperative for devising effective conservation strategies and promoting sustainable urban development (Nitoslawski *et al*., 2016).

Tree species diversity is fundamental to ecosystem health and resilience and is crucial in maintaining ecological balance and functionality (Nadrowski *et al*., 2010). Evaluating the diversity of tree species holds critical importance in comprehending ecosystem dynamics, directing conservation efforts, and informing sustainable management strategies (Porth and El-Kassaby, 2014). The choice between Simpson's and Shannon-Wiener 's indices often depends on the specific objectives of the study, the ecological context, and the characteristics of the species assemblages under investigation (Nagendra, 2002). While Simpson's index is more sensitive to changes in dominant species, Shannon-Wiener's index provides a more balanced assessment of diversity by accounting for both richness and evenness (Nagendra, 2002). However, the response of these indices can vary, with Simpson's index stabilizing at low sample sizes and Shannon-Wiener's index being more affected by the addition of rare species (Gimaret-Carpentier *et al*., 1998).

Several studies have explored using Simpson's and Shannon-Wiener's diversity indices for estimating tree species diversity. Kumar *et al*. (2022) found that the Shannon-Wiener index was best for assessing species richness, while Simpson's index was more suited for determining species diversity. Lewis *et al*. (1988) applied these indices to evaluate the impact of forest management practices on plant community structure and succession. These studies collectively highlight the potential of both indices for estimating tree species diversity, with the choice of index and the use of additional data sources being key considerations. In Nigeria, Simpson's and/or Shannon-Wiener's diversity indices have been widely applied in forestry studies (Adekunle *et al*., 2013; Olajuyigbe and Adaja, 2014; Shamaki *et al*., 2015; Ogwu *et al*., 2016; Salami and Akinyele, 2017; Olajuyigbe and Jeminiwa, 2018; Olajuyigbe and Akwarandu, 2019; Adeyemi and Taofeek, 2020; Bukar *et al*., 2021; Salami *et al*., 2022; Moshood *et al*., 2023; Moshood and Olajuyigbe, 2024). Also, Saka *et al*. (2022) compared Shannon-Wiener's and Simpson's indices for estimating bird species diversity in Bodel Forest of Gashaka Gumti National Park, Nigeria, and found that the two indices are significant in measuring bird species diversity, but Shannon-Wiener 's is more preferred. However, little or no study exists comparing Simpson's and Shannon-Wiener's indices for assessing tree species diversity in urban settings in Nigeria. This study, therefore, focused on comparing the two most common diversity indices to evaluate tree species diversity in Ilorin metropolis to recommend the best index for species diversity assessment. By examining these indices within the context of the study area, this research contributes to the growing body of knowledge to enhance our understanding of urban biodiversity dynamics and inform evidence-based conservation strategies in rapidly urbanizing regions of Nigeria and beyond.

Materials and Methods

Study Area

The study was carried out in Ilorin metropolis, Kwara State, Nigeria (Figure 1). It lies within latitude 08°26′237″ - 08°31′267″ N and longitude 04°30′02″ - 04°33′77″ E of the equator. This city is situated within the North central geopolitical zone of Nigeria. Ilorin consists of three major Local Government Areas: Ilorin East, Ilorin South, and Ilorin West. According to the 2006 National Population Census, Ilorin's population is 777,667, with an annual population growth rate of approximately 3% (NPC, 2006). The amount of rainfall experienced in Ilorin varies between 1000 mm and 1500 mm per year, with the highest rainfall occurring during September and early October. The range of temperature ranges between 33ºC and 35ºC from November to January, and from February to April, the temperature ranges from 34ºC to 37ºC (Ahmed, 2008; Ajadi *et al*., 2016).

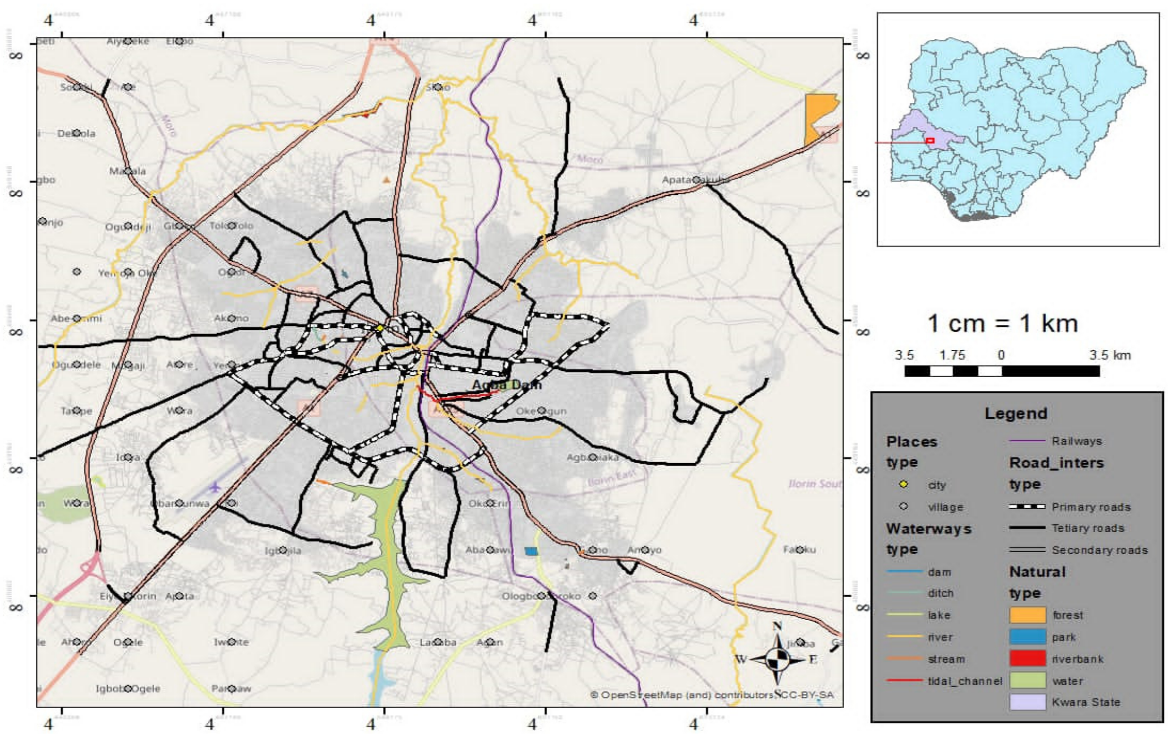

Fig. 1: Study area (Ilorin metropolis) map (inset: Map of Nigeria showing Kwara State)
Source: Moshood *et al*. (2022)

Sampling Method and Data Collection

Data on tree species were gathered from the central areas encompassing approximately 20% of the landmass of Ilorin (Agbelade and Onyekwelu, 2020). These areas included Irewolede (New Yidi Road), Asadam, Taiwo, Muritala Mohammed Way, Offa Garage, Ahmadu Bello Way, Fate, Tanke, Gaa Akanbi, Sawmill, Adewole, Olohunsogo, Kwara Polytechnic campus, Kwara State College of Education campus, and University of

Ilorin campus. Data was collected using a systematic sampling method, which involved selecting road networks and houses with trees within the central districts of Ilorin. An experienced taxonomist was employed to ensure accurate tree species identification, and trees were identified to species level.

Data Analysis

Data was analyzed and summarized using descriptive (frequency, mean, standard deviation and standard error of mean) and inferential statistics (student t-test and Pearson Product Moment Correlation). Tree species diversity was assessed using Shannon-Wiener's index of diversity (Price, 1997) and Simpson's diversity index (Simpson, 1949).

(i) Shannon-Wiener's index of diversity $= -\sum_{t=1}^{s} PiIn(Pi)$ ... ... (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.

(ii) Simpson Index = $1 - \sum\left(\frac{n}{N}\right)^2$ ... ... (2)

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

The student t-test was used to compare the significant effect of the two indices (Simpson's and Shannon-Wiener's diversity indices) on tree species diversity in the study area.

(iii) $t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{S_1{}^2}{n_1} + \frac{S_2{}^2}{n_2}}}$...........(3)

Where $\overline{X_1}$ and $\overline{X_2}$ = the mean number of Simpson's and Shannon-Wiener 's diversity indices, respectively; S_1^2 and S_2^2 = variance of Simpson's and Shannon-Wiener's diversity indices, respectively and n = sample size.

The linear statistical association between Simpson's and Shannon-Wiener's diversity indices was examined using the Pearson Product Moment Correlation coefficient.

(iv) $r = \frac{\sum ab - \frac{(\sum a)(\sum b)}{n}}{\sqrt{(\sum a^2 - \frac{(\sum a)^2}{n})(\sum b^2 - \frac{(\sum b)^2}{n})}}$ ... ... (4)

Where a and b = values for the variables considered (Simpson's and Shannon-Wiener's diversity indices respectively) and n = sample size.

Results and Discussion

Tree Species Composition and Distribution

The study identified a total of 3225 individual trees belonging to 86 species and 23 taxonomic families (Figure 2). The most common species was *Polyalthia longifolia* (8.40%), while *Ceiba pentadra*, *Ficus carica*, and *Strychnos spinosa* (0.06% each) were the least common (Table 1). The Shannon-Wiener's index for the study area was 3.88, while the Simpson's index was 0.97.

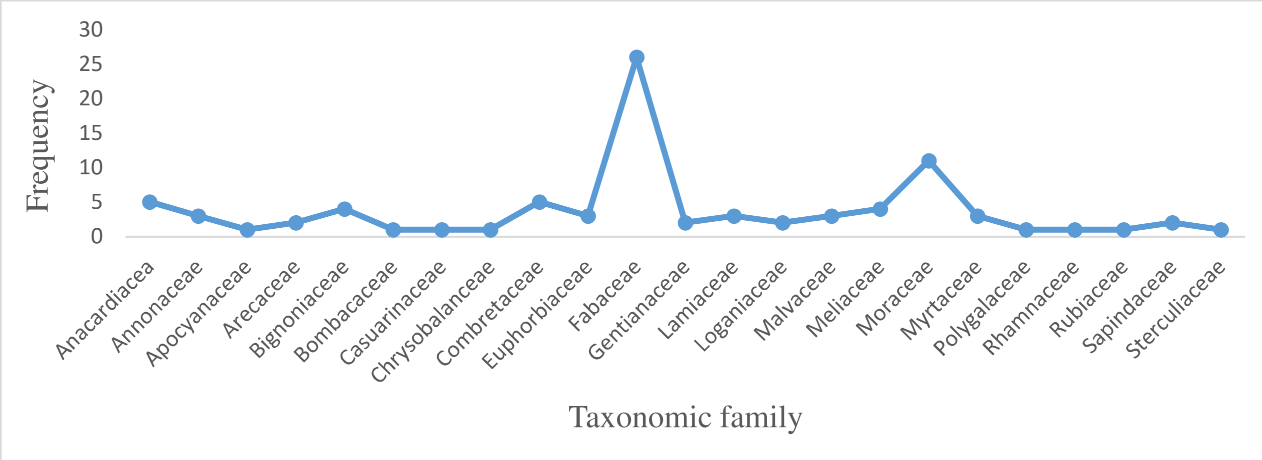

Fig. 2: Taxonomic families of trees in Ilorin metropolis

The Shannon-Wiener's diversity index was higher than some urban cities in Nigeria such as Abuja, Minna and Port Harcourt (Agbelade *et al.*, 2016; Agbelade and Onyekwelu, 2020). Based on Magurran's (2004) classification, Shannon-Wiener's diversity index could be classified as low diversity (0–2), moderate diversity (2–3), and high diversity (>3). The study area, therefore, could be classified as one with a high diversity of tree species. For Simpson's diversity, it ranges from 0 to 1 (Nguyen, 2017). The index in the study was close to 1, showing high species diversity.

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

Tree species diversity holds significant ecological implications. It enhances ecosystem resilience, mitigating risks of disease and pests, as diverse species exhibit varying susceptibilities (Guyot *et al*., 2016). It also fosters nutrient cycling and soil health, supports wildlife habitats, offers varied food sources and shelter, promotes aesthetic value, and provides cultural significance and recreational opportunities (Larjavaara, 2008; Silva Pedro *et al*., 2015). However, threats like deforestation and climate change endanger this diversity, necessitating conservation efforts to sustain the multifaceted benefits of diverse tree ecosystems (Gomes *et al*., 2019). Following several studies (Iheyen *et al*., 2009; Ogwu *et al*., 2016; Moshood *et al*., 2023), Fabaceae was the dominant taxonomic family in the study area. This could be attributed to their seed dispersal mechanism because most family members are known to disperse their seed by wind (Ogwu *et al*., 2016).

Comparison of Simpson's and Shannon-Wiener's indices

Table 2 presents the summary statistics, association, and comparison between Simpson's and Shannon-Wiener's diversity indices in the study area. The result revealed that Simpson's had a mean of 0.00035, a standard error of mean of 0.00011 and a standard deviation of 0.00098. Conversely, Shannon-Wiener's had a mean of 0.045, a standard error of mean of 0.0045 and a standard deviation of 0.041. The result showed a high positive correlation ($r = 0.83$) between the two indices, and the t-test showed a significant relationship ($p< 0.05$) (Table 2 and Figure 3).

Table 2: Statistics, correlation, and association between Simpson's and Shannon-Weinner's diversity indices

Diversity index	N	Mean	Std. Error mean	Std. Dev.	r	t	Sig.
Simpson	86	0.00035	0.00011	0.00098	0.83	10.189	0.000
Shannon-Wiener	86	0.045	0.0045	0.041			

The findings indicate that the two indices are suitable for tree species diversity assessment in Ilorin metropolis. However, Simpson's is more suitable because its lower standard error of mean indicates less variability or dispersion of data points from the mean value. The finding agrees with Kumar *et al*. (2022) that Simpson's index is more appropriate for determining species diversity in Mahavir Swami Wildlife Sanctuary, India. Conversely, Saka *et al*. (2020) found Shannon-Wiener's index more suitable for bird species diversity measurement in Bodel forest of Gashaka Gumti National Park.

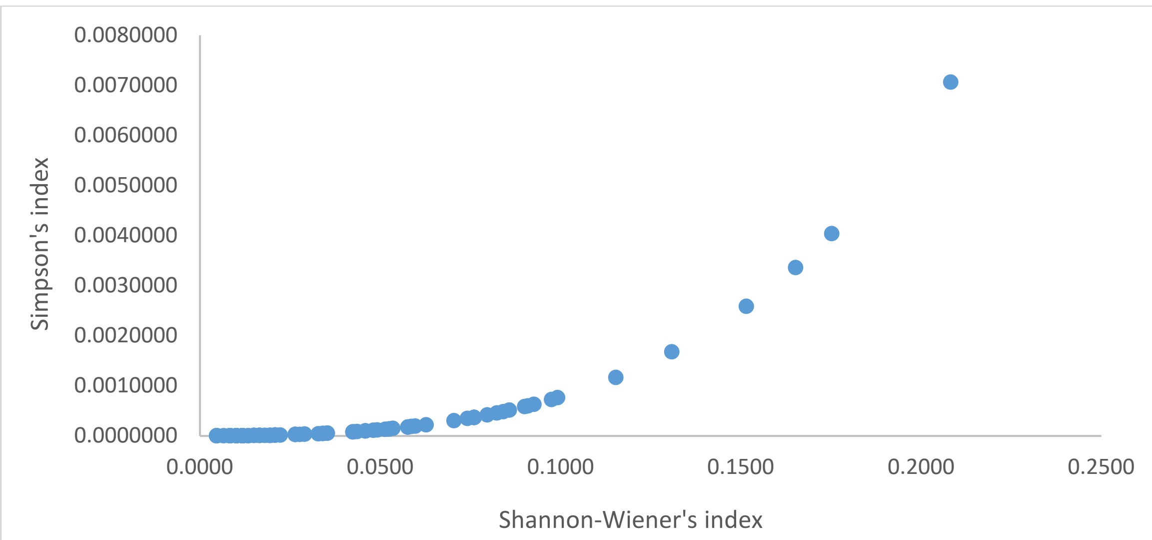

Fig. 3: Correlation analysis of Simpson's and Shannon-Wiener's Indices for tree species diversity in Ilorin metropolis

The highly positive correlation between the two indices indicates that they move in similar directions, reinforcing each other's conclusion regarding species diversity in the study area. The significant relationship shown by the t-test ($p<0.05$) further emphasizes the reliability of the comparison. This suggests that both indices effectively capture and reflect the underlying patterns of species diversity within Ilorin Metropolis.

Conclusion

The study shows that the study area (Ilorin metropolis) is rich in tree species, evidenced by the high species diversity index from the two indices compared. The two diversity indices are suitable for assessing tree species diversity in the study area, but Simpson's diversity is more suitable. The existence of a discrepancy between diversity measures emphasizes the importance of employing a variety of indices to provide a comprehensive and precise depiction of species diversity. The findings of this study hold implications for urban planning, biodiversity conservation, and ecosystem management in the Ilorin Metropolis and other similar urban areas worldwide. Therefore, future research works should explore additional indices and incorporate long-term monitoring efforts to track changes in urban tree diversity over time.

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