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Article

Diversity indices and structural metrics of wild fruit tree communities in Zuru Local Government Area, Kebbi State, Nigeria

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Abstract
This study assessed the ecological diversity and structural characteristics of wild fruit tree species across six districts of Zuru Local Government Area. A systematic line transect design was used, comprising 18 plots (200 m × 200 m) subdivided into four quadrats (100 m × 100 m), covering a total area of 72 ha. All trees with diameter at breast height (DBH) ≥ 5 cm were identified and measured. A total of 3,438 individual trees belonging to 43 species were recorded. Mean DBH ranged from 9.42 ± 2.72 cm in Guiera senegalensis to 74.45 ± 8.60 cm in Parkia biglobosa, while mean height ranged from 3.70 ± 0.65 m to 14.28 ± 0.74 m, indicating substantial structural variability. Significant differences in DBH and height occurred among districts (Kruskal–Wallis, $p < 0.001$), with Manga recording the highest mean DBH (46.36 cm) and Dabai the lowest (24.15 cm). The Shannon–Wiener diversity index (H') ranged from 1.22 in Ushe to 2.37 in Manga, indicating generally low to moderate species diversity. Simpson's diversity index (1 − D) ranged from 0.54 to 0.86, while Pielou's evenness (J') ranged from 0.49 to 0.75. Detarium microcarpum recorded the highest Importance Value Index (IVI = 63.59), dominating three districts. Universal flowering and fruiting observed during sampling reflected peak fruiting season conditions, while dormancy varied significantly among species across districts (χ^2, $p < 0.001$). The findings provide baseline ecological information for biodiversity conservation, sustainable utilization, and food security planning in semi-arid savannah ecosystems.

Keywords: *ecological diversity, wild fruit tree species, Shannon–Wiener index, DBH, Savannah woodland*

INTRODUCTION
Tree ecological diversity plays a fundamental role in sustaining ecosystem functioning and rural livelihoods, particularly in semi-arid regions where woody vegetation buffers climatic extremes and supports food security. Globally, recent assessments emphasize that forest and tree biodiversity underpin ecosystem resilience, carbon sequestration, soil stabilization and hydrological regulation, especially under increasing climate variability [1,2]. In dryland landscapes, tree diversity is closely linked to ecosystem multifunctionality, influencing productivity, nutrient cycling and carbon storage [3]. Maintaining diverse tree assemblages is therefore critical for ecological stability and human well-being in climate-sensitive environments.

The Sudan–Sahelian zone of West Africa is characterized by seasonal rainfall, recurrent droughts and heterogeneous topography, conditions that shape woody vegetation structure and composition. Recent studies across West African drylands report that tree species richness and structural diversity vary significantly with land-use intensity, soil conditions and anthropogenic disturbance [4]. Despite environmental constraints, semi-arid savannah systems often harbor considerable woody species diversity, reflecting adaptive strategies to water limitation and seasonal stress [5]. However, agricultural expansion, fuelwood harvesting and climate change are increasingly altering species composition and reducing ecological heterogeneity in these landscapes [6].

Within these ecosystems, wild fruit trees constitute an ecologically and socio-economically important component of woody diversity. They contribute to dietary diversification, income generation and traditional medicine, while also supporting pollinators and maintaining habitat structure [7,8]. Their ecological importance extends beyond subsistence value, as species with high structural dominance often influence stand dynamics, basal area distribution and carbon stocks. Quantitative assessment of ecological diversity using indices such as the Shannon–Wiener and Simpson measures remains essential for understanding patterns of richness, evenness and dominance in such systems [9]. These metrics provide insight into ecosystem stability and can guide conservation and sustainable management strategies.

Therefore, this study aims to evaluate the ecological diversity of tree species in Zuru Local Government Area of Kebbi State, Nigeria, by assessing species richness, diversity indices, structural attributes (diameter at breast height and height), and spatial variation across districts. The findings are intended to provide baseline ecological data to support biodiversity conservation and sustainable utilization of woody plant resources in semi-arid West African ecosystems.

MATERIALS AND METHODS

Studied area

Zuru LGA (11.4350°N, 5.2338°E) is located in the southeastern part of Kebbi State, northwestern Nigeria (Fig. 1). The area lies within the Sudan–Sahelian ecological zone and is characterized by heterogeneous topography comprising hills, valleys, and plateaus [10, 11]. Zuru LGA experiences a semi-arid climate marked by a distinct wet season (May ÷ September) and a dry season (October ÷ April), with mean annual rainfall of approximately 900÷1,100 mm. Vegetation is dominated by Guinea–Sudan savannah woodlands interspersed with cultivated and fallow lands. The region's soils, rainfall variability, and land-use patterns collectively influence the distribution, composition, and structural characteristics of woody plant species. Its position within a transitional savannah landscape makes it ecologically significant for assessing tree species diversity and structural variation in semi-arid West African environments. Zuru Local Government Area is predominantly inhabited by rural agrarian communities, mainly the Dakarkari, Fulani, and Hausa ethnic groups, with Zuru town serving as the major commercial centre. The area supports diverse savanna fauna, including small mammals, birds, reptiles, and domesticated livestock such as cattle, goats, and sheep. Agriculture is the principal occupation, with farmers cultivating crops such as millet, sorghum, maize, cowpea, rice, groundnut, and sesame under rain-fed conditions. Small-scale agro-processing activities, local trading, weaving, pottery, and livestock rearing also contribute to the local economy. Major water sources include rivers, streams, ponds, boreholes, and hand-dug wells, although seasonal water scarcity occurs during prolonged dry periods [12].

The study was conducted across six administrative districts of Zuru LGA: Dabai, Rikoto, Rafin Zuru, Manga, Ushe, and Senchi. These districts span the full latitudinal and land-use gradient of the LGA and were selected to ensure representative coverage of the ecological conditions within the study area.

Tree sampling design and plot layout

A systematic line transect sampling method was employed following the approach described by Bolaji *et al.* [4]. In each district, three line transects were established at 1-kilometre intervals. On each transect, one main sampling plot of 200 m × 200 m (4 ha) was demarcated. Each main plot was subdivided into four contiguous quadrats of 100 m × 100 m (1 ha each), yielding four sampling units per plot. This hierarchical design resulted in 3 plots × 4 quadrats = 12 quadrats per district, and a total of 18 plots (72 quadrats) covering 72 hectares across all six districts (data presented in Table 1). All trees with a diameter at breast height (DBH) ≥ 5 cm encountered within each quadrat were recorded, measured, and identified to species level.

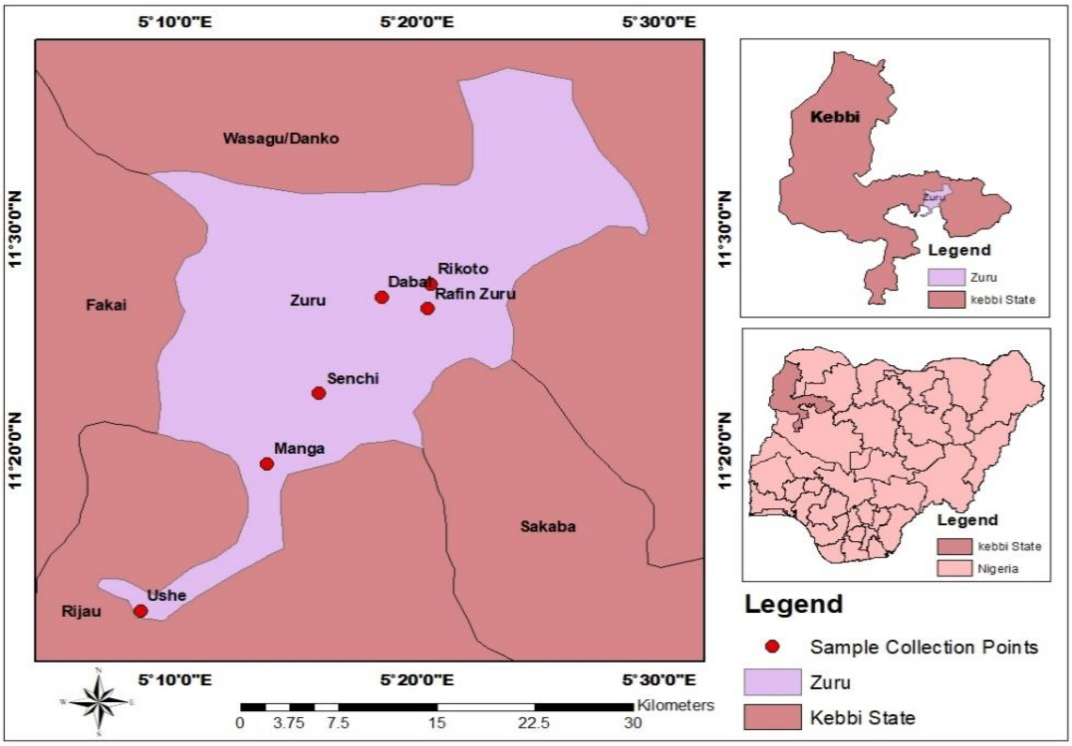

Fig. 1. Map of Zuru local government showing the six districts

Measurement of tree structural attributes

The diameter at breast height (DBH) of each recorded tree was measured at 1.3 m above ground level using a calibrated diameter tape, following standard forestry procedures. On sloped terrain, measurements were taken on the uphill side of the tree. For buttressed trees, DBH was measured immediately above the buttress formation. Forked stems originating below breast height were treated as separate individuals and recorded accordingly. All measurements were recorded to the nearest 0.1 cm.

Tree height was measured using a clinometer and measuring tape, or estimated using the tangent method for tall trees. The basal area (BA) of each individual tree was calculated from DBH as:

$$BA = (\pi /4) \times (DBH)^2 \quad (1)$$

where BA is expressed in m² and DBH is in meters. Total basal area per species per district was obtained by summing the individual basal areas of all stems of that species within the district.

Tree species classification and diversity indices

All tree species encountered within the sampling plots were identified to species level using field guides and voucher specimens where necessary. Scientific nomenclature followed the Flora of West Tropical Africa and current taxonomic databases. Species were classified by family, and the number of species per family was recorded for diversity classification purposes. Both local (Hausa/Dakarkari) and botanical names were documented to facilitate ethnobotanical cross-referencing.

Computation of ecological diversity metrics

The following ecological parameters were computed for each species in each district, following standard vegetation analysis procedures [14,13]:

(i) Density and relative density

Density (D) was calculated as the total number of individuals of a species per unit area:

$$D = N / A \quad (2)$$

where *N* is the total number of individuals of the species and *A* is the total survey area in hectares (12 ha per district). Relative density (RD%) expresses the density of a species as a proportion of the total density of all species:

$$RD\ (\%) = (D_i / \Sigma D) \times 100 \quad (3)$$

where D_i is the density of species i and ΣD is the sum of densities of all species.

(ii) Frequency and relative frequency

Frequency (F%) was calculated as the proportion of quadrats in which a species was present:

$$F (\%) = (Q_i / Q_t) \times 100 \quad (4)$$

where Q_i is the number of quadrats in which species i was recorded and Q_t is the total number of quadrats sampled per district ($Q_t = 12$). Relative frequency (RF%) was computed as:

$$RF (\%) = (F_i / \Sigma F) \times 100 \quad (5)$$

where ΣF is the sum of frequency values for all species.

(iii) Abundance

Abundance (Ab) was calculated as the mean number of individuals of a species per quadrat in which it was present:

$$Ab = N_i / Q_i \quad (6)$$

where N_i is the total number of individuals of species i and Q_i is the number of quadrats in which the species occurred.

(iv) Dominance and relative dominance

Dominance was expressed as the basal area per unit area (m^2/ha). Relative dominance (RDom%) was computed as:

$$RDom (\%) = (BA_i / \Sigma BA) \times 100 \quad (7)$$

where BA_i is the total basal area of species i and ΣBA is the total basal area of all species recorded in the district.

(v) Importance Value Index (IVI)

The Importance Value Index (IVI) integrates the relative ecological contribution of each species and was calculated as:

$$IVI = RD (\%) + RF (\%) + RDom (\%) \quad (8)$$

IVI ranges from 0 to 300. Species with higher IVI values contribute more to the overall structure, composition, and dominance of the plant community [13].

Species diversity indices

(i) Shannon–Wiener Diversity Index (H')

The Shannon–Wiener diversity index was used to quantify species diversity, incorporating both species richness and the evenness of individual distribution among species:

$$H' = -\Sigma (p_i \times \ln p_i) \quad (9)$$

where p_i is the proportion of individuals belonging to species i (i.e., $p_i = n_i / N$), n_i is the number of individuals of species i, and N is the total number of individuals across all species in the district. Higher H′ values indicate greater species diversity. Values were interpreted using widely applied classification thresholds for tropical and savannah woodland communities [14]: $H' < 2.0$ = low diversity; $2.0 \leq H' \leq 4.0$ = moderate diversity; $H' > 4.0$ = high diversity.

(ii) Simpson's Diversity Index (1 − D)

Simpson's index measures the probability that two randomly selected individuals belong to different species. The complement form (1 − D) was used, where higher values indicate greater diversity and lower dominance:

$$1 - D = 1 - [\Sigma n(n-1) / N(N-1)] \quad (10)$$

where n is the number of individuals of each species and N is the total number of individuals. Values range from 0 (no diversity) to 1 (maximum diversity).

(iii) Pielou's Evenness Index (J')

Species evenness was assessed using Pielou's evenness index (J′), which expresses the observed Shannon diversity relative to the maximum possible diversity:

$$J' = H' / \ln(S) \quad (11)$$

where S is the total number of species recorded (species richness). J′ ranges from 0 (complete dominance by one species) to 1 (perfectly even distribution).

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to test for significant differences in mean DBH and mean tree height among the six districts, using individual tree measurements as the unit of analysis. Prior to ANOVA, Levene's test was applied to assess homogeneity of variances. Where the assumption of homogeneity was violated ($p < 0.05$), the non-parametric Kruskal–Wallis test was used as the primary test for between-district differences in DBH and height, given the expected heteroscedasticity associated with mixed species compositions across districts. Where significant differences were detected ($p < 0.05$), Tukey's Honest Significant Difference (HSD) post hoc test was used to identify which pairs of districts differed. District-level variation in Shannon–Wiener diversity (H′) was also examined using one-way ANOVA, with the three replicate plots per district as the sampling units (n = 3 per district), corroborated by the Kruskal–Wallis test. Chi-square (χ^2) tests were used to assess variation in phenological stages (dormancy) among species within each district. All statistical analyses were performed using SPSS version 26.0 (IBM, USA).

RESULTS AND DISCUSSION

Diameter at Breast Height and Height of Wild Fruit Tree Species

A total of 3,438 individual trees belonging to 43 species were recorded across the six districts of Zuru LGA. The mean diameter at breast height (DBH) of wild fruit tree species ranged from 9.42 ± 2.72 cm in *Guiera senegalensis* to 74.45 ± 8.60 cm in *Parkia biglobosa*, indicating wide structural variation across species. Similarly, mean tree height ranged from 3.70 ± 0.65 m in *Guiera senegalensis* to 14.28 ± 0.74 m in *Parkia biglobosa*. These extremes reflect the contrasting growth forms present in the community, from shrub-like multi-stemmed species to tall emergent canopy trees. Total basal area across all districts was 373.66 m², equivalent to a stand basal area of 5.19 m²/ha, which is consistent with values reported for Sudan–Sahelian savannah woodlands [4]. The full species-level structural data are presented in Table 1.

Table 1. Diameter at breast height (DBH) and height characteristics of wild fruit tree species in Zuru LGA

S/N	Species	N	Mean DBH ± SD (cm)	DBH Range (Mean−SD to Mean+SD, cm)	Mean Height ± SD (m)	Height Range (Mean−SD to Mean+SD, m)
1	*Acacia dealbata*	6	32.48 ± 1.02	31.46 ÷ 33.50	8.12 ± 0.78	7.34 ÷ 8.89
2	*Acacia sieberiana*	24	31.76 ± 6.85	24.91 ÷ 38.61	9.51 ± 1.31	8.20 ÷ 10.82
3	*Adansonia digitata*	61	35.55 ± 11.41	24.15 ÷ 46.96	7.30 ± 1.63	5.68 ÷ 8.93
4	*Anacardium occidentale*	23	46.80 ± 4.52	42.28 ÷ 51.32	6.99 ± 1.34	5.65 ÷ 8.33
5	*Annona senegalensis*	18	24.50 ± 3.49	21.01 ÷ 27.99	4.19 ± 0.86	3.33 ÷ 5.05
6	*Anogeissus leiocarpus*	6	39.65 ± 11.63	28.02 ÷ 51.28	7.73 ± 1.90	5.83 ÷ 9.63
7	*Azadirachta indica*	43	37.65 ± 10.44	27.21 ÷ 48.10	8.84 ± 1.59	7.25 ÷ 10.43
8	*Balanites aegyptiaca*	25	36.05 ± 9.61	26.44 ÷ 45.66	9.47 ± 1.24	8.23 ÷ 10.71
9	*Borassus aethiopum*	1	32.30	32.30	5.10	5.10
10	*Calotropis procera*	12	36.43 ± 3.01	33.43 ÷ 39.44	8.58 ± 1.46	7.11 ÷ 10.04
11	*Carica papaya*	1	25.30	25.30	10.80	10.80
12	*Cestrum aurantiacum*	178	32.66 ± 7.89	24.77 ÷ 40.56	8.20 ± 1.84	6.36 ÷ 10.04
13	*Citrus sinensis*	1	22.50	22.50	5.30	5.30
14	*Cocos nucifera*	60	38.90	38.90	5.30	5.30
15	*Daniellia oliveri*	29	24.41 ± 3.85	20.56 ÷ 28.25	10.98 ± 1.15	9.83 ÷ 12.12
16	*Detarium microcarpum*	890	40.45 ± 7.93	32.52 ÷ 48.38	8.46 ± 2.04	6.42 ÷ 10.51
17	*Diospyros mespiliformis*	339	35.15 ± 8.96	26.19 ÷ 44.12	8.29 ± 1.88	6.41 ÷ 10.18
18	*Euphorbia leucocephala*	130	45.85 ± 5.41	40.44 ÷ 51.25	8.56 ± 1.78	6.78 ÷ 10.34
19	*Ficus aurea*	10	35.74 ± 9.88	25.86 ÷ 45.62	8.69 ± 1.97	6.72 ÷ 10.66
20	*Ficus benghalensis*	1	29.00	29.00	6.80	6.80
21	*Ficus glumosa*	3	30.77 ± 7.71	23.06 ÷ 38.48	9.53 ± 0.35	9.18 ÷ 9.88
22	*Gardenia erubescens*	7	33.90	33.90	11.60	11.60
23	*Gardenia sokotensis*	1	32.00	32.00	7.90	7.90
24	*Gmelina arborea*	5	39.30 ± 13.08	26.22 ÷ 52.38	9.48 ± 1.74	7.74 ÷ 11.22
25	*Guiera senegalensis*	636	9.42 ± 2.72	6.70 ÷ 12.14	3.70 ± 0.65	3.05 ÷ 4.35
26	*Hura crepitans*	16	34.38 ± 9.40	24.98 ÷ 43.78	6.97 ± 1.43	5.54 ÷ 8.41

S/N	Species	N	Mean DBH ± SD (cm)	DBH Range (Mean−SD to Mean+SD, cm)	Mean Height ± SD (m)	Height Range (Mean−SD to Mean+SD, m)
27	*Hyphaene thebaica*	189	34.17 ± 8.33	25.84 ÷ 42.50	8.00 ± 2.65	5.35 ÷ 10.65
28	*Jatropha curcas*	28	32.59 ± 10.81	21.78 ÷ 43.39	6.67 ± 1.25	5.42 ÷ 7.93
29	*Lannea acida*	53	34.36 ± 9.05	25.32 ÷ 43.41	9.16 ± 2.12	7.05 ÷ 11.28
30	*Lannea coronandelica*	3	44.30	44.30	6.50	6.50
31	*Mangifera indica*	57	35.73 ± 7.61	28.12 ÷ 43.34	9.64 ± 1.99	7.65 ÷ 11.62
32	*Manihot esculenta*	6	37.13 ± 13.50	23.63 ÷ 50.63	10.42 ± 1.21	9.21 ÷ 11.63
33	*Moringa oleifera*	5	31.46 ± 13.09	18.37 ÷ 44.55	9.94 ± 1.86	8.08 ÷ 11.80
34	*Parkia biglobosa*	106	74.45 ± 8.60	65.85 ÷ 83.04	14.28 ± 0.74	13.54 ÷ 15.02
35	*Piliostigma thonningii*	237	36.01 ± 5.48	30.53 ÷ 41.50	8.55 ± 2.48	6.07 ÷ 11.02
36	*Psidium guajava*	26	35.68 ± 4.61	31.07 ÷ 40.29	8.36 ± 0.98	7.38 ÷ 9.34
37	*Quercus rugosa*	1	38.20	38.20	11.55	11.50
38	*Sterculia setigera*	4	39.23 ± 12.23	26.99 ÷ 51.46	7.55 ± 1.57	5.98 ÷ 9.12
39	*Tamarindus indica*	11	34.09 ± 8.62	25.47 ÷ 42.71	8.25 ± 1.64	6.61 ÷ 9.90
40	*Vitellaria paradoxa*	143	46.07 ± 8.60	37.46 ÷ 54.67	11.73 ± 1.89	9.84 ÷ 13.63
41	*Vitex doniana*	21	38.11 ± 7.50	30.61 ÷ 45.61	7.73 ± 1.75	5.99 ÷ 9.48
42	*Ximenia americana*	17	39.84 ± 8.74	31.09 ÷ 48.58	6.43 ± 1.72	4.71 ÷ 8.15
43	*Ziziphus mauritiana*	5	29.46 ± 11.45	18.01 ÷ 40.91	8.76 ± 1.70	7.06 ÷ 10.46
—	**Total / Overall Range**	**3,438**	**9.42 ÷ 74.45**	**6.70 ÷ 83.04**	**3.70 ÷ 14.28**	**3.05 ÷ 15.02**

Note: N = total number of individual trees recorded across all districts. Mean DBH and Mean Height calculated from all individual measurements per species. SD = standard deviation (sample, delta degrees of freedom (ddof=1). DBH Range and Height Range represent the interval Mean − SD to Mean + SD; for species with N = 1, SD = 0 and only the single measured value is shown. DBH measured at 1.3 m above ground level (threshold ≥ 5 cm). Species sorted alphabetically. Family classification follows Angiosperm Phylogeny Group (APG) IV.

The DBH range recorded (9.42–74.45 cm) reflects the structural heterogeneity of the wild fruit tree community in Zuru LGA. The exceptionally large girth of *Parkia biglobosa* (74.45 ± 8.60 cm) is consistent with its life form as a long-lived emergent tree widely protected by farming communities for its nutritional and economic value [15], while the small mean DBH of *Guiera senegalensis* (9.42 ± 2.72 cm) reflects its shrubby, pioneer growth habit in disturbed Sahelian landscapes [4]. The significant between-district variation (Kruskal–Wallis H = 1003.89, $p < 0.001$) was driven primarily by species composition: the low mean DBH in Dabai (24.15 cm) is explained by the numerical dominance of *G. senegalensis* (40.8% of individuals), while the highest mean DBH in Manga (46.36 cm) reflects the structural contribution of *P. biglobosa* (IVI = 81.64). The violation of variance homogeneity (Levene's test, $p < 0.001$) is itself ecologically informative, indicating unequal disturbance levels across districts, consistent with patterns reported for comparable savannah communities where land-use intensity selectively removes large-diameter trees [6, 3].

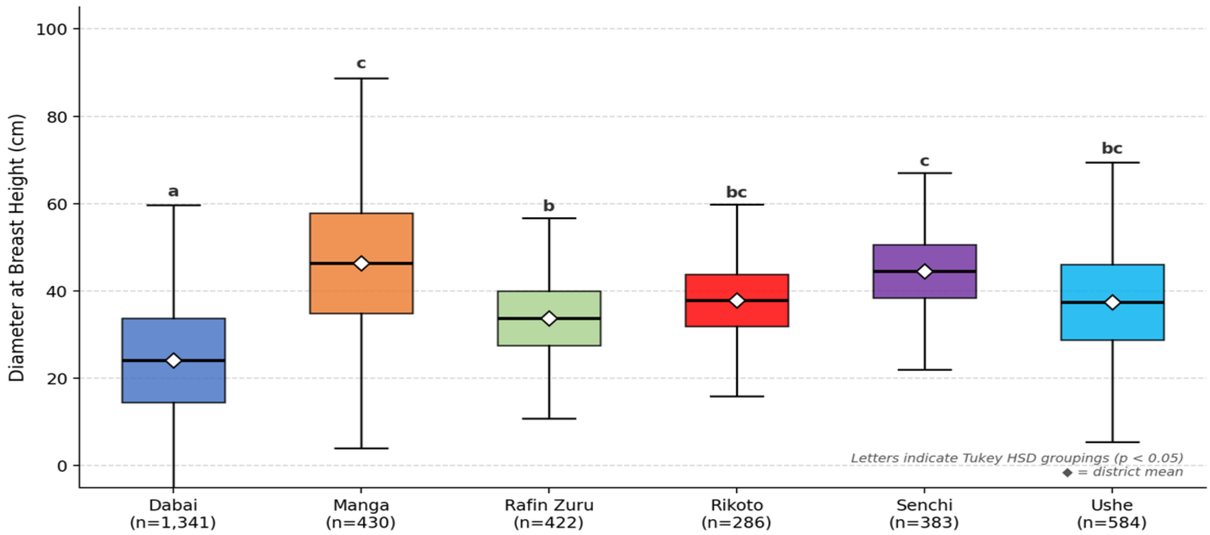

Fig. 2. DBH distribution of wild fruit tree species by district (ZURU LGA; n=3,438 trees, 43 species)

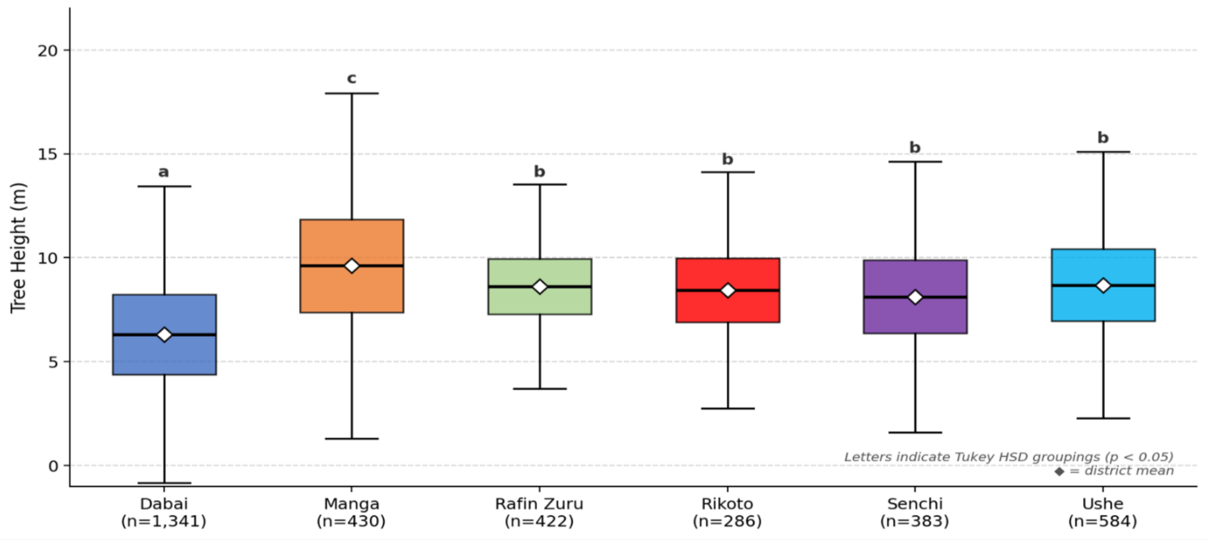

Fig. 3. Height distribution of wild fruit tree species by district (ZURU LGA; n=3,438 trees, 43 species)

Variation of DBH and Height Among Districts

A one-way ANOVA was conducted to compare the differences in diameter at breast height (DBH) and height among the six districts. Levene's test for homogeneity of variances indicated significant heteroscedasticity for both DBH ($F = 50.64$, $p < 0.001$) and height ($F = 28.84$, $p < 0.001$), against the assumption of standard ANOVA (Table 2).

Tukey HSD identified Manga (46.36 ± 16.94 cm) and Senchi (44.60 ± 9.01 cm) as having significantly larger mean DBH than Dabai (24.15 ± 14.20 cm), Rafin Zuru (33.78 ± 9.16 cm), Rikoto (37.86 ± 8.79 cm) and Ushe (37.48 ± 12.82 cm), which formed intermediate groups (Table 3). The exceptionally low mean DBH in Dabai is largely attributable to the numerical dominance of *Guiera senegalensis* (N = 547; mean DBH = 9.42 cm), a shrubby species that contributes 40.8% of all individuals in that district.

For tree height, Dabai consistently recorded the shortest trees (6.31 ± 2.86 m), differing significantly from all other districts. Manga recorded the tallest mean height (9.61 ± 3.32 m), differing significantly from Dabai, Senchi and the intermediate group comprising Rafin Zuru, Rikoto, and Ushe (8.12–8.69 m; Table 3). The structural dominance of *Parkia biglobosa* in Manga (IVI = 81.64; mean height = 14.28 m) likely contributes to the elevated canopy height observed in that district.

Table 2. ANOVA for DBH and Height by District

Variable	Source of Variation	SS	df	MS	F	p	Sig.
DBH (cm)	Between districts	249993.10	5	49998.62	297.72	< 0.001	*
	Within districts	577701.65	3440	167.94			
	Total	827694.75	3445				
Height (m)	Between districts	5312.74	5	1062.55	144.52	< 0.001	*
	Within districts	25292.49	3440	7.35			
	Total	30605.23	3445				
Levene — DBH	Homogeneity test				50.64	< 0.001	†
Levene — Ht	Homogeneity test				28.84	< 0.001	†

*Note: Sig. < 0.05 indicates significant differences among districts. SS = sum of squares, df = degrees of freedom, ms = mean square, f = F-statistic (F-value), p = Probability Value (p-value), sig = significance level, * Indicates statistical significance at p < 0.05, † marginally significant or approaching significance at p < 0.05.*

Table 3. Mean ± SD of DBH (cm) and Height (m) by District with Statistical Grouping (Tukey HSD)

District	N	DBH_cm (Mean ± SD)	Height_m (Mean ± SD)	BA/ha (m^2)
Dabai	1341	24.15 ± 14.20a	6.31 ± 2.86a	6.89
Manga	430	46.36 ± 16.94c	9.61 ± 3.32c	6.85
Rafin Zuru	422	33.78 ± 9.16b	8.62 ± 1.97b	3.38

District	N	DBH_cm (Mean ± SD)	Height_m (Mean ± SD)	BA/ha (m²)
Rikoto	286	37.86 ± 8.79bc	8.44 ± 2.27b	2.83
Senchi	383	44.60 ± 9.01c	8.12 ± 2.61b	5.19
Ushe	584	37.48 ± 12.82bc	8.69 ± 2.57b	6.00

Note: Values sharing the same letter within a column are not significantly different at $p < 0.05$ (Tukey HSD). BA/ha = stand basal area per hectare per district. n = number of individual trees. Mean ± SD calculated from descriptive statistics.

Ecological diversity of wild fruit tree species across districts

Species richness (S) ranged from 12 in Ushe to 28 in Dabai (Table 4). The Shannon–Wiener diversity index (H′) ranged from 1.22 in Ushe to 2.37 in Manga (Table 4). Using the classification thresholds of Magurran [14], Manga was the only district with moderate diversity (H′ = 2.37), while all remaining five districts recorded low diversity (H′ = 1.22–1.95). Ushe recorded the lowest diversity overall, reflecting the near-total dominance of *Detarium microcarpum*, which accounted for 66.3% of all individuals in that district.

Pielou's evenness index (J′) ranged from 0.49 (Ushe) to 0.75 (Manga), indicating moderate to poor evenness across districts, with communities generally dominated by a few abundant species rather than a uniform distribution of individuals. Simpson's diversity index (1 − D) ranged from 0.54 (Ushe) to 0.86 (Manga), corroborating the pattern of moderate dominance in most districts. (Table 4).

One-way ANOVA on plot-level H′ values (three replicate plots per district) revealed no statistically significant difference in Shannon diversity among districts ($F(5, 12) = 1.40$, $p = 0.291$), a result corroborated by the Kruskal–Wallis test ($H = 5.89$, $p = 0.317$). This suggests that despite variation in species composition among districts, the overall level of diversity — accounting for within-district variability — did not differ significantly at the district scale.

Table 4. Ecological diversity indices of wild fruit tree species across districts in Zuru LGA

District	Number of Species	Species Richness (S)	Shannon–Wiener Diversity Index (H′)	Simpson's Diversity Index (1 − D)	Evenness (J)	Diversity Class
Dabai	1341	28	1.83	0.74	0.55	Low
Manga	430	24	2.37	0.86	0.76	Moderate
Rafin Zuru	422	24	1.92	0.73	0.61	Low
Rikoto	286	17	1.95	0.80	0.69	Low
Senchi	383	17	1.83	0.77	0.65	Low
Ushe	584	12	1.22	0.55	0.49	Low

Note: J′ = Pielou's evenness (H′/ln S); Classification: H′ < 2.0 = Low; 2.0 ≤ H′ ≤ 4.0 = Moderate (Magurran, 2004).

Phenological stages of tree species across districts

All 3,438 sampled individuals across the six districts exhibited active flowering and fruiting at the time of survey, representing 100% occurrence of these stages in every district (Table 5). The proportion of individuals in the dormant stage varied considerably among districts, ranging from 70.9% in Manga to 97.9% in Rikoto. Ushe recorded 93.3% dormancy (545 of 584 individuals), while Senchi had the second-lowest dormancy rate at 85.1% (326 of 383).

Chi-square analysis revealed significant variation in the distribution of the dormant stage among species within all six districts ($p < 0.001$ in all cases), indicating that dormancy is not uniformly distributed across species within any district (Table 5). The highest chi-square value was recorded in Dabai ($\chi^2 = 1341.0$, df = 27), reflecting the high species richness and the unequal dormancy patterns across 28 species. This significant within-district variation in dormancy, combined with 100% uniform flowering and fruiting, suggests that these phenological observations were made during the peak fruiting season of the Sudan–Sahelian zone, when reproductive activity is widespread but dormancy onset varies by species depending on their individual phenological calendars.

Shannon–Wiener diversity (H′ = 1.22÷2.37) indicates predominantly low to moderate diversity, consistent with values reported for semi-arid savannah woody plant communities in West Africa and the Horn of Africa where a few drought-tolerant species dominate [8,17]. Manga was the only district with moderate diversity (H′ = 2.37), likely reflecting lower agricultural pressure, while Ushe recorded the lowest diversity (H′ = 1.22), driven by the near-total dominance of *Detarium microcarpum* (66.3% of individuals; IVI = 164.32). Pielou's evenness (J′ = 0.49÷0.75) and Simpson's index (1 − D = 0.54÷0.86) corroborate the pattern of skewed abundance distributions characteristic of ecosystems under sustained anthropogenic disturbance [5, 9]. The non-significant plot-level ANOVA ($F(5, 12) = 1.40$, $p = 0.291$) indicates that within-district variability was comparable to between-district variability at the current replication level, underscoring the need for greater plot replication in future surveys [4].

Table 5. Phenological stages of tree species across districts

District	Total Individuals	Flowering (n, %)	Fruiting (n, %)	Dormant Individuals (n, %)	Non-dormant Individuals (n, %)	χ^2 (*df*)	Sig.	*p*
Dabai	1341	1341	1341 (100.0)	1341 (100.0)	1287 (96.0)	54 (4.0)	1341.0	< 0.001
Manga	430	430	430 (100.0)	430 (100.0)	305 (70.9)	125 (29.1)	430.0	< 0.001
Rafin Zuru	422	422	422 (100.0)	422 (100.0)	410 (97.2)	12 (2.8)	422.0	< 0.001
Rikoto	286	286	286 (100.0)	286 (100.0)	280 (97.9)	6 (2.1)	286.0	< 0.001
Senchi	383	383	383 (100.0)	383 (100.0)	326 (85.1)	57 (14.9)	383.0	< 0.001
Ushe	584	584	584 (100.0)	584 (100.0)	545 (93.3)	39 (6.7)	584.0	< 0.001

Note: All values expressed as n (%). χ^2 = chi-square statistic for variation in dormancy among species within each district; df = number of species − 1. All $p < 0.001$, indicating significant within-district variation in dormancy stage among species. Survey was conducted during the fruiting season; 100% flowering and fruiting therefore reflects seasonal timing rather than universal simultaneous phenology. sig = significance level.

Universal flowering and fruiting (100% across all 3,438 individuals) confirm that the survey was conducted during peak fruiting season, a finding significant for food security planning as it demonstrates the potential for simultaneous community-wide harvesting (Duguma, 2020). Significant within-district variation in dormancy ($\chi^2 = 286÷1341$, $p < 0.001$ in all districts) confirms species-specific phenological strategies rather than synchronized dormancy, consistent with the staggered fruiting calendars documented in Ethiopian and Ugandan savannah communities that extend the period of fruit availability for rural populations [8,16]. These phenological data were collected at a single time point; longitudinal monitoring across seasons is required to fully characterize inter-annual variability in fruiting synchrony [17].

Importance Value Index (IVI) of wild fruit tree species

Parkia Detarium microcarpum recorded the highest overall IVI (63.59) across all districts combined, driven by high relative density (25.83%) and relative dominance (31.78%). *Diospyros mespiliformis* ranked second (IVI = 30.08), with the widest frequency distribution (F = 55.56%), indicating its presence in more than half of all sampling quadrats. *Guiera senegalensis* ranked third (IVI = 23.82), its prominence attributable to high density (8.83 ind./ha) despite a low relative dominance (1.29%) owing to its small stem size. *Vitellaria paradoxa* had the highest frequency of all species (58.33%), making it the most widely distributed species across the study area, yet it ranked fourth (IVI = 22.16) due to its relatively low density.

Parkia biglobosa ranked fifth overall (IVI = 18.58) but had by far the highest mean basal area per individual (74.45 cm DBH), contributing 12.51% of relative dominance from only 106 individuals. This pattern reflects the ecological role of *P. biglobosa* as a keystone structural species in Guinea–Sudan savannah systems [15]. At the district level, dominant species differed notably: *Detarium microcarpum* dominated Dabai (IVI = 84.85), Senchi (IVI = 81.14), and Ushe (IVI = 164.32); *Diospyros mespiliformis* dominated Rafin Zuru (IVI = 115.65); *Hyphaene thebaica* dominated Rikoto (IVI = 93.70); and *Parkia biglobosa* dominated Manga (IVI = 81.64). The exceptionally high IVI of *Detarium microcarpum* in Ushe (164.32 out of a maximum 300) signals an ecologically depauperate community with severe structural dominance by a single species. The IVI data for all 43 species are presented in Table 6.

Detarium microcarpum was the most ecologically important species overall (IVI = 63.59), dominant in three districts, with its persistence across the landscape likely reflecting deliberate farmer retention rather than purely natural regeneration [15]. District-level dominance shifted markedly: *Diospyros mespiliformis* led in Rafin Zuru (IVI = 115.65; frequency 91.7%), *Hyphaene thebaica* in Rikoto (IVI = 93.70; frequency 100%), and *Parkia biglobosa* in Manga (IVI = 81.64) despite low abundance, owing to its exceptional basal area contribution (RDom = 51.54%). The contrasting IVI drivers — frequency-driven (*Vitellaria paradoxa*, F = 58.33%) versus density-driven (*Guiera senegalensis*, D = 8.83 ind./ha) — have direct implications for conservation prioritisation, as frequency-dominant species are generally more resilient to localised disturbance [16]. The fact that 65.2% of species had IVI < 3.0 signals that the majority of wild fruit tree species are rare or locally restricted and potentially vulnerable to harvesting pressure or climate variability [1, 2].

The low to moderate species diversity observed across the districts of Zuru Local Government Area is largely attributable to sustained anthropogenic disturbances that favour a few stress-tolerant and economically valuable species while suppressing overall community heterogeneity [6, 5]. This is evident from the disproportionately high Importance Value Index (IVI) of *Detarium microcarpum* (63.82), which alone contributed 25.89% relative density and 31.89% relative dominance. Such dominance indicates that a limited number of species have become ecologically successful under prevailing disturbance regimes, thereby reducing species evenness and increasing floristic imbalance. The relatively low Shannon diversity values reported in several districts further support this interpretation, as healthy undisturbed savanna woodlands typically exhibit higher species richness and more equitable species distribution [18,19].

Several human-driven activities likely explain this pattern. Continuous fuelwood harvesting, charcoal production, agricultural expansion, overgrazing, selective logging, bush burning, and settlement development can progressively eliminate sensitive or slow-regenerating species while promoting disturbance-adapted taxa such as *Guiera senegalensis* and *Piliostigma thonningii*. In addition, economically important multipurpose species such as *Vitellaria paradoxa*, *Parkia biglobosa*, and *Detarium microcarpum* may be intentionally protected by local communities because of their nutritional, medicinal, and socioeconomic value, leading to uneven dominance patterns. Spatial variability among districts also suggests differing intensities of land-use pressure, edaphic conditions, and conservation practices [20, 21].

These findings imply that the savanna ecosystem of Zuru LGA may be undergoing ecological simplification and gradual loss of functional biodiversity. Reduced diversity can weaken ecosystem resilience, lower regeneration potential, diminish habitat quality for wildlife, and reduce long-term adaptability to climate variability and environmental stress. High single-species dominance may also increase vulnerability to disease outbreaks, invasive species, and ecological instability because ecosystem functioning becomes increasingly dependent on a narrow range of taxa. Furthermore, the rarity of several species with extremely low IVI values indicates possible localised decline or early stages of local extinction, highlighting the urgent need for conservation-oriented management, assisted regeneration, and sustainable harvesting strategies [22, 23]. Conservation strategies must be spatially differentiated by district: Ushe warrants priority attention given its ecological simplification (IVI of *D. microcarpum* = 164.32; only 12 species), while the presence of nutritionally critical species — *Vitellaria paradoxa* (shea), *Parkia biglobosa* (locust bean), *Tamarindus indica*, and *Adansonia digitata* — across multiple districts underscores the food security importance of these communities and the need to integrate their management into local land-use and agroforestry planning [8, 17, 1].

Table 6. IVI of wild fruit tree species in Zuru LGA (Combined across all six districts; 72 ha

Rank	Species	N	D (ind/ha)	F (%)	Ab	BA (m^2)	RD (%)	RF (%)	RDom (%)	IVI	IVI Rank
1	***Detarium microcarpum***	**890**	12.36	30.56	40.45	118.7514	25.89	6.04	31.89	**63.82**	**1**
2	***Diospyros mespiliformis***	**339**	4.71	55.56	8.47	35.0307	9.86	10.99	9.41	**30.26**	**2**
3	***Guiera senegalensis***	**636**	8.83	20.83	42.40	4.8017	18.50	4.12	1.29	**23.91**	**3**
4	*Vitellaria paradoxa*	143	1.99	58.33	3.40	24.6595	4.16	11.54	6.62	**22.32**	4
5	*Parkia biglobosa*	106	1.47	15.28	9.64	46.7521	3.08	3.02	12.55	**18.66**	5
6	*Hyphaene thebaica*	189	2.62	33.33	7.88	18.3575	5.50	6.59	4.93	**17.02**	6

Rank	Species	N	D (ind/ha)	F (%)	Ab	BA (m²)	RD (%)	RF (%)	RDom (%)	IVI	IVI Rank
7	*Piliostigma thonningii*	237	3.29	13.89	23.70	24.6971	6.89	2.78	6.63	**16.27**	7
8	*Cestrum aurantiacum*	178	2.47	23.61	10.47	15.7788	5.18	4.67	4.24	**14.08**	8
9	*Euphorbia leucocephala*	130	1.81	9.72	18.57	21.7561	3.78	1.92	5.84	**11.50**	9
10	*Lannea acida*	53	0.74	26.39	2.79	5.2499	1.54	5.22	1.41	**8.17**	10
11	*Adansonia digitata*	61	0.86	19.44	4.36	6.6696	1.79	3.85	1.79	**7.41**	11
12	*Azadirachta indica*	43	0.60	22.22	2.69	5.1480	1.25	4.40	1.38	**7.03**	12
13	*Mangifera indica*	57	0.79	15.28	5.18	5.9692	1.66	3.02	1.60	**6.28**	13
14	*Balanites aegyptiaca*	25	0.35	13.89	2.50	2.7256	0.73	2.75	0.73	**4.21**	14
15	*Vitex doniana*	21	0.29	13.89	2.10	2.4837	0.61	2.75	0.67	**4.03**	15
16	*Cocos nucifera*	60	0.83	1.39	60.00	7.1308	1.76	0.27	1.91	**3.94**	16
17	*Psidium guajava*	26	0.36	11.11	3.25	2.6414	0.75	2.20	0.71	**3.66**	17
18	*Anacardium occidentale*	23	0.33	6.94	4.60	3.9918	0.67	1.37	1.08	**3.11**	18
19	*Jatropha curcas*	28	0.39	6.94	5.60	2.5827	0.81	1.37	0.69	**2.88**	19
20	*Acacia sieberiana*	24	0.33	8.33	4.00	1.9859	0.70	1.65	0.53	**2.88**	20
21	*Tamarindus indica*	11	0.15	11.11	1.38	1.0624	0.33	2.20	0.29	**2.80**	21
22	*Ficus aurea*	10	0.14	11.11	1.25	1.0722	0.29	2.20	0.29	**2.75**	22
23	*Hura crepitans*	16	0.22	8.33	2.67	1.5896	0.47	1.65	0.43	**2.54**	23
24	*Daniellia oliveri*	29	0.40	5.56	7.25	1.3893	0.84	1.10	0.37	**2.32**	24
25	*Ximenia americana*	17	0.24	5.56	4.25	2.2148	0.49	1.10	0.59	**2.19**	25
26	*Annona senegalensis*	18	0.25	6.94	3.60	0.8648	0.52	1.37	0.23	**2.13**	26
27	*Calotropis procera*	12	0.17	5.56	3.00	1.2588	0.35	1.10	0.34	**1.77**	27
28	*Anogeissus leiocarpus*	6	0.08	6.94	1.20	0.7939	0.17	1.37	0.21	**1.75**	28
29	*Manihot esculenta*	6	0.08	5.56	1.50	0.7214	0.17	1.10	0.19	**1.47**	29
30	*Gmelina arborea*	5	0.07	4.17	1.67	0.6603	0.15	0.82	0.18	**1.15**	30
31	*Sterculia setigera*	4	0.06	4.17	1.33	0.5186	0.12	0.82	0.14	**1.07**	31
32	*Ficus glumosa*	3	0.04	4.17	1.00	0.2324	0.09	0.82	0.06	**0.97**	33
33	*Acacia dealbata*	6	0.08	2.78	3.00	0.4976	0.17	0.55	0.13	**0.85**	34
34	*Moringa oleifera*	5	0.07	2.78	2.50	0.4425	0.15	0.55	0.12	**0.81**	35
35	*Ziziphus mauritiana*	5	0.07	2.78	2.50	0.3820	0.15	0.54	0.10	**0.79**	36
36	*Gardenia erubescens*	7	0.10	1.39	7.00	0.6318	0.20	0.27	0.17	**0.65**	37
37	*Lannea coronandelica*	3	0.04	1.39	3.00	0.4624	0.09	0.27	0.12	**0.49**	38
38	*Quercus rugosa*	1	0.01	1.39	1.00	0.1146	0.03	0.27	0.03	**0.33**	40
39	*Gardenia sokotensis*	1	0.01	1.39	1.00	0.0804	0.03	0.27	0.02	**0.32**	42
40	*Borassus aethiopum*	1	0.01	1.39	1.00	0.0819	0.03	0.27	0.02	**0.32**	43
41	*Ficus benghalensis*	1	0.01	1.39	1.00	0.0661	0.03	0.27	0.02	**0.32**	44
42	*Citrus sinensis*	1	0.01	1.39	1.00	0.0398	0.03	0.27	0.01	**0.32**	45
43	*Carica papaya*	1	0.01	1.39	1.00	0.0503	0.03	0.27	0.01	**0.31**	46
—	**Total (43 species)**	**3438**	**47.75**	**100.00**	—	**372.3914**	**100.00**	**100.00**	**100.00**	**300.00**	**43 spp.**

Note: N = Total number; D = Density (individuals per hectare); F = Frequency of occurrence (% of 72 quadrats in which species was recorded); Ab = Abundance (mean individuals per quadrat of occurrence); BA = Total Basal Area (m²); RD = Relative Density (%); RF = Relative Frequency (%); RDom = Relative Dominance (% of total basal area); IVI = Importance Value Index = RD + RF + RDom (theoretical maximum = 300). Species sorted by IVI in descending order. Shading: orange = top 3 dominant species (IVI > 20); yellow = ranks 4–10; alternating white/blue = ranks 11–46. Survey design: 3 plots × 4 quadrats (100 × 100 m each) per district; 6 districts; 72 quadrats total (72 ha). DBH threshold ≥ 5 cm at 1.3 m above ground. Species names follow Plants of the World Online taxonomy.

CONCLUSIONS

This study provides the first systematic ecological assessment of wild fruit tree communities across all six districts of Zuru Local Government Area, Kebbi State, northwestern Nigeria. A total of 3,438 individual trees belonging to 43 species were recorded across 72 ha. Shannon–Wiener diversity was predominantly low to moderate (H′ = 1.22÷2.37), with five of six districts classified as low diversity, indicating that community structure is shaped primarily by a few dominant species rather than a balanced multi-species assemblage. Detarium microcarpum was the most ecologically important species overall, while district-level dominance varied substantially, with Diospyros mespiliformis, Hyphaene thebaica, and Parkia biglobosa each leading in their respective districts. The presence of nutritionally and commercially important species including Vitellaria paradoxa, Parkia biglobosa, Tamarindus indica, and Adansonia digitata underscores the food security significance of this community. Future research should extend sampling across multiple seasons, incorporate ethnobotanical data on harvesting pressure, and assess population size-class distributions to determine the regeneration status of the most ecologically important species.

AI Use Statement

We used an AI assistant to support sentence structure correction, improve grammar, and enhance clarity during manuscript preparation. All AI-generated suggestions were carefully reviewed, and all final editorial decisions were made by the authors. We confirm that the content, interpretations, and any remaining errors remain solely the responsibility of the authors.

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