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Mangrove Species Composition and Structural Characteristics Across Degradation and Restoration Statuses in Douala, Limbe And Tiko Sub-Divisions of Southwest Region-Cameroon

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ABSTRACT: Mangrove ecosystems provide critical ecological services, including shoreline stabilization, nursery habitat provision, biodiversity conservation and blue carbon storage; however, they remain increasingly threatened by degradation, land-use pressure and unevenly monitored restoration interventions. This study assessed the species composition and structural characteristics of mangrove stands across three degradation and restoration statuses in Douala, Limbe and Tiko, Cameroon. A total of nine 20 m x 20 m plots were surveyed, comprising one non-degraded, one naturally regenerated and one reforested mangrove plot in each municipality. All plant individuals were identified, counted and measured for diameter at breast height and height. Species abundance, family abundance, diversity indices, diameter and height class distributions, basal area, tree volume, importance value index, Sorenson similarity, non-metric multidimensional scaling and PERMANOVA were used to analyze compositional and structural patterns. A total of 3,428 plant individuals belonging to 20 species and 11 families were recorded. Avicennia germinans was the most abundant species, accounting for 1,863 individuals, followed by Laguncularia racemosa with 859 individuals and Rhizophora mangle with 403 individuals. Douala was dominated by A. germinans, Limbe by L. racemosa and Tiko by R. mangle. Naturally regenerated mangroves recorded the highest abundance, while non-degraded mangroves showed stronger structural maturity, particularly in height class distribution. Diameter structure followed a reverse J-shaped pattern, with 77.35% of individuals occurring in the <1 cm DBH class, indicating strong recruitment but limited representation of mature stems. The highest overall importance value index was recorded for A. germinans (91.06), followed by R. mangle (67.22) and L. racemosa (40.85). PERMANOVA showed that species composition differed significantly among sites ($p = 0.013$), but not among degradation-status categories ($p = 0.579$). The findings indicated that site-specific conditions influenced mangrove composition more strongly than broad degradation-status categories. Restoration planning should therefore prioritize local hydrology, species-site suitability, long-term monitoring and structural recovery rather than relying only on planting density or seedling abundance.

KEYWORDS: Mangroves; Species Composition; Stand Structure; Natural Regeneration; Reforestation; Avicennia Germinans; Cameroon

INTRODUCTION

Mangroves are highly productive intertidal forest ecosystems that occur along tropical and subtropical coastlines. They provide critical ecological and socio-economic services, including coastal protection, sediment stabilization, fish nursery support, biodiversity conservation, nutrient cycling and climate regulation through carbon storage (Alongi, 2020; Friess et al., 2019). Their ecological value is particularly high in low-lying coastal regions where communities depend on mangrove resources for fisheries, fuelwood, shoreline protection and livelihood support. Despite their importance, mangroves have continued to face widespread degradation caused by urban expansion, wood harvesting, aquaculture, pollution, coastal infrastructure, altered hydrology and climate-related stressors such as sea-level rise and extreme weather events (Goldberg et al., 2020; Murray et al., 2022). In many tropical coastal zones, mangrove restoration has been promoted as a response to degradation. However, restoration success has often been variable because many interventions emphasized planting without adequately considering hydrology, sediment dynamics, species-site matching and post-planting monitoring (Lee et al., 2019; Romañach et al., 2018).

In Cameroon, mangrove ecosystems form an important component of the Gulf of Guinea coastal landscape. They support fisheries, protect settlements and contribute to biodiversity conservation. However, mangroves around urbanizing coastal municipalities such as Douala, Limbe and Tiko are exposed to multiple pressures, including settlement expansion, resource extraction, waste disposal and hydrological disturbance. These pressures may alter species composition, regeneration patterns, stand structure and the ecological dominance of mangrove species. Assessing mangrove condition requires more than counting seedlings or planted individuals. A stand may be numerically dense but structurally immature if it is dominated by short individuals and small DBH classes. Conversely, a less dense stand may have better structural development if mature trees are well represented. Therefore, scientific assessment of mangrove recovery should combine abundance, diversity, DBH structure, height structure, basal area, ecological importance and multivariate compositional analyses. This study assessed the composition and structural characteristics of mangrove species across different degradation and restoration statuses in Douala, Limbe and Tiko, Cameroon. Specifically, it examined species and family abundance, diversity indices, DBH and height class distributions, forest structural metrics, species importance value index and compositional similarity among non-degraded, naturally regenerated and reforested mangrove stands.

MATERIALS AND METHODS

Study area

The study was conducted in mangrove ecosystems located within three coastal municipalities: Douala, Limbe and Tiko. These municipalities occur within the coastal zone of Cameroon and contain mangrove stands exposed to different levels of disturbance, natural regeneration and restoration intervention. The sampled sites represented non-degraded mangroves, naturally regenerated mangroves and reforested mangroves.

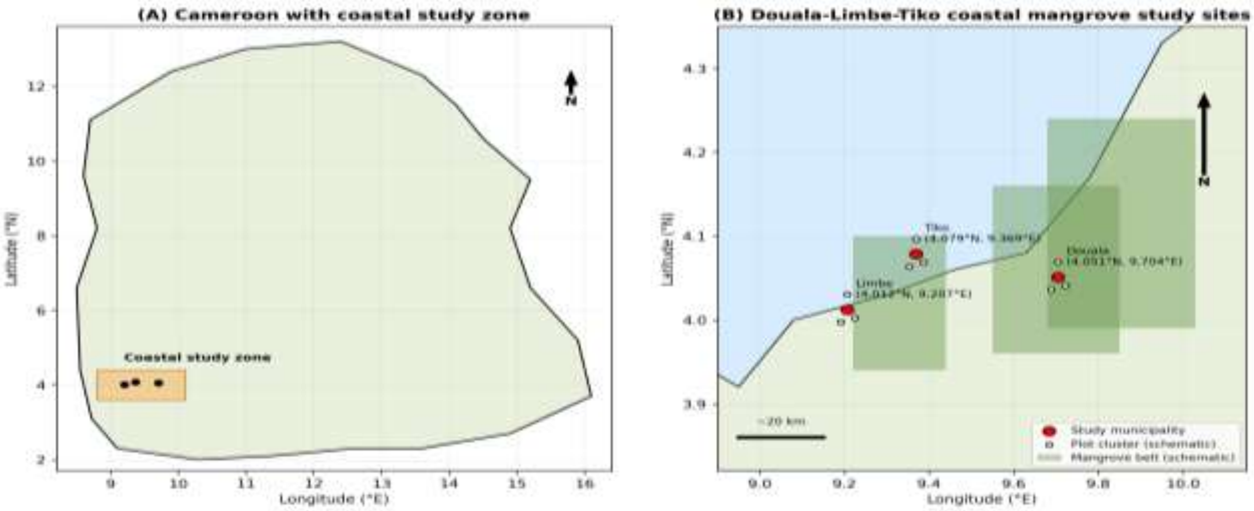

Figure 1. Study-area map showing the coastal study zone and the Douala-Limbe-Tiko mangrove study municipalities.

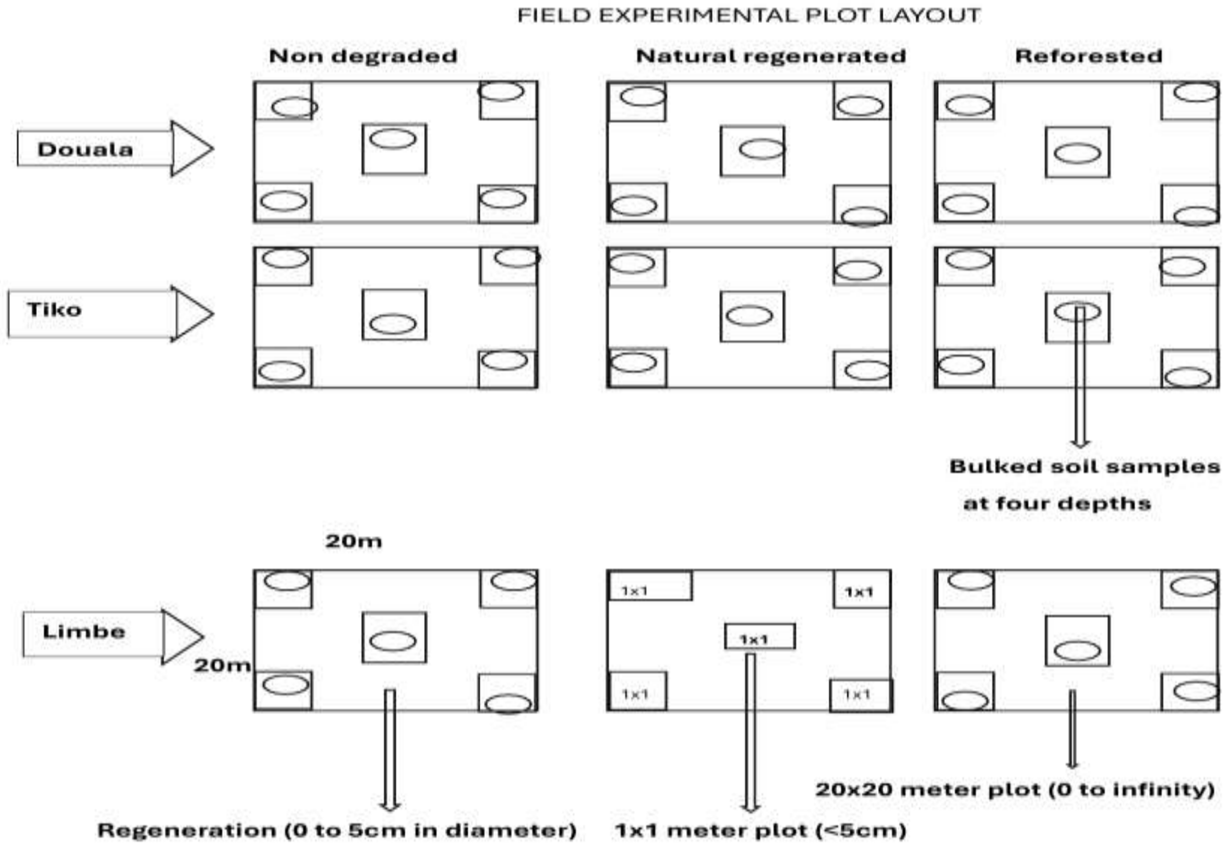

Figure 2. Original field experimental plot layout showing 20 m x 20 m plot arrangement, subplot structure and measurement zones.

Research design and sampling strategy

A field-based ecological survey design was used. Purposive sampling was applied to select mangrove sites where non-degraded, naturally regenerated and reforested stands were available and this was greatly constrained by its relatively scarcity and uneven distribution.

Reconnaissance surveys were first conducted to identify suitable sites, consult local authorities and verify accessibility. Local councils, forestry officials, community leaders, non-governmental organizations and other stakeholders were consulted before plot establishment. A total of nine plots measuring 20 m x 20 m were surveyed. Three plots were established in each municipality. Within each municipality, one plot represented a non-degraded mangrove stand, one represented a naturally regenerated stand and one represented a reforested stand. Plots were demarcated using ropes, tapes and PVC corner markers.

Reconnaissance with community members **Community engagement**

Figure 3. Reconnaissance and community consultation.

Vegetation data collection

Biophysical data were collected in March 2024. All plant individuals encountered within the plots were counted and identified. Species identification was conducted in the field with support from a botanist and relevant mangrove field guides. Unidentified juvenile specimens were collected, pressed, dried and taken for further herbarium verification. Diameter measurements were taken using calipers and diameter tapes, while plant height was measured using measuring tapes for smaller individuals and clinometers for taller individuals. For each recorded individual, the species name, family, site, mangrove-status category, DBH and height were entered into field data sheets.

Figure 4. Field images showing mangrove tagging, pilot measurement and structural field assessment

Data cleaning and standardization

Before analysis, the dataset was checked for completeness, consistency and correctness. Species names, family names, site names and mangrove-status categories were standardized. Unidentified records were excluded from species-level analyses where taxonomic identity was required. Records with missing DBH or height values were excluded only from analyses requiring those specific variables. For clarity in this article, mangrove-status categories were standardized as follows: ND = non-degraded, NR = naturally regenerated and RF = reforested.

Data analysis

Species composition was analyzed using abundance counts and relative abundance. Family abundance was calculated by summing individuals belonging to each family. Species diversity was assessed using species richness, Shannon diversity index, evenness, Margalef richness index and dominance index. Basal area was calculated as $BA = \pi \times (DBH / 200)^2$, where DBH was measured in centimeters and basal area was expressed in square meters. Tree volume was estimated from basal area and height. DBH classes were grouped as <1 cm, 1-2.5 cm, 2.6-5 cm, 5.1-10 cm and >10 cm. Height classes were grouped as <0.5 m, 0.5-1 m, 1.1-2 m, 2.1-5 m and >5 m.

The importance value index was calculated from relative density, relative frequency and relative dominance using the formula: IVI = Relative density + Relative frequency + Relative dominance. Sorenson similarity index was used to compare species compositional similarity among site-status combinations. Non-metric multidimensional scaling was performed using Bray-Curtis distance to visualize species compositional patterns. PERMANOVA was used to test whether species composition differed significantly among sites and mangrove-status categories. Statistical significance was assessed at $p < 0.05$.

RESULTS

Species abundance and composition

A total of 3,428 plant individuals belonging to 20 species and 11 families were recorded. Douala had the highest abundance with 1,744 individuals, representing 50.88% of the total abundance. Limbe recorded 1,244 individuals, representing 36.29%, while Tiko recorded 440 individuals, representing 12.84%. Across mangrove-status categories, naturally regenerated mangroves recorded the highest abundance with 2,448 individuals, representing 71.41% of all individuals. Reforested mangroves recorded 607 individuals, representing 17.71%, while non-degraded mangroves recorded 373 individuals, representing 10.88%.

Overall, the vegetation was strongly dominated by a few species. Avicennia germinans was the most abundant species, with 1,863 individuals, representing 54.35% of total abundance. This was followed by Laguncularia racemosa with 859 individuals, representing 25.06%, and Rhizophora mangle with 403 individuals, representing 11.76%. Together, A. germinans, L. racemosa, R. mangle, Rhizophora racemosa and Nypa fruticans accounted for 98.10% of all recorded individuals.

Table 1. Species abundance across study sites and mangrove-status categories.

Species	Family	Douala	Limbe	Tiko	ND	NR	RF	Total
Avicennia germinans	Acanthaceae	1508	205	150	57	1759	47	1863
Laguncularia racemosa	Combretaceae	0	859	0	42	454	363	859
Rhizophora mangle	Rhizophoraceae	129	8	266	201	81	121	403
Rhizophora racemosa	Rhizophoraceae	0	143	0	48	37	58	143
Nypa fruticans	Arecaceae	88	3	4	25	70	0	95
Conocarpus erectus	Combretaceae	0	26	0	0	26	0	26
Acrostichum aureum	Pteridaceae	13	0	12	0	12	13	25
Albergia sp.	Fabaceae	0	0	2	0	2	0	2
Cocos nucifera	Arecaceae	0	0	1	0	1	0	1
Combretum malabaricum	Combretaceae	0	0	1	0	1	0	1
Commelina diffusa	Commelinaceae	1	0	0	0	0	1	1
Cyperus brevifolius	Cyperaceae	0	0	1	0	1	0	1
Dumasia villosa	Fabaceae	1	0	0	0	1	0	1
Eichhornia crassipes	Pontederiaceae	1	0	0	0	0	1	1

Gnetum parvifolium	Gnetaceae	0	0	1	0	1	0	1
Leersia oryzoides	Poaceae	1	0	0	0	0	1	1
Mimosa pudica	Fabaceae	1	0	0	0	0	1	1
Palm tree	Arecaceae	0	0	1	0	1	0	1
Phoenix sp.	Arecaceae	0	0	1	0	1	0	1
Terminalia catappa	Combretaceae	1	0	0	0	0	1	1
Column total		1744	1244	440	373	2448	607	3428

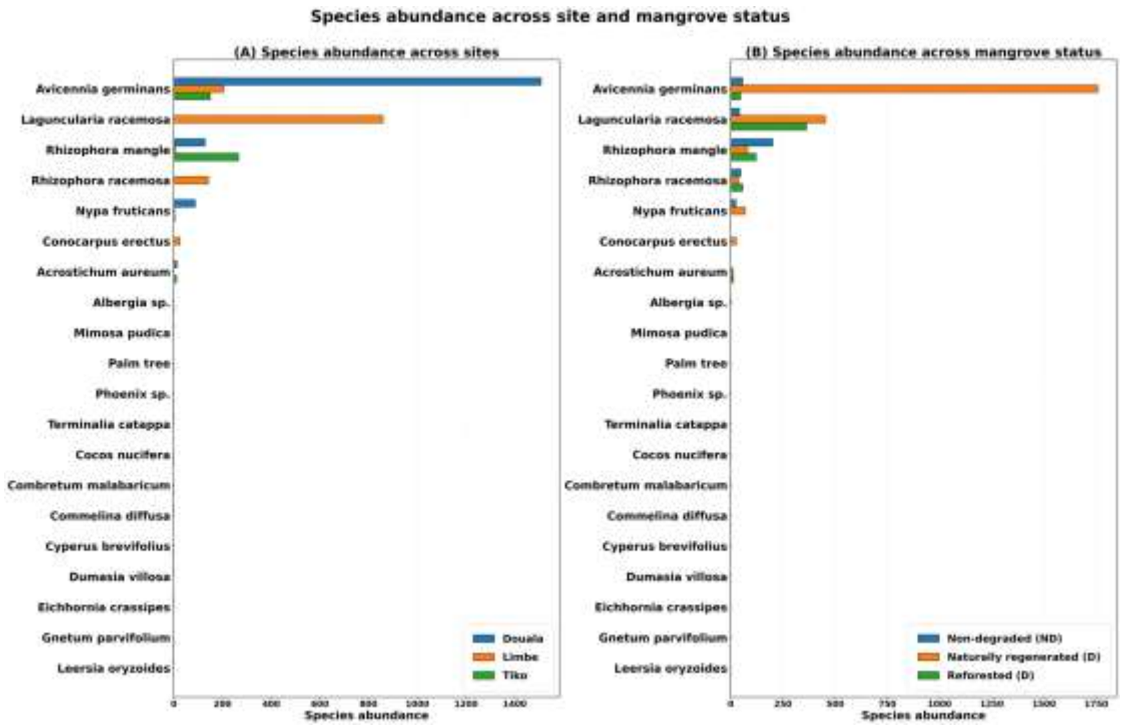

Figure 5. Species abundance distribution across study sites and mangrove-status categories.

Family composition

The dominant families were Acanthaceae, Combretaceae and Rhizophoraceae. Acanthaceae was the most abundant family, mainly because of the dominance of Avicennia germinans. It recorded 1,863 individuals, representing 54.35% of total abundance. Combretaceae followed with 887 individuals, representing 25.88%, largely due to Laguncularia racemosa. Rhizophoraceae recorded 546 individuals, representing 15.93%, mainly represented by Rhizophora mangle and Rhizophora racemosa.

Table 2. Family abundance across study sites and mangrove-status categories.

Family	Douala	Limbe	Tiko	ND	NR	RF	Total
Acanthaceae	1508	205	150	57	1759	47	1863
Combretaceae	1	885	1	42	481	364	887
Rhizophoraceae	129	151	266	249	118	179	546
Arecaceae	88	3	7	25	73	0	98
Pteridaceae	13	0	12	0	12	13	25
Fabaceae	2	0	2	0	3	1	4
Commelinaceae	1	0	0	0	0	1	1
Cyperaceae	0	0	1	0	1	0	1

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Gnetaceae	0	0	1	0	1	0	1
Poaceae	1	0	0	0	0	1	1
Pontederiaceae	1	0	0	0	0	1	1
Column total	1744	1244	440	373	2448	607	3428

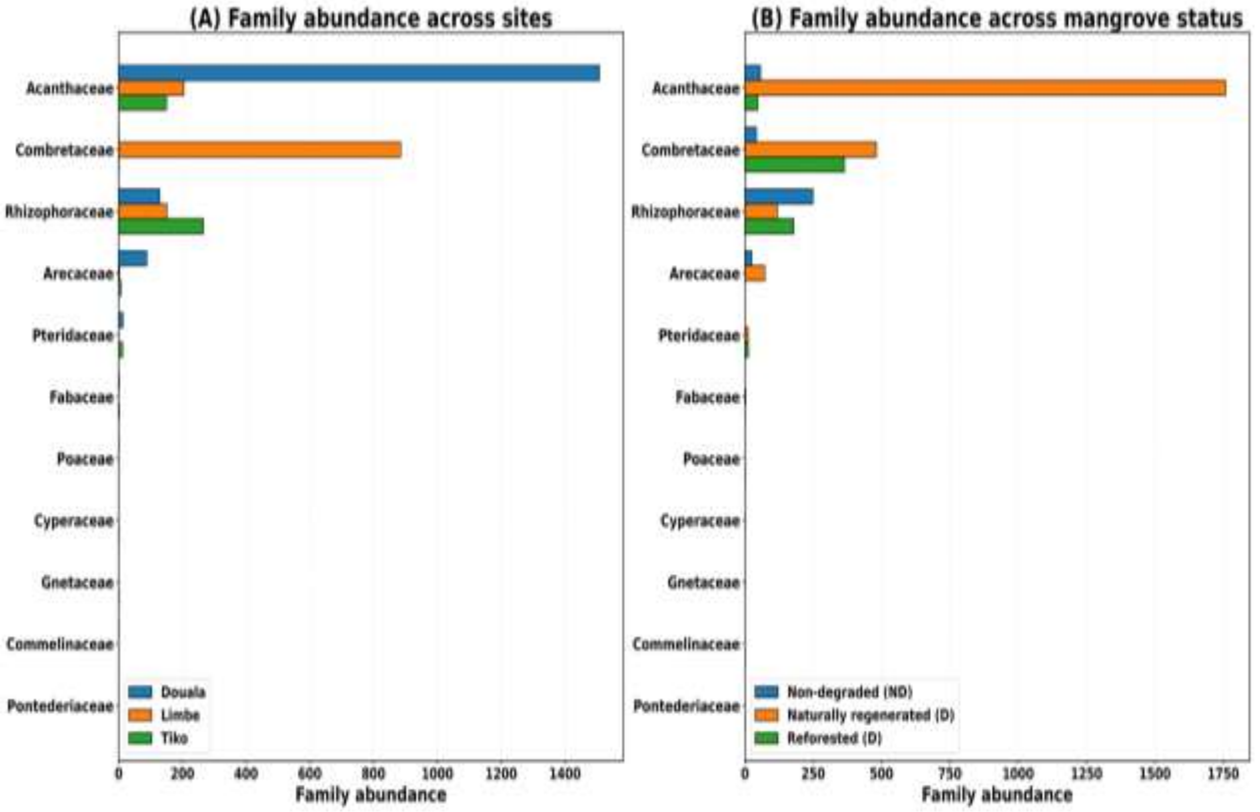

Figure 6. Family abundance distribution across study sites and mangrove-status categories.

Diversity indices

Diversity indices varied numerically across sites and mangrove-status categories, but no statistically significant differences were recorded. Douala had the highest mean abundance, species richness, Shannon diversity and Margalef richness index. Tiko recorded the highest dominance value, indicating stronger concentration of individuals in fewer species. Across mangrove-status categories, naturally regenerated mangroves had the highest mean abundance, species richness and Margalef richness. Non-degraded mangroves recorded the highest evenness and slightly higher Shannon diversity, while reforested mangroves had the highest dominance.

Table 3. Variation of mean (±SD) diversity indices across site and mangrove-status categories.

Scope	Category	Abundance N	Species richness	Shannon H′	Evenness J′	Margalef	Dominance D
Site	Douala	581.67 ± 825.64a	5.33 ± 3.21a	0.861 ± 0.471a	0.576 ± 0.346a	0.847 ± 0.735a	0.532 ± 0.278a
Site	Limbe	414.67 ± 309.11a	4.00 ± 1.00a	0.810 ± 0.322a	0.580 ± 0.170a	0.530 ± 0.174a	0.544 ± 0.183a
Site	Tiko	146.67 ± 65.43a	4.33 ± 4.93a	0.316 ± 0.456a	0.174 ± 0.183a	0.634 ± 0.935a	0.857 ± 0.209a
Status	Non-degraded (ND)	124.33 ± 43.04a	3.00 ± 1.00a	0.718 ± 0.527a	0.609 ± 0.402a	0.427 ± 0.228a	0.582 ± 0.324a
Status	Naturally regenerated (NR)	816.00 ± 675.74a	6.33 ± 3.21a	0.712 ± 0.337a	0.401 ± 0.184a	0.908 ± 0.700a	0.649 ± 0.191a
Status	Reforested (RF)	202.67 ± 192.72a	4.33 ± 4.16a	0.557 ± 0.624a	0.320 ± 0.289a	0.675 ± 0.899a	0.704 ± 0.323a

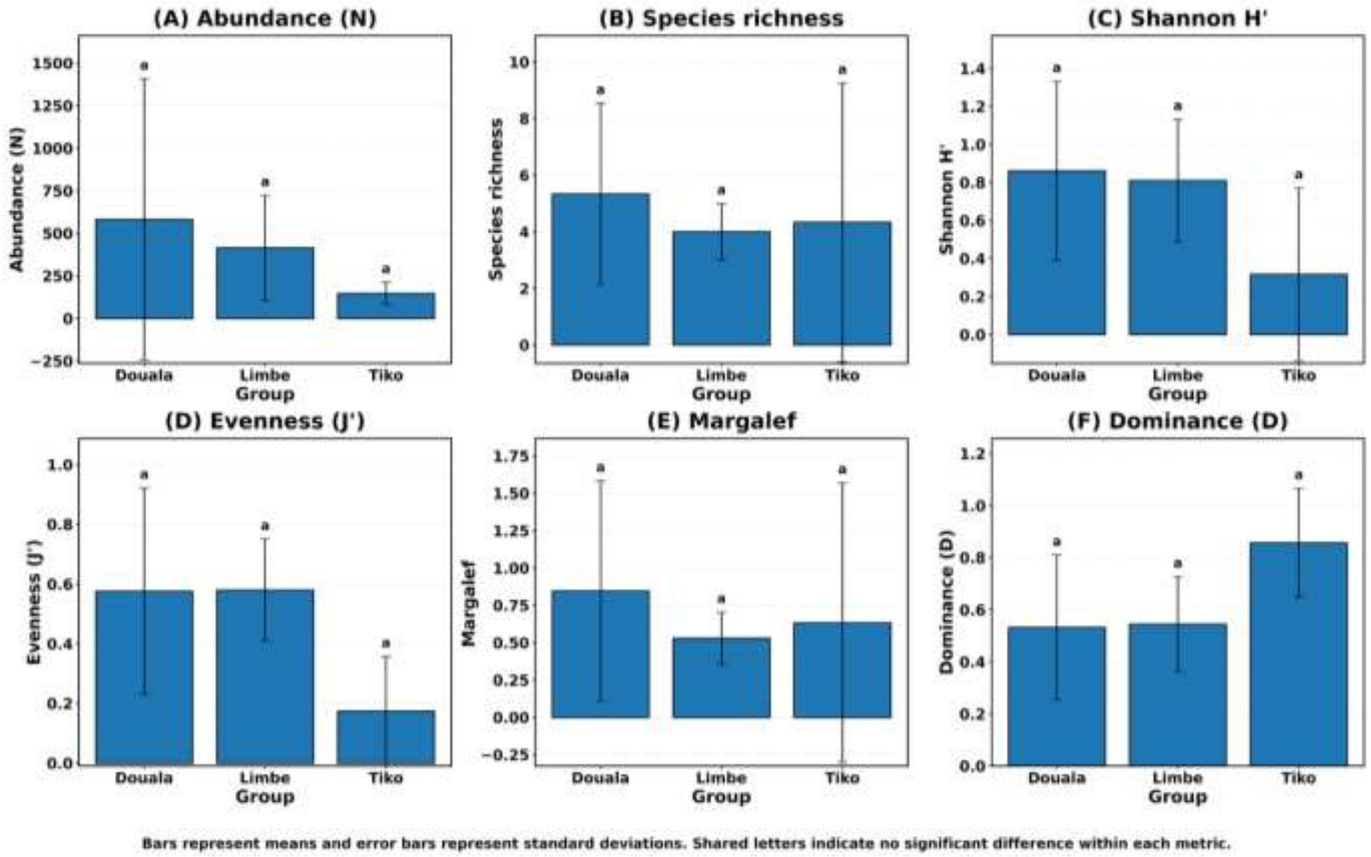

Figure 7. Variation of mean diversity indices across study sites.

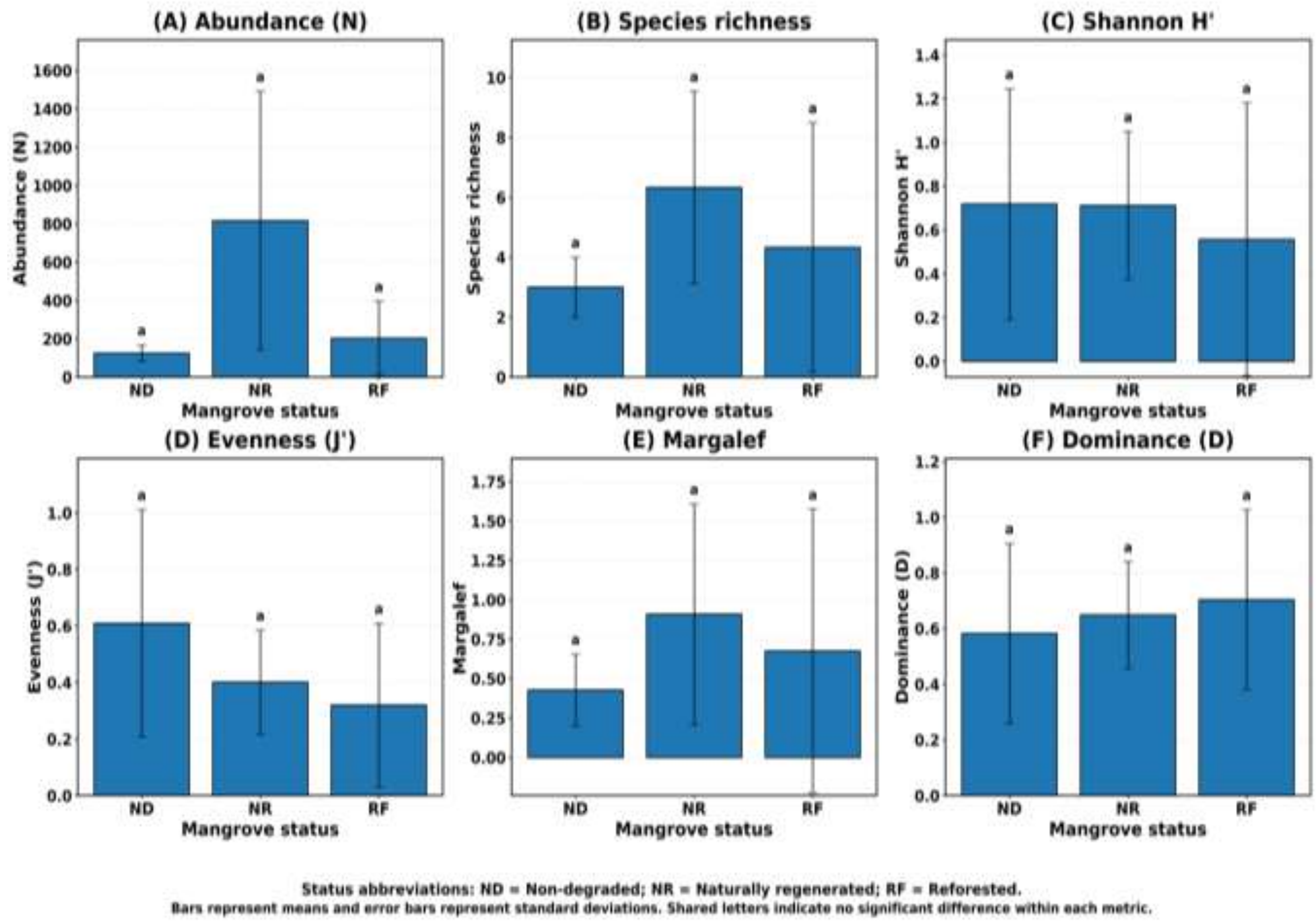

Figure 8. Variation of mean diversity indices across mangrove-status categories.

DBH and height class distributions

The DBH class distribution showed strong dominance of small-diameter individuals. Out of 3,413 individuals with recorded DBH values, 2,640 individuals, representing 77.35%, occurred in the <1 cm DBH class. The 1-2.5 cm class contained 451 individuals, representing 13.21%, while only 36 individuals, representing 1.05%, occurred in the >10 cm class. This pattern produced a clear reverse J-shaped distribution, especially in Douala, Limbe and naturally regenerated mangroves.

Table 4. Distribution of species abundance by DBH class across study site and mangrove status.

DBH class	Douala	Limbe	Tiko	ND	NR	RF	Total
<1 cm	1482	975	183	132	2176	332	2640
1-2.5 cm	152	142	157	136	134	181	451
2.6-5 cm	64	70	46	66	71	43	180
5.1-10 cm	28	49	29	25	43	38	106
>10 cm	10	8	18	11	16	9	36
Column total	1736	1244	433	370	2440	603	3413

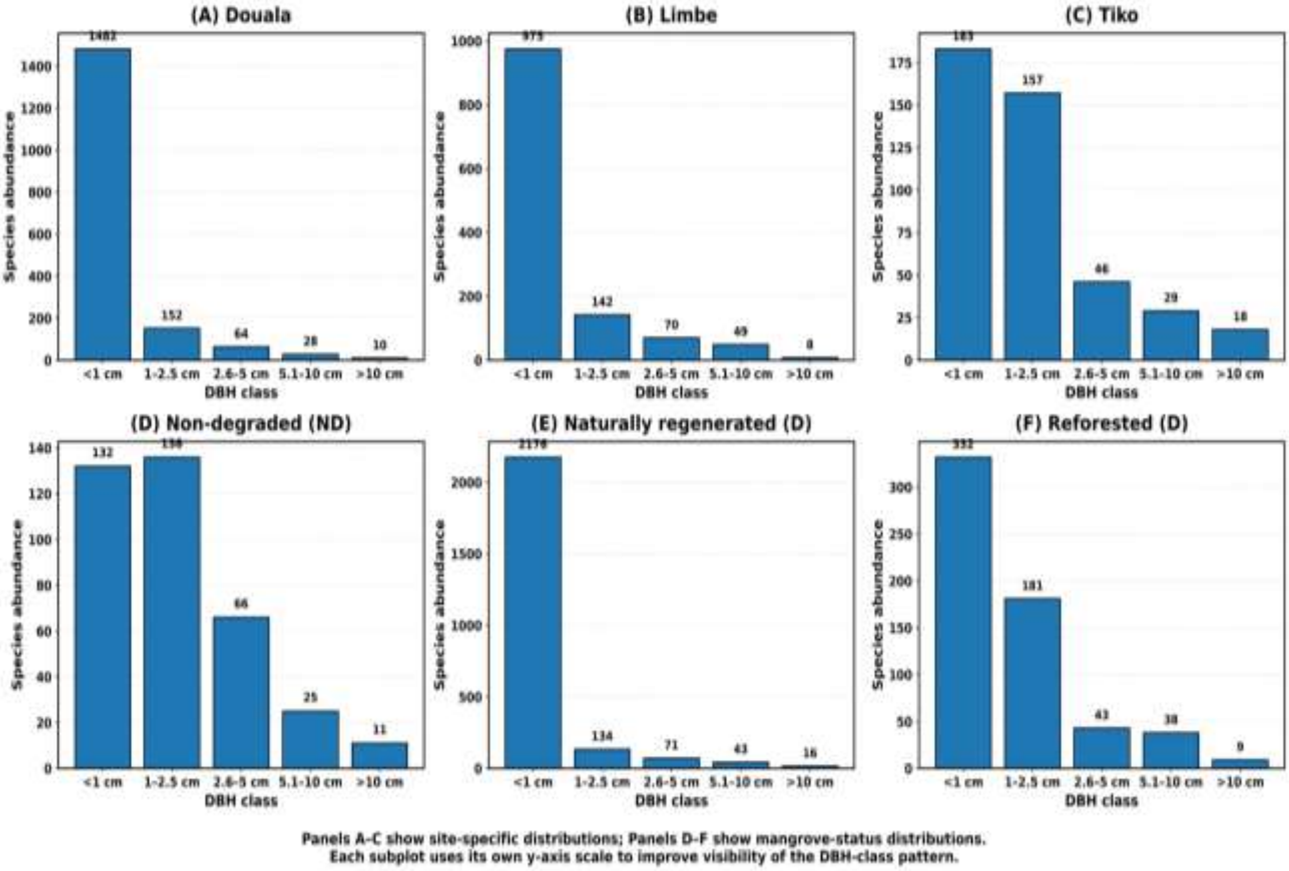

Figure 9. DBH class distribution of mangrove species abundance across study sites and mangrove-status categories.

Height class distribution also showed dominance of short individuals. Of the 3,413 individuals with recorded height values, 2,325 individuals, representing 68.12%, occurred in the <0.5 m class. The 0.5-1 m class recorded 450 individuals, representing 13.19%, while the >5 m class recorded only 134 individuals, representing 3.93%. Naturally regenerated mangroves were strongly dominated by individuals below 0.5 m, whereas non-degraded mangroves had stronger representation in taller classes.

Table 5. Distribution of species abundance by plant height class across study site and mangrove status.

Height class	Douala	Limbe	Tiko	ND	NR	RF	Total
<0.5 m	1409	864	52	52	2038	235	2325
0.5-1 m	143	192	115	63	206	181	450
1.1-2 m	118	127	101	35	150	161	346
2.1-5 m	35	47	76	101	31	26	158
>5 m	31	14	89	119	15	0	134
Column total	1736	1244	433	370	2440	603	3413

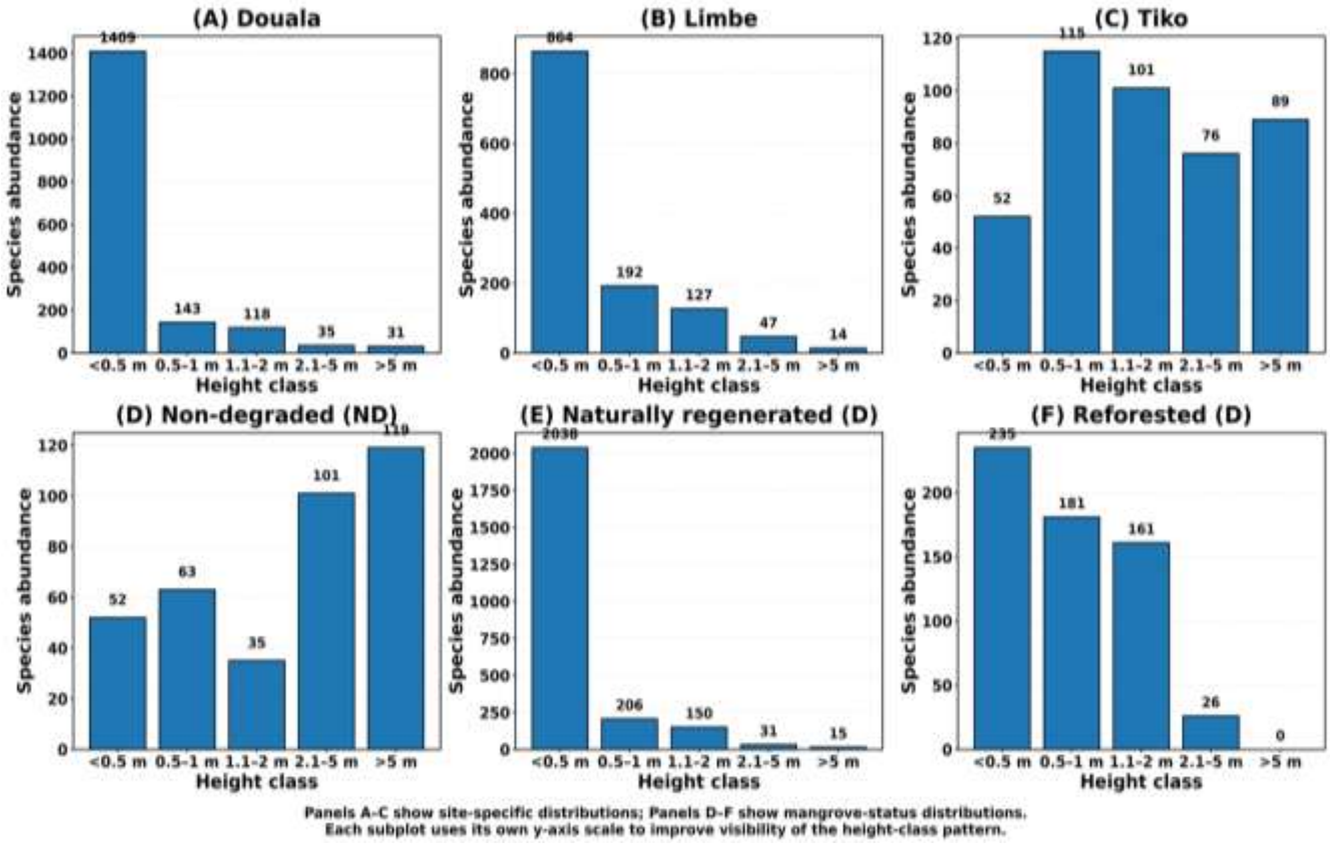

Figure 10. Height class distribution of mangrove species abundance across study sites and mangrove-status categories.

Forest structural metrics

Forest structural metrics varied across site-status combinations. Tiko non-degraded mangroves recorded the highest mean DBH and height, indicating better structural development. Across degradation-status categories, non-degraded mangroves recorded the highest overall mean DBH and height. Reforested mangroves had intermediate values, while naturally regenerated mangroves recorded the lowest values. Basal area and tree volume varied numerically but generally did not differ significantly, probably because the dataset was dominated by small stems and a few larger individuals.

Table 6. Variation of mean (±SD) forest structural metrics across site-by-status groups.

Site	Status	DBH (cm)	Height (m)	Basal area (m^2)	Tree volume (m^3)
Douala	Non-degraded (ND)	1.82 ± 1.62bc	1.35 ± 0.74c	0.000537 ± 0.011688a	0.003809 ± 0.010570a
Douala	Naturally regenerated (NR)	0.54 ± 2.56e	0.31 ± 1.26e	0.000464 ± 0.000850a	0.002388 ± 0.009609a
Douala	Reforested (RF)	2.76 ± 4.79ab	3.64 ± 4.18b	0.002383 ± 0.009634a	0.006570 ± 0.133771a
Limbe	Reforested (RF)	1.37 ± 2.06c	1.80 ± 2.13c	0.000481 ± 0.001438a	0.001215 ± 0.014500a
Limbe	Non-degraded (ND)	1.09 ± 1.07cde	0.60 ± 0.50de	0.000402 ± 0.004302a	0.000779 ± 0.001717a
Limbe	Naturally regenerated (NR)	0.75 ± 2.14de	0.46 ± 0.77e	0.000181 ± 0.000291a	0.000740 ± 0.002403a
Tiko	Non-degraded (ND)	3.53 ± 4.21a	6.40 ± 5.16a	0.002578 ± 0.021346a	0.022958 ± 0.055740a

Tiko	Naturally regenerated (NR)	1.93 ± 5.41bc	1.33 ± 0.73cd	0.002366 ± 0.005805a	0.004021 ± 0.029078a
Tiko	Reforested (RF)	1.60 ± 0.95bcd	1.29 ± 4.34c	0.000273 ± 0.000379a	0.000468 ± 0.000751a
Overall	Non-degraded (ND)	2.41 ± 3.22a	4.41 ± 4.69a	0.001266 ± 0.004098a	0.011832 ± 0.039616a
Overall	Reforested (RF)	1.64 ± 2.72b	0.82 ± 0.67b	0.000794 ± 0.004289a	0.004794 ± 0.106577a
Overall	Naturally regenerated (NR)	0.71 ± 2.80c	0.43 ± 1.64c	0.000656 ± 0.011259a	0.001001 ± 0.004565a

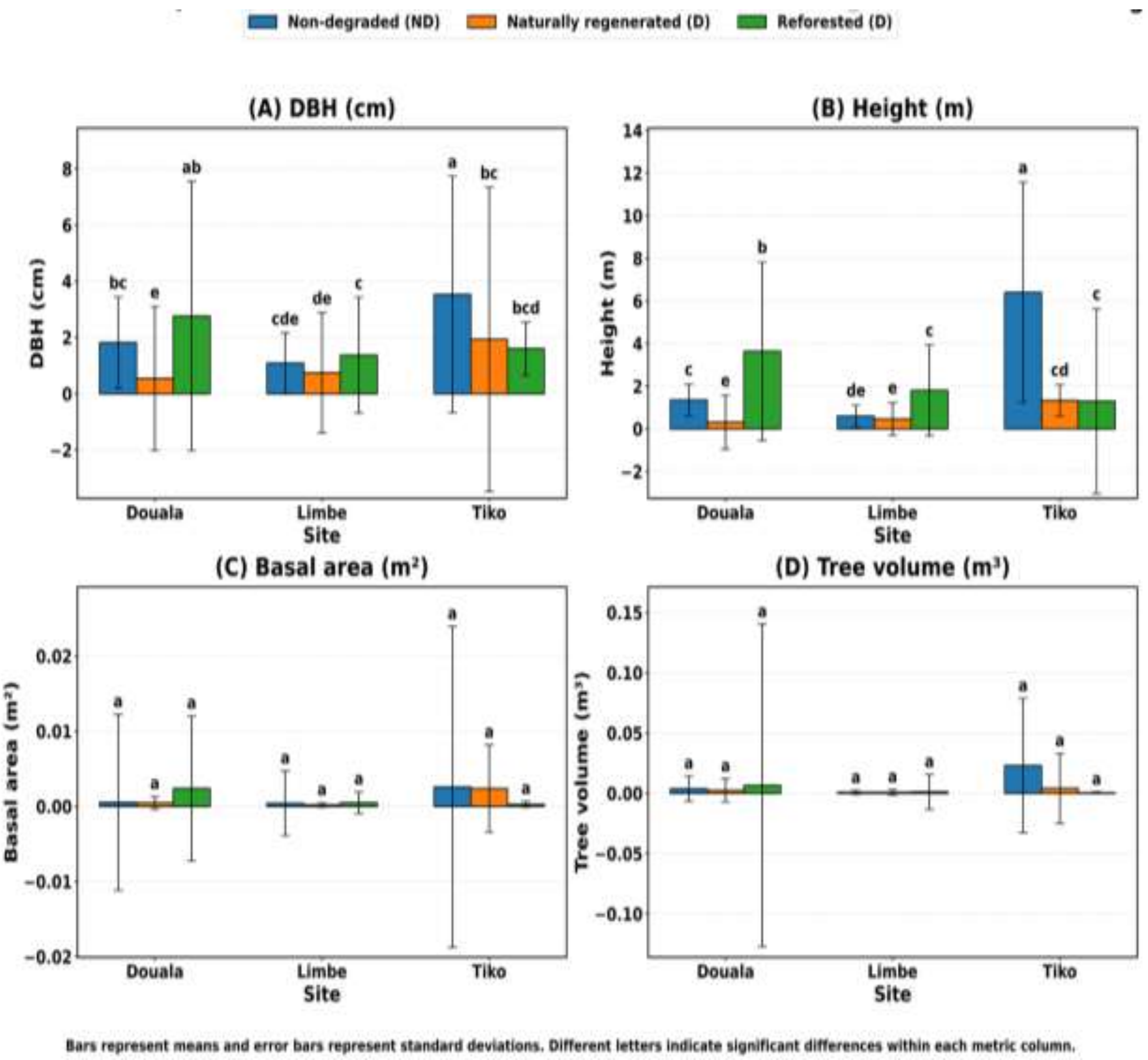

Figure 11. Variation of mean forest structural metrics across sites and degradation-status categories.

Importance value index and compositional analysis

The importance value index showed that ecological dominance was concentrated in a few species. Avicennia germinans recorded the highest overall IVI of 91.06, making it the most ecologically important species in the study area. Rhizophora mangle ranked second with an IVI of 67.22. Although it was less abundant than A. germinans, it contributed strongly to basal area and structural dominance. Laguncularia racemosa ranked third with an IVI of 40.85, reflecting high abundance but more limited plot occurrence. Acrostichum aureum recorded a notable IVI of 30.78 despite low abundance because of its strong contribution to relative dominance where it occurred.

Table 7. Overall species importance value index for dominant species in the entire study area.

Species	Family	Abundance	Rel. density (%)	Plot freq.	Rel. freq. (%)	Basal area (m²)	Rel. dominance (%)	IVI
Avicennia germinans	Acanthaceae	1863	54.33	7	17.07	0.500743	19.66	91.06
Rhizophora mangle	Rhizophoraceae	403	11.75	7	17.07	0.978098	38.39	67.22
Laguncularia racemosa	Combretaceae	859	25.05	3	7.32	0.216195	8.49	40.85
Acrostichum aureum	Pteridaceae	25	0.73	2	4.88	0.641375	25.18	30.78
Nypa fruticans	Arecaceae	95	2.77	4	9.76	0.120061	4.71	17.24
Rhizophora racemosa	Rhizophoraceae	143	4.17	3	7.32	0.080390	3.16	14.64
Conocarpus erectus	Combretaceae	26	0.76	1	2.44	0.000601	0.02	3.22

Sorenson similarity values varied among site-status combinations, ranging from complete dissimilarity to high similarity. High similarity was observed between Douala non-degraded and Douala naturally regenerated mangroves, and between Limbe non-degraded and Limbe reforested mangroves. The NMDS ordination had a low stress value of 0.031, indicating that the ordination provided a reliable representation of species compositional differences. The ordination showed overlap among degradation-status categories, suggesting that the broad status classes were not completely distinct floristically. However, some site-status points were separated, indicating site-level differences in species composition.

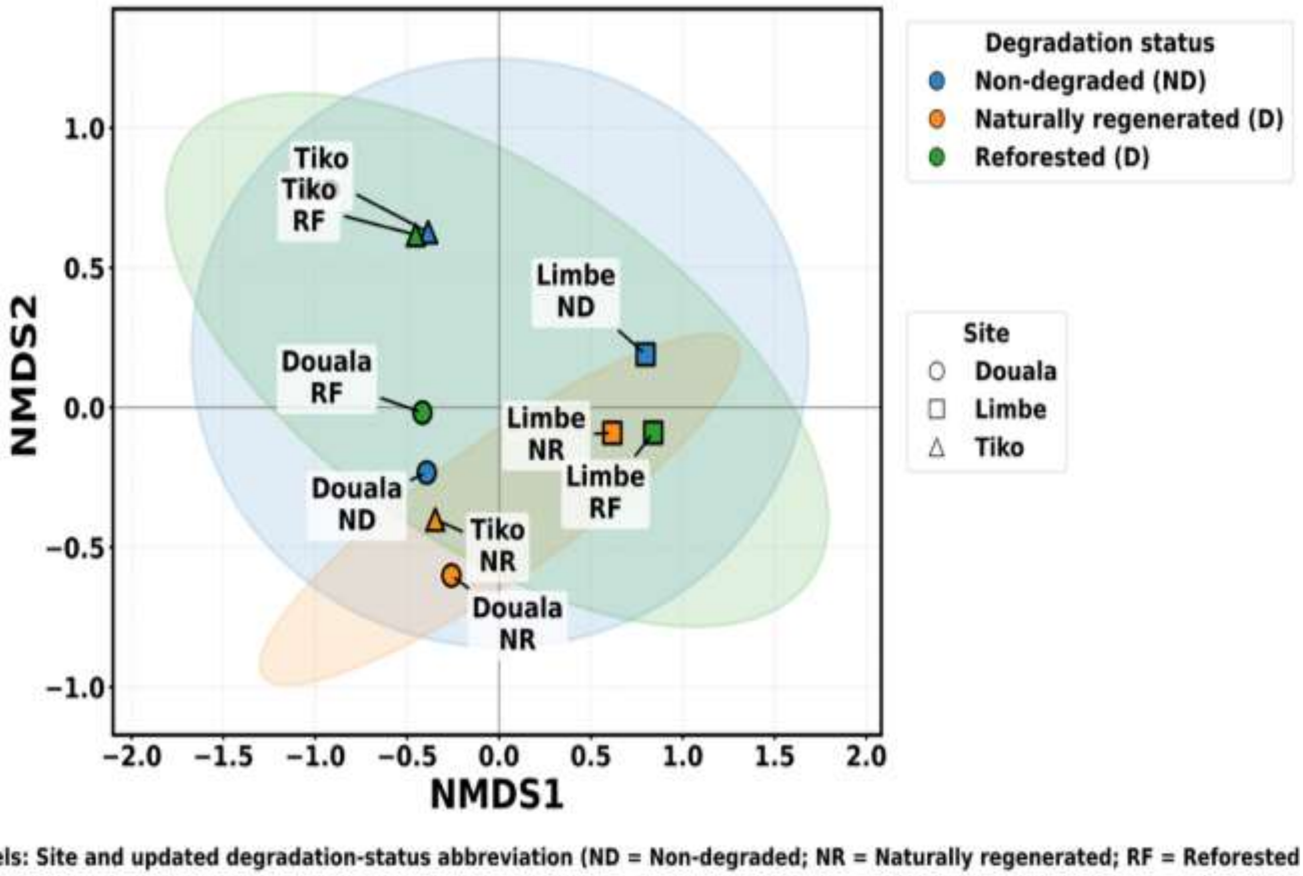

Figure 12. NMDS ordination of mangrove species composition across sites and degradation-status categories, based on Bray-Curtis distance.

Table 8. PERMANOVA test for differences in mangrove species composition across sites and degradation-status categories.

Factor	SS between	SS within	SS total	df between	df within	Pseudo-F	p-value
Site	1.519835	0.875287	2.395122	2	6	5.209157	0.013
Degradation status	0.541969	1.853153	2.395122	2	6	0.877373	0.579

DISCUSSION

The study showed that mangrove composition in the sampled coastal municipalities was strongly dominated by a few species, especially Avicennia germinans, Laguncularia racemosa and Rhizophora mangle. This pattern was consistent with the ecological tendency of mangrove communities to be species-poor but structurally and functionally important in tropical intertidal zones (Friess et al., 2019). However, the dominance pattern differed by site, suggesting that local conditions such as salinity, hydrology, sediment type, propagule supply and disturbance history influenced species establishment.

The high abundance of A. germinans in Douala and naturally regenerated mangroves suggested that this species was highly successful in colonizing disturbed or regenerating areas. Avicennia species are often early colonizers in disturbed coastal environments because they tolerate variable salinity, unstable substrates and exposed conditions. In contrast, the dominance of R. mangle in Tiko and non-degraded mangroves suggested better development of Rhizophoraceae-dominated stands, which often indicate more established mangrove structure where hydrological and sediment conditions are favourable.

The DBH and height class distributions were among the most important findings. The reverse J-shaped DBH pattern indicated active recruitment, but the low proportion of large stems showed that many stands were still structurally young or affected by previous disturbance. Similarly, the dominance of individuals below 0.5 m showed that regeneration was active, especially in naturally regenerated stands, but vertical maturity remained limited. This was particularly evident in naturally regenerated mangroves, where abundance was high but mean DBH and height were low.

Non-degraded mangroves showed better structural development, especially in height distribution, while Tiko had broader DBH and height class representation. This suggested that mature stand structure was more strongly retained in non-degraded areas and in site conditions favourable to growth. The finding was important because it demonstrated that high abundance did not automatically indicate ecological maturity. Natural regeneration may therefore be promising, but it requires time, protection and monitoring before it can be considered structurally restored.

The PERMANOVA result provided an important scientific interpretation. Species composition differed significantly among sites but not among degradation-status categories. This meant that Douala, Limbe and Tiko differed more strongly from one another than non-degraded, naturally regenerated and reforested categories did. Therefore, broad degradation-status labels alone were insufficient to explain mangrove composition. This supported recent restoration literature emphasizing that mangrove recovery depends heavily on site-specific biophysical conditions rather than planting alone (Lee et al., 2019; Worthington et al., 2020).

CONCLUSION

This study assessed mangrove species composition and structural characteristics across non-degraded, naturally regenerated and reforested stands in Douala, Limbe and Tiko. The mangrove vegetation was dominated by Avicennia germinans, Laguncularia racemosa and Rhizophora mangle. Douala was dominated by A. germinans, Limbe by L. racemosa and Tiko by R. mangle. Naturally regenerated stands recorded the highest abundance, but non-degraded stands and Tiko showed better structural development. The DBH and height class distributions indicated strong recruitment but limited mature stand representation. Species composition differed significantly among sites but not among degradation-status categories. The study therefore concluded that site-specific ecological conditions influenced mangrove composition more strongly than broad degradation or restoration status.

RECOMMENDATIONS

- Mangrove restoration programmes should prioritize site-specific ecological assessment before planting or assisted regeneration.
- Hydrology, tidal exchange, sediment stability and species-site compatibility should be evaluated before restoration interventions are implemented.
- Naturally regenerated mangroves should be protected and monitored because they showed high recruitment potential; however, their structural immaturity indicated that they required long-term protection before they could recover mature stand characteristics.
- Reforested mangroves should be enriched with appropriate native species where dominance by a single species is excessive.
- Mixed-species restoration should be promoted where site conditions allow, especially to improve ecological stability and structural complexity.
- Future research should include soil salinity, sediment properties, tidal inundation frequency, carbon stock estimation and long-term plot remeasurement. Exact GPS coordinates and permanent plot markers should be maintained to support future monitoring.

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CONFLICT OF INTEREST STATEMENT

The authors declared no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used for this article were obtained from field measurements conducted in mangrove plots across Douala, Limbe and Tiko. The raw dataset should be made available as supplementary material upon journal submission.

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