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Use and Natural Regeneration of Woody Species of High Ethnobotanical Value in Tropical Rainforest (Southern Cameroon)

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Abstract

This study assesses the natural regeneration of 25 woody species of high ethnobotanical value in the tropical rainforest of southern Cameroon. Quantitative ethnobotanical data (use value UV, relative frequency of citation RFC, informant consensus factor ICF) and dendrometric parameters (seedling density, DBH, height) were collected from up to 60 informants per species, covering 17 botanical families. Use value (UV) ranged from 0.031 to 2.60. The Shannon–Wiener diversity index revealed high diversity within botanical families ($H' = 2.654$) and an even distribution across the five use categories ($H' = 1.510$). Pearson correlations showed a significant negative relationship between UV and seedling density ($r = -0.487$; $p = 0.014$), as well as between ICF and seedling density ($r = -0.502$; $p = 0.011$). The Kruskal–Wallis test confirmed significant differences among UV groups ($H = 9.46$; $p = 0.009$). Five species combine high cultural value with concerning regeneration status: *Ricinodendron heudelotii*, *Baillonella toxisperma*, *Milicia excelsa*, *Alstonia boonei*, and *Irvingia gabonensis*. These results call for urgent sustainable management measures, including harvest quotas, agroforestry programs, and the closure of certain areas to exploitation.

Keywords: Quantitative Ethnobotany; Use Value; Natural Regeneration; Tropical Forest; Southern Cameroon

1. Introduction

The Congo Basin forest harbors significant biodiversity, making it the world's most important reservoir for a diverse range of fauna and flora [1]. Moreover, many species found in this forest are endemic, and a substantial proportion of them is threatened with extinction [2]. In Cameroon, this forest covers approximately 22.5 million hectares, or 48% of the national territory [3]. According to WCMC (2000), the country hosts nearly 8,260 vascular plant species, of which about 150 are endemic, making Cameroon the second most floristically rich country in Central Africa after the Democratic Republic of Congo [4]. These forests provide a wide variety of resources, grouped into timber and non-timber forest products (NTFPs), as well as a multitude of ecosystem goods and services [5] [6]. However, increasing exploitation, coupled with population growth and market expansion, places growing pressure on certain highly sought-after woody species [7]. Among the most exploited forest resources are woody species of high ethnobotanical value, i.e., those subject to multiple and intensive uses (food, medicinal, ritual, artisanal, and commercial). This is the case for species such as *Irvingia gabonensis* (Andok), *Ricinodendron heudelotii* (Njansang), and *Baillonella toxisperma* (Moabi), which are at the heart of domestic economies and cultural practices of many forest-dependent communities [8] [7].

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Indeed, the ethnobotanical value of a species – that is, its perceived and actual importance in local uses – is often a reliable predictor of its vulnerability [9]. Studying this value together with regeneration status could provide a reliable basis for decision-making aimed at restoring and sustainably managing biodiversity. Species with multiple uses (timber, food, medicine, ritual) are subject to repeated harvesting of different plant parts (trunk, bark, fruits, leaves), which can compromise their natural renewal [10]. However, quantitative studies directly linking the intensity of ethnobotanical use to natural regeneration status remain rare. In other words, few studies have rigorously quantified the relationship between ethnobotanical value and natural regeneration status for a representative set of woody species in Central Africa [11]. Yet understanding whether high ethnobotanical value of a species is associated with a natural regeneration deficit is crucial for guiding conservation and participatory management strategies. Furthermore, this knowledge gap limits the identification of priority species that combine socio-economic importance with conservation urgency.

The present study aims to fill this gap by combining a quantitative ethnobotanical approach with a standardized forest inventory for 25 woody species belonging to 17 botanical families. To achieve this, it aims to: (1) characterize the botanical and ethnobotanical diversity of the studied species, (2) assess their natural regeneration status, and (3) analyze the statistical relationships between use value and regeneration density, in order to identify the most vulnerable species and formulate recommendations for sustainable management. The originality of this research lies in the integration of standardized ethnobotanical indices (UV, RFC, ICF) with ecological regeneration surveys, enabling a quantitative analysis of the sustainability of traditional uses. The expected results will contribute to identifying priority species for conservation measures and guiding community forest management policies in the sub-region.

2. Materials and Methods

2.1. Study area

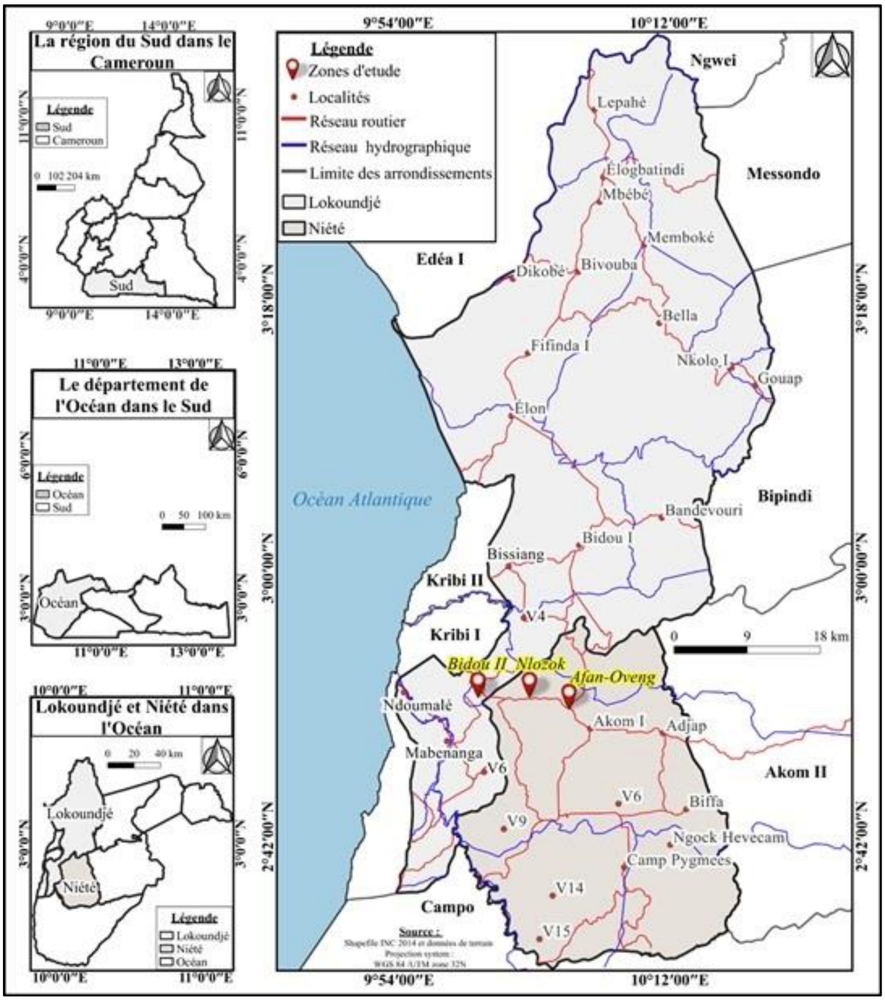

Figure 1 Map of study sites

This study was conducted in forest remnants located in the coastal forest dominated by *Sacoglottis gabonensis* (Bidou) and *Lophira alata* (Azobé), belonging to the Biafran forest type in southern Cameroon. Data were collected in the villages of Nko'olong, Nlozok, and Andjeck, situated in the Niété subdivision (southern Cameroon), at mean geographical coordinates of 10°03'00'' E and 2°40'00'' N (Figure 1). The locality experiences a Guinean-type equatorial climate, characterized by high and constant temperatures, with annual rainfall ranging between 1600 and 3300 mm distributed over two rainy seasons. The relief is a low-altitude plateau (100–200 m). The soils are young, yellow ferrallitic, with an amorphous texture typical of coastal areas [12].

2.2. Ethnobotanical data collection

This study combines a participatory ethnobotanical approach with a standardized forest inventory, following the integrated methodological frameworks advocated for assessing the sustainability of forest resource exploitation [13].

2.2.1. Selection of informants and surveys

Ethnobotanical data were collected from up to 60 informants per species, selected through purposive sampling targeting individuals with proven knowledge of local plants [14]. Following this logic, data collection targeted traditional healers, hunters, farmers, herbalists, and elders from each study locality. Surveys employed semi-structured interviews and free-listing methods [15], conducted in the local language without interpreters. Following standard protocols in quantitative ethnobotany, for each species, informants spontaneously mentioned the uses they made of it. Uses were grouped into four categories: timber (construction, woodworking), medicinal (disease treatment), food (fruits, seeds, oils), and ritual (cultural and spiritual practices).

2.2.2. Calculated ethnobotanical indices

Three quantitative indices were calculated to assess the relative ethnobotanical value of each species. These indices are presented in Table I below.

Table 1 Ethnobotanical indices used and their calculation formulas

Index	Formula	Description	Reference
UV (Use Value)	UV = ΣU / n	Sum of use citations (U) divided by the number of informants (n). Reflects the relative importance of the species.	[16]
RFC (Relative Frequency of Citation)	RFC = FC / N	Frequency of citation (FC) divided by the total number of informants (N). Proportion of informants citing the species.	[10]
CI (Cultural Importance)	CI = Σ(URs,c) / N	Sum of use reports by category and by informant. Integrates use diversity and frequency.	[10]

The use value index (UV), proposed by Phillips & Gentry (1993), is among the most commonly used tools in quantitative African ethnobotany [17] [18]. The relative frequency of citation (RFC) and cultural importance (CI) indices, developed by Tardío & Pardo-de-Santayana (2008), allow for more robust interspecific comparison. Unlike UV, these two indices simultaneously integrate species citation frequency and the diversity of reported uses.

2.3. Dendrometric inventory and regeneration assessment

Dendrometric surveys were conducted following standard tropical forest inventory protocols [19] [20]. For each adult individual, two parameters were measured: total height (H, in meters), measured using a hypsometer, and diameter at breast height (DBH, in cm), measured at 1.30 m above ground using a diameter tape [21]. A total of 25 woody species belonging to 13 botanical families were selected, with the number of adult individuals (N) ranging from 5 to 24 depending on the species.

Natural regeneration was assessed by counting seedlings inside circular plots of 25 m radius around each seed tree included in this study. Seedlings were defined as any juvenile individual of the target species, less than 1.30 m in height, resulting from sexual reproduction [22]. This threshold of 1.30 m corresponds to the conventional limit used to distinguish regeneration stages [19]. The result is expressed as the mean number of seedlings per inventoried adult individual:

Mean number of seedlings = Total number of observed seedlings / Number of seed trees

The result obtained from this relationship characterizes the renewal potential of each species in its natural environment.

2.4. Statistical analyses

Statistical analyses were performed using R software with the packages vegan (diversity indices), stats (correlations, Kruskal–Wallis), and ggplot2 (visualizations) [23].

Bivariate Pearson correlations (r) were calculated between the three ethnobotanical indices (UV, RFC, CI) and the regeneration and structure variables (mean number of seedlings, height, DBH), following approaches used in similar studies [11] [24]. Statistical significance was tested at the $\alpha = 0.05$ threshold (* for $p < 0.05$; ** for $p < 0.01$).

2.5. Classification by UV groups

Species were grouped into three categories according to their use value: low UV (UV < 0.5, n = 14), moderate UV (0.5 ≤ UV ≤ 1, n = 6), and high UV (UV > 1, n = 5). This classification follows the grouping proposed by Phillips & Gentry (1993) and adopted in several African studies [25] [26]. Given the small sample sizes per group, a non-parametric Kruskal–Wallis test was applied to compare seedling densities among the three groups. This test is the non-parametric equivalent of one-way ANOVA and does not require the assumption of normality [27].

3. Results

3.1. Botanical and ethnobotanical diversity

3.1.1. Diversity of botanical families

The data collected during this study allowed the identification of 25 species belonging to 17 botanical families, reflecting a diversity of plant resources exploited by local communities in this forest ecosystem. The Shannon index calculated for families reached $H' = 2.654$ nats, with a Pielou evenness of $J' = 0.937$, indicating a very regular distribution of species among families. The Fabaceae family was the best represented, with five species (20% of the total), followed by Apocynaceae (three species, 12%), and Clusiaceae and Annonaceae (two species each, 8%). The remaining 13 families contained only one species each, reflecting the selectivity of local communities in their use practices, which draw on a broad taxonomic spectrum rather than focusing on a few families. From the perspective of ethnobotanical value, monospecific families exhibited the highest UV values: Irvingiaceae (UV = 2.60), Euphorbiaceae (UV = 2.18), and Sapotaceae (UV = 1.87). This concentration of cultural value in families with few species highlights the vulnerability of these taxa to selective and intensive harvesting.

3.1.2. Species richness by use category

Table 2 Diversity indices for botanical families and use categories

Diversity parameter	Unit	Botanical families	Use categories	Interpretation
Richness (S)	N	17	5	Number of distinct units
Shannon index (H′)	nats	2.654	1.510	Overall diversity
Pielou evenness (J′)	0–1	0.937	0.938	Regularity of distribution
Dominant species/category	N	Fabaceae (5 spp.)	Timber (25 spp.; 100%)	Dominant trend

Analysis of use categories revealed that 100% of the inventoried species are used for timber (construction, firewood, or woodworking), making this the universal category in this ecosystem. Medicinal uses concerned 15 species (60%), followed by food uses (10 species, 40%), artisanal uses (9 species, 36%), and ritual uses (8 species, 32%). On average, each species was involved in 2.68 use categories (min = 2, max = 4). Four species cumulated all four use categories (*Baillonella toxisperma*, *Garcinia kola*, *Syzygium aromaticum*, and *Pentaclethra macrophylla*), illustrating their central cultural role. The Shannon index calculated for the distribution of species across use categories was $H' = 1.510$ nats ($J' = 0.938$), confirming a balanced use of different categories. Notably, food-use species exhibited the highest mean UV (mean UV = 1.12), followed by ritual species (UV = 0.97) and medicinal species (UV = 0.95). This suggests that species involved in food provision are subject to the most intense harvesting pressure, which may have direct consequences for their regeneration.

3.2. Ethnobotanical values of the studied species

The 25 woody species studied exhibited marked heterogeneity in their ethnobotanical uses. Use values (UV) ranged from 0.031 (*Monodora myristica* and *Tabernaemontana crassa*) to 2.60 (*Irvingia gabonensis*), revealing a 1 to 84-fold amplitude. Five species stood out with a major ethnobotanical value (UV > 1): *Irvingia gabonensis*, *Ricinodendron heudelotii*, *Baillonella toxisperma*, *Alstonia boonei*, and *Scorodophloeus zenkeri*. These taxa were characterized by a high citation frequency and a relative frequency of citation (RFC) close to unity, reflecting their critical importance in local knowledge systems.

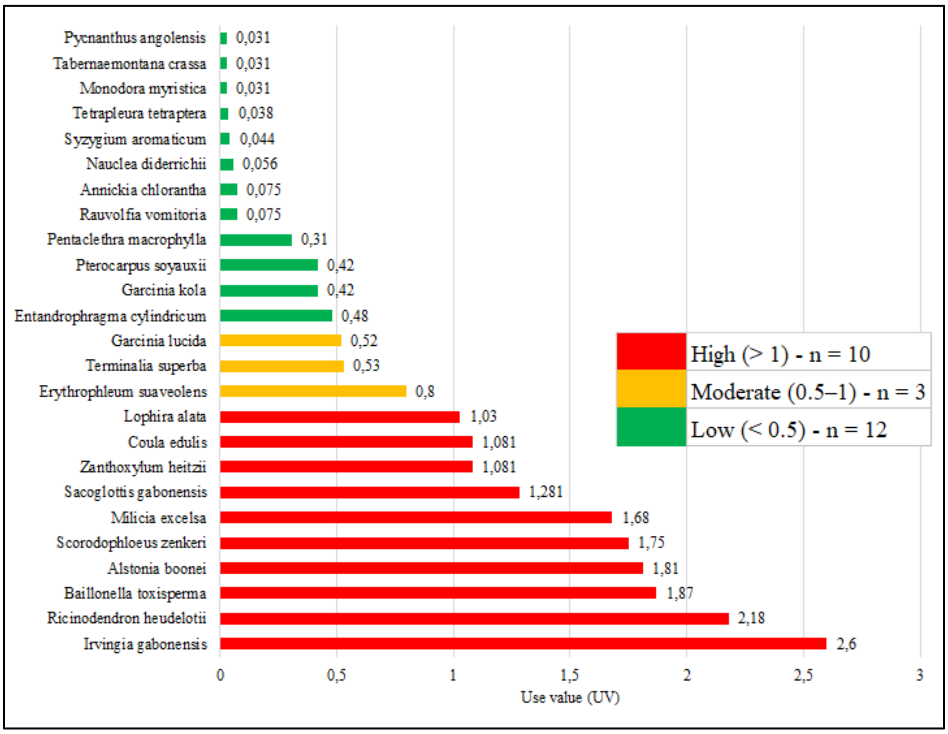

Figure 2 Use value (UV) of the 25 woody species studied, ranked in descending order

Regeneration density varied considerably among species: it ranged from 0.4 seedlings per seed tree for *Erythrophleum suaveolens* to 7.6 seedlings per seed tree for *Pentaclethra macrophylla*. While the overall mean was 3.42, a clear disparity was observed according to exposure: species in the "high UV" group exhibited the lowest densities (mean of 2.05), compared with 4.33 for the "low UV" group (Table III).

Table 3 Ethnobotanical values and seedling densities for a sample of representative species

Species	n	UV	RFC	CI	Seedlings	Groups
Irvingia gabonensis	60	2.60	1.00	1.45	3.0	High
Ricinodendron heudelotii	57	2.18	0.95	1.24	1.4	High
Baillonella toxisperma	60	1.87	0.97	1.12	2.2	High
Alstonia boonei	60	1.81	0.98	0.93	2.3	High
Scorodophloeus zenkeri	58	1.75	0.95	0.91	2.6	High
Milicia excelsa	58	1.68	0.93	1.41	1.7	Moderate
Lophira alata	58	1.03	0.80	1.67	2.8	Moderate
Entandrophragma cylindricum	25	0.48	0.42	0.55	5.8	Low
Pterocarpus soyauxii	35	0.42	0.58	0.55	6.4	Low
Pentaclethra macrophylla	33	0.31	0.33	0.31	7.6	Low

3.3. Relationships between ethnobotanical value and regeneration

3.3.1. Pearson Correlations

The analysis revealed significant negative correlations between mean number of seedlings and, on the one hand, Use Value (UV: r = –0.487; p = 0.014) and, on the other hand, Cultural Importance (CI: r = –0.502; p = 0.011). Furthermore, UV was positively correlated with tree height (r = +0.409; p = 0.042). This result may suggest that the most highly valued species are also the largest, making them preferential targets of selective logging. Finally, no significant correlation was observed between RFC and regeneration.

Table 4 Pearson correlation coefficients between ethnobotanical indices and regeneration and structure variables

Indices	Variables	r	p-value	Signif.	Interpretation
UV	Seedlings	–0.487	0.014	*	Significant negative correlation
CI	Seedlings	–0.502	0.011	*	Significant negative correlation
UV	Height (m)	+0.409	0.042	*	Significant positive correlation
RFC	Seedlings	–0.303	0.141	NS	Non-significant trend
RFC	Height (m)	+0.355	0.082	NS	Trend (p close to threshold)
UV	DBH (cm)	+0.382	0.060	NS	Marginal trend
CI	DBH (cm)	+0.290	0.160	NS	Not significant

NB: * p < 0,05; NS: not significant.

The values from this table enable the scatter plot shown below.

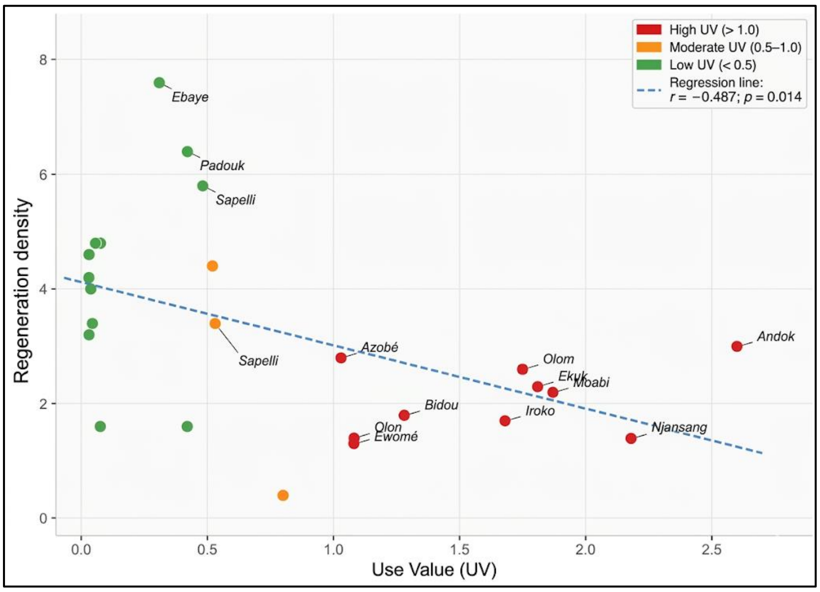

Figure 3 Relationship between use value (UV) and natural regeneration density (seedlings per individual).

Note: The dashed line represents the linear regression (r = –0.487; p = 0.014). Species with high UV are annotated in red, species with high regeneration in green.

3.3.2. Comparison of Use Value Groups

Table 5 Regeneration density and structural parameters by UV group

UV Group	N	Mean number of seedlings	Mean height (m)	Mean DBH (cm)	Status
High UV (> 1)	10	2.05	30.5	71.2	Concerning
Moderate UV (0.5–1)	3	2.73	34.5	76.3	Moderate
Low UV (< 0.5)	12	4.33	22.5	59.6	Satisfactory
Kruskal–Wallis test	—	H = 9.46	p = 0.009	df = 2	Sig. **

The Kruskal–Wallis test confirmed a highly significant difference among groups ($H = 9.46$; $p = 0.009$). Regeneration density decreased monotonically with increasing use value (UV), from 4.33 seedlings per individual for the "low UV" group to 2.73 for the "moderate UV" group, reaching its minimum at 2.05 for the "high UV" group. This gradual, statistically validated trend represents the major finding of this study.

4. Discussion

4.1. Botanical and Ethnobotanical Diversity: Selective but Diversified Exploitation

The distribution of the 25 recorded woody species across 17 botanical families showed a high Shannon index ($H' = 2.654$) and very high evenness ($J' = 0.937$). These values indicate that local communities exploit a broad taxonomic spectrum, with no single family dominating excessively. This finding agrees with observations in tropical environments, where use diversity is generally correlated with available floral diversity, although certain key species are subject to marked cultural preferences [28]. However, the overrepresentation of Fabaceae (five species) is not surprising in Central African forests, where this family is often dominant in both diversity and abundance [29]. Even more interesting is the contrast between the low taxonomic diversity of monospecific families (Irvingiaceae, Euphorbiaceae, Sapotaceae) and their very high use values (UV > 1.8). This phenomenon, already reported by Cunningham (2001), shows that anthropogenic pressure is not uniformly distributed: the most culturally valued species often belong to poorly diversified lineages, which increases their vulnerability. In other words, the loss of a single species may suffice to make an entire family disappear from the local ethnobotanical landscape.

4.2. Multiplicity of Uses and Differential Pressure

The near-universality of timber use (100% of species) underscores the central role of this resource in rural economies and local crafts, a result comparable to that of Phillips & Gentry (1993) in Amazonia, where over 90% of the inventoried woody species were used as timber. The originality of our study lies in highlighting a gradient of use values across categories: food (mean UV = 1.12) ranked higher than ritual (0.97) and medicinal (0.95) uses. This hierarchy suggests that harvesting pressure is highest for species providing both a nutritional and often a commercial function. Food species (*Irvingia gabonensis*, *Ricinodendron heudelotii*) are indeed regularly traded on local markets, which amplifies harvesting [30]. The coexistence of four uses (timber, food, medicine, ritual) on the same taxon (e.g., *Baillonella toxisperma*, *Garcinia kola*) represents an extreme case of multi-purpose pressure. These “multipurpose” species are generally the first to decline in abundance because each use type adds an additional layer of harvesting (bark, fruits, wood, leaves). Tardío & Pardo-de-Santayana (2008) showed that intraspecific functional diversity increases the risk of overexploitation, a finding confirmed by our results through the negative correlation observed between use value and regeneration density.

4.3. Negative relationship between ethnobotanical value and regeneration

The most striking result of this study is the significant negative correlation between use value (UV) and seedling density ($r = -0.487$; $p = 0.014$), a correlation reinforced by that observed with the citation index (CI: $r = -0.502$; $p = 0.011$). Although moderate, these coefficients are statistically robust and indicate that the more a species is valued by local communities, the fewer young individuals it exhibits in natural regeneration. This pattern, classic in the ecology of anthropogenic disturbances, is explained by the fact that preferential harvesting of adult trees (for timber, fruits, or bark) reduces the potential for viable seed production and alters population age structure [31].

Our analysis by UV groups reinforces this interpretation: species with high UV (> 1) had on average 2.05 seedlings per individual, compared to 4.33 for the low-UV group. The Kruskal–Wallis test ($H = 9.46$; $p = 0.009$) confirms that this difference is not due to chance. It is striking that species with high regeneration (e.g., *Pentaclethra macrophylla*: 7.6 seedlings per individual) are precisely those with very low UV (0.31), often used occasionally or for non-destructive purposes.

A notable complementary result is the marginal positive correlation between UV and tree height ($r = +0.409$; $p = 0.042$). This suggests that the most sought-after species are also those that attain a large size, making them more visible and accessible to logging. In contrast, the absence of a significant correlation between UV and diameter (DBH) indicates that selection pressure does not simply translate into a reduction in mean size, but rather into a deficit of juvenile recruitment. This demographic signal is typical of slowly declining populations [33].

4.4. Comparison with regional literature

Our results agree with those of Ndoye et al. (1997) in Cameroon, who showed that *Irvingia gabonensis* and *Ricinodendron heudelotii* suffer from insufficient regeneration due to intensive fruit collection and selective cutting [33]. Similarly, Similarly, Zébazé et al. (2023) showed that in South-East Cameroon, the regeneration dynamics of socio-economically valuable species are severely hindered by anthropogenic disturbance gradients [34]. Our study provides original quantification by directly linking use intensity (UV) to a population renewal indicator.

However, some species escape this trend. *Scorodophloeus zenkeri* (UV = 1.75) exhibits moderate regeneration density (2.6 seedlings per individual), higher than that of other species with high UV. This could be explained by a broader ecological tolerance (pioneer species) or by less destructive use practices (bark harvested without felling the tree). This case illustrates the need not to mechanically generalize the use-regeneration relationship without considering life-history traits.

4.5. Implications for Conservation and Management

Five priority species emerge from our analysis: *Ricinodendron heudelotii*, *Baillonella toxisperma*, *Milicia excelsa*, *Alstonia boonei*, and *Irvingia gabonensis*. Their high use value combined with low regeneration density (≤ 2.3 seedlings per individual) justifies the implementation of targeted management measures. We therefore recommend:

Adapted harvesting plans: establish quotas per individual and introduce fallow periods, particularly for food species;

Promotion of assisted regeneration: use nursery seedlings and enrichment planting in agroforestry parks for species with UV > 1.5;

Participatory demographic monitoring: involve local communities in seedling counting and identification of seed trees;

Complementary studies on reproductive biology (pollination, dispersal) of species with low regeneration, as our correlative approach does not allow establishing a direct causal link.

5. Conclusion

Our results demonstrate that, within the tropical rainforest of Central Africa, woody species of high ethnobotanical value suffer from a significant natural regeneration deficit. This pattern, consistent with the literature on overexploitation of non-timber forest resources, calls for a more systematic integration of ethnobotanical indicators into vulnerability assessments. The preservation of multipurpose species cannot be conceived without community-based management that reconciles local needs with the renewal capacity of plant populations.

This study confirms the inverse relationship between ethnobotanical value and natural regeneration for woody species in Central African tropical rainforest: species with high UV had on average 2.1 times fewer seedlings than species with low UV. Five species combine high cultural value with concerning regeneration status (*R. heudelotii*, *B. toxisperma*, *M. excelsa*, *A. boonei*, *I. gabonensis*) and constitute priority targets for conservation.

The integrated methodological approach (quantitative ethnobotany + forest inventory + diversity indices) provides a robust framework that is replicable in other tropical forest contexts. It should be noted, however, that UV is a composite index that aggregates citation frequency and use diversity, but it does not directly measure the volume of biomass harvested nor the lethality of harvesting practices (e.g., fruit collection vs. felling) – this could be identified as a limitation of this study. To address this, extending this type of study to other sites by incorporating a gradient of anthropogenic pressure (lightly disturbed forests, peri-urban areas, managed community forests) would allow testing the generality of the observed pattern and identifying the environmental and socio-economic factors that modulate the relationship between cultural value and regeneration.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. All authors have participated in the research and the development of the manuscript and have no financial or personal involvement with organizations that could bias the results or interpretations presented in this study.

Statement of ethical approval

This research was conducted in accordance with the ethical standards of the institutional and national research committees. All procedures involving the collection of ethnobotanical data from community participants followed the ethical guidelines for research on traditional knowledge, ensuring respect for local customs and biodiversity conservation protocols.

Statement of informed consent

Informed consent was obtained from all participants involved in the ethnobotanical surveys. Objectives were clearly explained, and participants voluntarily shared their knowledge on woody species management.

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