

Structure and Diversity of Threatened Timber Species in Managed Forests of Cameroon: The Case of FMUs 10 038/10 054

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Abstract

Unsustainable logging constitutes major threats to numerous timber species, several of which are listed on the IUCN Red List of Threatened Species. Certified production forests under sustainable management provide valuable sites for assessing the impact of logging on these threatened species. The objective of this study was to analyse the structure and diversity of timber species listed on the IUCN Red List in logged and unlogged stands of Forest Management Units (FMUs) 10 038/10 054 in Cameroon. Six plots of 4 ha each (three in logged and three in unlogged stands) were established. Within each plot, all timber species with a diameter at breast height ≥ 10 cm

were inventoried. Results showed that FMUs 10 038/10 054 harbour 34 timber species listed on the IUCN Red List, belonging to 30 genera and 13 families. ANOVA showed that species richness of IUCN Red List timber species was not significantly different between logged and unlogged stands. Species classified as Least Concern and Vulnerable were the most represented in both stands, whereas Endangered and Near Threatened species were the least represented. The low Shannon diversity index values recorded in logged and unlogged stands indicate that both stands have relatively low diversity of threatened timber species. Selective logging under certification did not significantly affect the diversity of threatened timber species, but it modified the distribution of abundances. These findings highlight the value of reduced-impact logging practices and forest certification for the conservation of IUCN Red List timber species in Cameroon's production forests.

Keywords: Logged stand; Unlogged stand; Timber species; Threatened species; IUCN

1. Introduction

The Congo Basin forests constitute the second-largest tropical rainforest in the world, covering an area of approximately 2 million km² (Mayaux et al., 1997). The Congo Basin is at the centre of international attention regarding climate change mitigation and biodiversity conservation (Miabangana et al., 2020). Cameroon is one of the most biodiverse countries in Africa in terms of species richness, abundance, ecosystems, and genetic resources, with a high level of endemism (WWF, 2016). Cameroon's forests constitute the second-largest forest massif in the Congo Basin, covering approximately 22.5 million hectares, equivalent to about 45% of the national territory (MINEPDED, 2017). These forests harbour remarkable floristic diversity, with more than 8,000 plant species distributed across 220 families and 1,800 genera, as well as considerable faunal diversity (Vivien and Depierre, 2012; Onana, 2018). They provide essential resources and ecosystem services to nearly eight million Cameroonians living in rural areas and experiencing poverty, including food, traditional medicines, domestic energy, and construction materials (Ngomin and Mvongo, 2015; Njinang et al., 2025).

Despite this exceptional biological richness, Cameroon's biodiversity is increasingly threatened. Approximately 10% of plant species and 815 wildlife species are considered threatened with extinction. Furthermore, about 50% of plant species occurring in biodiversity hotspots associated with mountain and forest ecosystems, and approximately 30% of those found in

coastal and marine ecosystems, are reported to be endangered (MINEPDED, 2017).

Ecosystem degradation and unsustainable resource exploitation constitute major threats to biodiversity conservation in Cameroon (Usongo et al., 2021). The main direct drivers of biodiversity loss include shifting cultivation, poaching, overexploitation of non-timber forest products, unsustainable resource-use practices, climate change and its associated impacts such as floods and droughts, various forms of pollution, and the introduction of non-native invasive species. These anthropogenic pressures contribute to extensive forest degradation and habitat loss, thereby increasing the risk of local extinction of several plant species, including commercially valuable timber species (Konan et al., 2015).

Timber harvesting remains an important component of Cameroon's forest economy, contributing significantly to state revenues and supporting the implementation of social development programmes (de Wasseige et al., 2015). Over the past decades, the country has experienced a substantial increase in wood-processing capacity, which rose from approximately 1.2 million m³ in 1993–1994 to nearly 3 million m³ in 2000 (Pinta and Fometé, 2001). Between 1999 and 2000, log production reached approximately 2.5 million m³ (ATIBT, 2001). Of the approximately 300 tree species recorded in the country, only about 60 are currently harvested for timber production (Ecofin, 2026). Among these, the company SEFECCAM harvests approximately 26 timber species, including species listed on the IUCN Red List of Threatened Species. According to Ettien (2005) and Kouadio et al. (2007), timber species listed on the IUCN Red List are particularly vulnerable to regeneration deficits, which may compromise their long-term persistence under continued harvesting pressure.

In Cameroon, Forest Management Units (FMUs) 10 038 and 10 054, covering a combined area of approximately 214,610 hectares, constitute an important refuge for forest flora and fauna (Anonymous, 2023). Since 2023, these FMUs have been certified under the Pan-African Forest Certification (PAFC) scheme for sustainable forest management. Their management is coordinated under a single management plan because of their geographical contiguity (Anonymous, 2023). The concession encompasses ecosystems characterized by high biological diversity and the presence of species of conservation concern. More than 26 timber species are harvested within the concession (Anonymous, 2023), some of which are listed on the IUCN Red List.

Given the occurrence of IUCN-listed timber species within the concession, assessing their composition, abundance, structure, and diversity is of particular importance for sustainable forest management. The information generated by such an assessment can contribute to the

establishment of a reliable database to support conservation planning, monitoring, and the rational and sustainable management of forest resources within the concession.

Therefore, the general objective of this study was to assess the structure and diversity of timber species listed on the IUCN Red List within FMUs 10 038 and 10 054. Specifically, the study aimed to **(i)** determine the richness of timber species listed on the IUCN Red List and **(ii)** assess their diversity within the study area.

2. Materials and Method

2.1. Study area

This study was conducted in Forest Management Units (FMUs) 10 038 and 10 054, located in the Eastern Region of Cameroon. FMU 10 038 covers an area of approximately 147,463 ha and extends across the administrative districts of Mbang (11,919 ha), Mindourou (110,311 ha), and Lomie (25,233 ha), within the Kadey and Haut-Nyong Departments. FMU 10 054 covers approximately 67,942 ha and is located in the districts of Mbang (67,355 ha) and Mindourou (587 ha), within the Kadey and Haut-Nyong Departments, respectively. These two contiguous FMUs are located in southeastern Cameroon and form part of the country's production forest estate. Geographically, FMU 10 038 extends from approximately 3°21' to 3°44' N latitude and from 13°58' to 14°30' E longitude, whereas FMU 10 054 extends from 3°30' to 4°00' N latitude and from 14°00' to 14°30' E longitude. The field of both FMUs is generally flat to gently undulating, with an average elevation of approximately 600 m above sea level. The soils are predominantly red ferralitic and hydromorphic soils, with clayey characteristics and relatively low silica content. The area receives an average annual rainfall ranging from approximately 1,025.3 to 1,633.9 mm and is characterized by a humid equatorial climate of the Guinean type. The vegetation is mainly composed of species characteristic of the dense humid evergreen forests of the Guineo-Congolian domain. The flora includes several species belonging to the Malvaceae family, particularly the genera *Cola* and *Sterculia*, as well as *Triplochiton scleroxylon*. Species of high commercial and ecological importance occurring in the area include Moabi (*Baillonella toxisperma*), Sapelli (*Entandrophragma cylindricum*), and Fraké (*Terminalia superba*). These species are typical components of the dense humid evergreen forests of the Guineo-Congolian region (Anonymous, 2023).

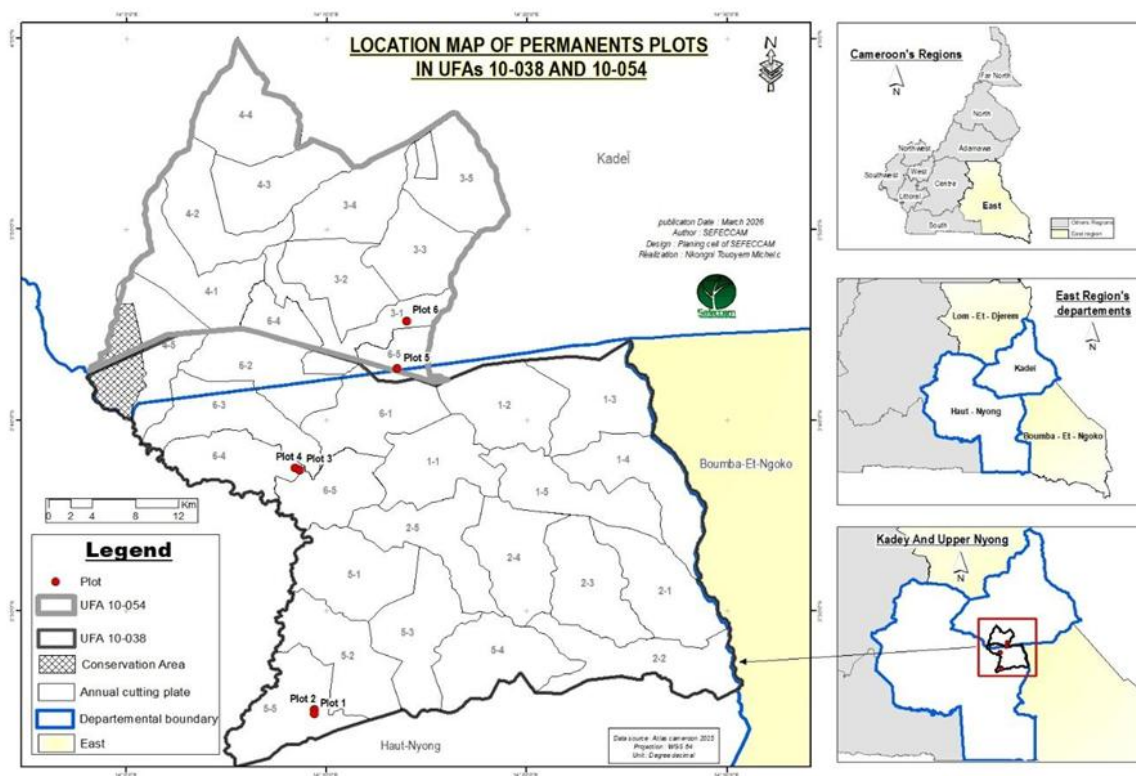


Figure 1: Plot location in FMU 10 038 and FMU 10 054

2.2. Collecte des données

To attain the objectives of this study, six permanent plots, each measuring 200 m × 200 m (4 ha), were established within Annual Allowable Cut (AAC) stands, including three plots located in logged stands and three in unlogged stands. The sampling design was adapted from methodologies previously used by Forni et al. (2018), MINFOF (2019), and Mounmemi (2021). Within each permanent plot, all timber trees with a diameter at breast height (DBH) ≥ 10 cm were inventoried and measured. DBH was measured at 1.30 m above ground level using a diameter tape. For trees with buttresses extending above 1.30 m, diameter measurements were taken 30 cm above the upper limit of the buttress to ensure accurate and standardized measurements. Tree species were identified directly in the field based on their morphological characteristics, with the assistance of botanical identification guides and taxonomic keys and in consultation with a botanist. Species nomenclature and taxonomic classification followed the Angiosperm Phylogeny Group III system (APG, 2009), which provides a phylogenetic classification of flowering plant families and orders. For timber species listed on the IUCN Red List of Threatened Species, geographic coordinates were

recorded using a Global Positioning System (GPS) device. These spatial data were subsequently used to document the distribution and occurrence of threatened timber species within the study stand.

2.3. Data Analysis

The data collected in the field were entered, cleaned, processed, and analysed using XLSTAT software, version 3.1.3. Graphical representations were generated using Microsoft Excel 2016. Various ecological parameters, including species richness, diversity indices, and tree density, were calculated to characterize and compare the forest stands.

Species richness

Species richness was assessed based on total species richness, defined as the total number of species recorded within a given study area (Ngom, 2013). A qualitative assessment of the floristic composition was conducted using the established floristic inventory, with particular emphasis on the distribution of species and families recorded in the study area

Shannon–Weaver Diversity Index (H')

The Shannon–Weaver diversity index (H') is one of the most widely used diversity indices for comparative studies of plant communities. It takes into account both species richness and the relative abundance of individuals within each species (Felfili et al., 2004). This index is considered one of the most reliable estimators of biological diversity and is commonly used as a measure of community heterogeneity (Ouattara et al., 2019).

The Shannon–Weaver index generally ranges from 0 to $\log_2 S$, with values of approximately 4.5 potentially occurring in relatively species-rich communities. The index reaches its maximum value when all individuals are distributed equally among the species present in the community. It gives considerable weight to rare species and is expressed in **bits**. The index was calculated using the following formula (Kenne et al., 2022):

$$H' = - \sum_{i=1}^N (N_i/N) \ln (N_i/N)$$

Where: **H'** = Shannon–Weaver diversity index; **N** = total number of species in the community; **N_i** = Number of individuals belonging to species *i*;

Pielou's Evenness Index (J')

Pielou's evenness index (J') measures the distribution of individuals among species, independently of species richness (Adjakpa et al., 2013). The index ranges from 0 to 1. Values close to 0 indicate that individuals are highly concentrated in one or a few species, whereas values close to 1

indicate that individuals are distributed more evenly among the species present in the community (Adamou, 2010). Pielou's evenness index was calculated using the following formula:

$$J' = H'/\ln S$$

Where: J' = Pielou's evenness index; H' = Shannon–Wiener diversity index; S = total number of species recorded;

Simpson's Diversity Index

Simpson's Diversity Index provides a measure of the relative abundance of one or a few species within a community (Ouaratta et al., 2019). The higher the Simpson's Diversity Index value, the more heterogeneous the environment and the greater the species diversity. The index ranges from 0 to 1 and is calculated using the following formula:

$$Es = 1 - \sum_i^N (Ni(Ni - 1)) / (N(N - 1))$$

Where n_i = the number of individuals of species i , and N = the total number of individuals of all species;

Species Density

Species density was calculated as the total number of stems belonging to a given species divided by the total area sampled. In other words, species density represents the number of stems of a particular species per unit area, generally expressed as stems per hectare (stems ha^{-1}). The species density was calculated using the following formula (Ngom, 2013):

$$\text{Species density (stems ha}^{-1}\text{)} = N / A$$

Where N is the total number of stems belonging to the species and A is the total sampled area, expressed in hectares.

3. Results

3.1. Species, Genus and Family Richness

Table 1 presents the species richness of timber species listed on the IUCN Red List recorded in FMUs 10 038 and 10 054. The inventories conducted within these FMUs recorded a total of 34 IUCN-listed timber species, belonging to 30 genera and 13 botanical families (Table 1). In the logged stands, 26 IUCN-listed timber species were recorded, belonging to 22 genera and 12 botanical families. In contrast, the unlogged stands recorded 29 IUCN-listed timber species, distributed across 26 genera and 12 botanical families. Analysis of variance (ANOVA) revealed no statistically significant differences between logged and unlogged stands in terms of species richness, genus richness, or family richness ($p > 0.05$). Thus, within the conditions of the present study, logging status was not associated with a statistically

significant variation in the taxonomic richness of IUCN-listed timber species at the species, genus, or family levels.

Table 1: Species richness of timber species listed on the IUCN Red List in FMUs 10 038 and 10 054

	Logged		Unlogged		Total
	Total Values	Mean values	Total values	Mean values	
Species	26	16,67 ± 2,31 ^a	29	19,33 ± 2,31 ^a	34
Genera	22	16,00 ± 3,46 ^a	26	15,67 ± 3,21 ^a	30
Famillies	12	9,33 ± 1,15 ^a	12	10,33 ± 0,58 ^a	13

^a : The means in the same rows marked with the same letters are not significantly different at the 5 % significance level

3.2. Family diversity

Table 2 shows that the Fabaceae were the most represented family in both logged and unlogged stands, with nine species recorded in each area, accounting for 34.61% and 31.03% of the IUCN Red List timber species, respectively. The Meliaceae were the second most represented family, with five species in the logged stands (19.28%) and six species in the unlogged stands (20.68%). In the logged stands, 30.76% of the IUCN Red List timber species were represented by a single species within each family. These families included Apocynaceae, Burseraceae, Combretaceae, Ebenaceae, Irvingiaceae, Lecythidaceae, Papilionaceae, and Rubiaceae. In the unlogged stands, 24.13% of the IUCN Red List timber species were represented by a single species in each family, namely Apocynaceae, Burseraceae, Combretaceae, Irvingiaceae, Lecythidaceae, Papilionaceae, and Rubiaceae.

Table 2 : Diversity of plant families represented by species listed on the IUCN Red List in FMUs 10 038 and 10 054

Logged		Unlogged	
Famillie	Number of species	Famillie	Number of species
Fabaceae	9	Fabaceae	9
Meliaceae	5	Meliaceae	6
Myristicaceae	2	Malvaceae	3
Sapotaceae	2	Myristicaceae	2
Apocynaceae	1	Sapotaceae	2
Burseraceae	1	Apocynaceae	1
Combretaceae	1	Burseraceae	1
Ebenaceae	1	Combretaceae	1
Irvingiaceae	1	Irvingiaceae	1
Lecythidaceae	1	Lecythidaceae	1
Papilionaceae	1	Papilionaceae	1
Rubiaceae	1	Rubiaceae	1
Total	26	Total	29

Table 3: Timber species listed on the IUCN Red List recorded within FMUs 10 038 and 10 054

Area	Commercial name	Scientifique name	Famillie	IUCN statut	years
Logged	Alep	<i>Desbordesia glaucescens</i>	Irvingiaceae	LC	1998
	Frake	<i>Terminalia superba</i>	Combretaceae	NT	1998
	Emien	<i>Alstonia boonei</i>	Apocynaceae	LC	1998
	Padouk	<i>Pterocarpus soyauxii</i>	Fabaceae	LC	1998
	Abale	<i>Petersianthus macrocarpus</i>	Lecythidaceae	LC	1998
	Tali	<i>Erythrophleum sauveokens</i>	Fabaceae	NT	1998
	Longhi	<i>Gambeya africana</i>	Sapotaceae	LC	1998
	Bosse c	<i>Guarea cedrata</i>	Meliaceae	VU	1998
	Sapelli	<i>Entandrophragma cylindricum</i>	Meliaceae	VU	1998
	Niove	<i>Staudtia gabonensis</i>	Myristicaceae	LC	1998
	Moabi	<i>Baillonella toxisperma</i>	Sapotaceae	VU	1998
	Aiele	<i>Canarium schweinfurthii</i>	Burseraceae	LC	2020
	Wamba	<i>Tessmannia africana</i>	Fabaceae	LC	1998
	Ebene	<i>Diospyros crassiflora</i>	Ebenaceae	VU	2018
	Dabema	<i>Piptadeniastrum africanum</i>	Fabaceae	LC	1998
	Doussie	<i>Azelia bipindensis</i>	Fabaceae	VU	1998
	Mubala	<i>Pentaclethra macrophylla</i>	Fabaceae	LC	1998
	Okan	<i>Cylicodiscus gabunensis</i>	Fabaceae	NT	1998
	Assamela	<i>Pericopsis elata</i>	Papilionaceae	EN	1998
	Bilinga	<i>Nauclea diderrichii</i>	Rubiaceae	NT	1998
	Doussie	<i>Azelia pachyloba</i>	Fabaceae	VU	1998
	Pao rosa	<i>Bobgunnia fistuloides</i>	Fabaceae	EN	1998
	Acajou blanc	<i>Khaya ivorensis</i>	Meliaceae	VU	1998
	Sipo	<i>Entandrophragma utile</i>	Meliaceae	VU	1998
	Tiama	<i>Entandrophragma angolense</i>	Meliaceae	VU	1998
	Ilomba	<i>Pycnanthus angolensis</i>	Myristicaceae	LC	1998
Unlogged	Alep	<i>Desbordesia glaucescens</i>	Irvingiaceae	LC	1998
	Sapelli	<i>Entandrophragma cylindricum</i>	Meliaceae	VU	1998
	Abale	<i>Petersianthus macrocarpus</i>	Lecythidaceae	LC	1998
	Longhi	<i>Gambeya africana</i>	Sapotaceae	LC	1998
	Frake	<i>Terminalia superba</i>	Combretaceae	NT	1998
	Padouk	<i>Pterocarpus soyauxii</i>	Fabaceae	LC	1998
	Niove	<i>Staudtia gabonensis</i>	Myristicaceae	LC	1998
	Tali	<i>Erythrophleum sauveokens</i>	Fabaceae	NT	1998
	Ilomba	<i>Pycnanthus angolensis</i>	Myristicaceae	LC	1998
	Eyong	<i>Eribroma oblongum</i>	Malvaceae	VU	1998
	Bosse claire	<i>Guarea cedrata</i>	Meliaceae	VU	1998
	Emien	<i>Alstonia boonei</i>	Apocynaceae	LC	1998
	Kossipo	<i>Entandrophragma candollei</i>	Meliaceae	VU	1998
	Kotibe	<i>Nosogordonia papaverifera</i>	Malvaceae	VU	1998
	Lati p	<i>Amphimas pterocarpoides</i>	Fabaceae	LC	1998
	Aiele	<i>Canarium schweinfurthii</i>	Burseraceae	LC	2020
	Doussie	<i>Azelia bipindensis</i>	Fabaceae	VU	1998

Iantandza	<i>Albizia ferruginea</i>	Fabaceae	VU	1998
Mambode	<i>Detarium macrocarpum</i>	Fabaceae	LC	1998
Sipo	<i>Entandrophragma utile</i>	Meliaceae	VU	1998
Acajou blanc	<i>Khaya ivorensis</i>	Meliaceae	VU	1998
Assamela	<i>Pericopsis elata</i>	Papilionaceae	EN	2020
Bilinga	<i>Nauclea diderrichii</i>	Rubiaceae	NT	2021
Lotofa	<i>Sterculia rhinopetala</i>	Malvaceae	LC	1998
Mubala	<i>Pentaclethra macrophylla</i>	Fabaceae	LC	1998
Mukulungu	<i>Autranella congolensis</i>	Sapotaceae	EN	1998
Okan	<i>Cylicodiscus gabunensis</i>	Fabaceae	NT	1998
Pao rosa	<i>Bobgunnia fistuloides</i>	Fabaceae	EN	1998
Tiama	<i>Entandrophragma angolense</i>	Meliaceae	VU	1998

(LC = Least Concern; VU = Vulnerable; NT = Near Threatened; EN = Endangered;

3.3. Density

Table 4 presents the density of timber species listed on the IUCN Red List in logged and unlogged stands of FMUs 10 038 and 10 054. The results show that the overall density of IUCN-listed timber species was 28.83 stems ha^{-1} in logged stands, compared with 16.50 stems ha^{-1} in unlogged stands. *Desbordesia glaucescens* was the IUCN-listed timber species with the highest density in both management conditions, with 10.75 stems ha^{-1} in logged stands and 3.08 stems ha^{-1} in unlogged stands. In addition to *Desbordesia glaucescens*, *Terminalia superba*, *Alstonia boonei*, *Petersianthus macrocarpus*, and *Pterocarpus soyauxii* recorded densities ≥ 1 stem ha^{-1} in logged stands. In unlogged stands, *Entandrophragma cylindricum*, *Petersianthus macrocarpus*, *Gambeya africana*, and *Pterocarpus soyauxii* had densities ≥ 1 stem ha^{-1} . However, 81.48% of the IUCN-listed timber species recorded in logged stands had densities below 1 stem ha^{-1} . These species included *Gambeya africana*, *Entandrophragma cylindricum*, *Baillonella toxisperma*, *Staudtia gabonensis*, *Piptadeniastrum africanum*, *Entandrophragma angolense*, *Entandrophragma utile*, and *Bobgunnia fistuloides*, among others. In unlogged stands, a total of 29 IUCN-listed timber species were recorded, of which 23 species (79.31%) had densities below 1 stem ha^{-1} . These included *Staudtia gabonensis*, *Erythrophleum suaveolens*, *Pycnanthus angolensis*, *Eriobroma oblongum*, *Guarea cedrata*, *Alstonia boonei*, and *Entandrophragma candollei*, among others. Overall, the results indicate that although the total density of IUCN-listed timber species was higher in logged stands than in unlogged stands, most individual species occurred at relatively low densities (<1 stem ha^{-1}) under both management conditions. This pattern highlights the uneven distribution of IUCN-listed timber species within the study area, with a substantial proportion represented by relatively few individuals per unit area.

Table 4: Density of timber species listed on the IUCN Red List in logged and unlogged stands

Logged			Unlogged		
Commercial name	Scientifique name	Density (Stems/ha)	Commercial name	Scientifique name	Density (Stems/ha)
Alep	<i>Desbordesia glaucescens</i>	10,75	Alep	<i>Desbordesia glaucescens</i>	3,08
Frake	<i>Terminalia superba</i>	4,75	Sapelli	<i>Entandrophragma cylindricum</i>	2,33
Emien	<i>Alstonia boonei</i>	4,33	Abale	<i>Petersianthus macrocarpus</i>	1,50
Abale	<i>Petersianthus macrocarpus</i>	1,50	Longhi	<i>Gambeya africana</i>	1,33
Padouk	<i>Pterocarpus soyauxii</i>	1,50	Frake	<i>Terminalia superba</i>	1,00
Longhi	<i>Gambeya africana</i>	0,67	Padouk	<i>Pterocarpus soyauxii</i>	1,00
Tali	<i>Erythrophleum sauveakens</i>	0,67	Niove	<i>Staudtia gabonensis</i>	0,92
Bosse	<i>Guarea cedrata</i>	0,58	Tali	<i>Erythrophleum sauveakens</i>	0,83
Sapelli	<i>Entandrophragma cylindricum</i>	0,50	Ilomba	<i>Pycnanthus angolensis</i>	0,67
Moabi	<i>Baillonella toxisperma</i>	0,42	Eyong	<i>Eribroma oblongum</i>	0,58
Niove	<i>Staudtia gabonensis</i>	0,42	Bosse	<i>Guarea cedrata</i>	0,50
Aiele	<i>Canarium schweinfurthii</i>	0,33	Emien	<i>Alstonia boonei</i>	0,33
Wamba	<i>Tessmannia africana</i>	0,33	Kossipo	<i>Entandrophragma candollei</i>	0,33
Dabema	<i>Piptadeniastrum africanum</i>	0,25	Kotibe	<i>Nosogordonia papaverifera</i>	0,25
Doussie	<i>Azelia bipindensis</i>	0,25	Lati p	<i>Amphimas pterocarpoides</i>	0,25
Ebene	<i>Diospyros crassiflora</i>	0,25	Aiele	<i>Canarium schweinfurthii</i>	0,17
Mubala	<i>Pentaclethra macrophylla</i>	0,25	Doussie	<i>Azelia bipindensis</i>	0,17
Assamela	<i>Pericopsis elata</i>	0,17	Iantandza	<i>Albizia ferruginea</i>	0,17
Bilinga	<i>Nauclea diderrichii</i>	0,17	Mambode	<i>Detarium macrocarpum</i>	0,17
Okan	<i>Cylicodiscus gabunensis</i>	0,17	Sipo	<i>Entandrophragma utile</i>	0,17
Acajou	<i>Khaya ivorensis</i>	0,08	Acajou	<i>Khaya ivorensis</i>	0,08
Doussie	<i>Azelia pachyloba</i>	0,08	Assamela	<i>Pericopsis elata</i>	0,08
Emien	<i>Alstonia boonei</i>	0,08	Bilinga	<i>Nauclea diderrichii</i>	0,08
Ilomba	<i>Pycnanthus angolensis</i>	0,08	Lotofa	<i>Sterculia rhinopetala</i>	0,08
Pao rosa	<i>Bobgunnia fistuloides</i>	0,08	Mubala	<i>Pentaclethra macrophylla</i>	0,08
Sipo	<i>Entandrophragma utile</i>	0,08	Mukulungu	<i>Autranella congolensis</i>	0,08
Tiama	<i>Entandrophragma angolense</i>	0,08	Okan	<i>Cylicodiscus gabunensis</i>	0,08
Total		28,83	Pao rosa	<i>Bobgunnia fistuloides</i>	0,08
			Tiama	<i>Entandrophragma angolense</i>	0,08
			Total		16,5

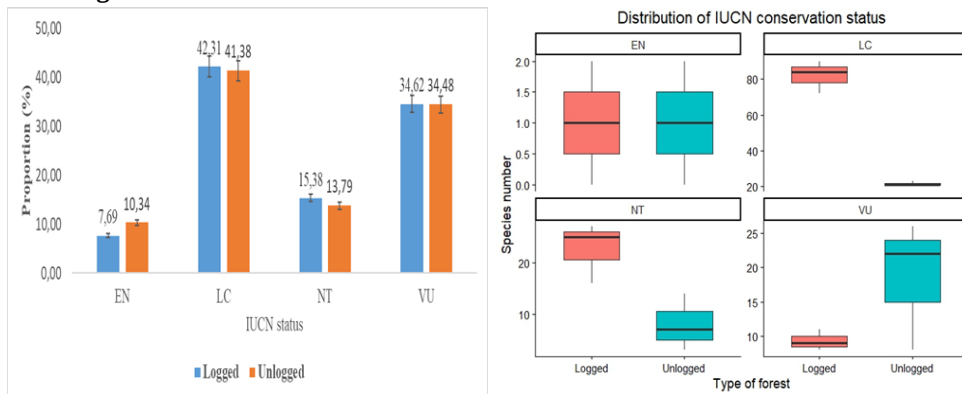
3.4. IUCN Conservation Status of Timber Species in FMUs 10 038 and 10 054

Figure 2 presents the distribution of IUCN conservation statuses among timber species listed on the IUCN Red List in logged and unlogged stands. The results show that species classified as Least Concern (LC) were the most represented category, accounting for 42.31% of the IUCN-listed timber species in logged stands and 41.38% in unlogged stands. Species classified as Vulnerable (VU) represented 34.62% and 34.48% of the species recorded in logged and unlogged stands, respectively. Near Threatened (NT) species accounted for 15.38% of the IUCN-listed timber species in logged stands and 13.79% in unlogged stands. Finally, Endangered (EN) species represented 7.69% of the species recorded in logged stands, compared with 10.34% in unlogged stands.

Analysis of variance (ANOVA) indicated that the densities of Endangered (EN) and Vulnerable (VU) timber species did not differ

significantly between logged and unlogged stands at the 5% significance level. This result suggests that, under the logging conditions observed in FMUs 10 038 and 10 054, no statistically significant difference in the density of EN and VU species was detected between logged and unlogged stands. In contrast, ANOVA revealed significant differences in the densities of timber species classified as Least Concern (LC) and Near Threatened (NT) between logged and unlogged stands at the 5% significance level. These differences indicate that particular attention should be given to the management and monitoring of LC and NT timber species within FMUs 10 038 and 10 054 to ensure their long-term conservation. Although LC species are not currently considered threatened, their monitoring remains relevant because some species may experience population declines and potentially move towards higher-risk categories over time.

Figure 2: Distribution of IUCN conservation statuses in FMUs 10 038/10 054



EN: Endangered; VU: Vulnerable; NT: Near Threatened; LC: Least Concern

3.5. Diversity indices

Table 5 presents the mean diversity indices of timber species listed on the IUCN Red List in the logged and unlogged stands of FMUs 10 038 and 10 054. The mean Shannon diversity index was 2.02 bits in logged stands and 2.50 bits in unlogged stands. These results suggest relatively low diversity of IUCN Red-listed timber species in both stands. Analysis of variance (ANOVA) indicated that the mean Shannon diversity index did not differ significantly between logged and unlogged stands ($F = 4.02$ $p = 0.6$). The mean Simpson diversity index was 0.80 in logged stands and 0.87 in unlogged stands. Both values approached 1, suggesting relatively high diversity under the interpretation of this index as a measure that increases with diversity. ANOVA revealed no significant difference in the mean Simpson diversity index between logged and unlogged stands ($F = 6.182$; $p = 0.068$). The mean Pielou's evenness index was 0.72 in logged stands and 0.85 in unlogged stands. These values indicate a relatively even distribution of individuals among IUCN Red-listed timber species in both stands, with

greater evenness in unlogged stands. ANOVA showed a significant difference in mean Pielou's evenness between logged and unlogged stands ($F = 14.034$; $p = 0.020$).

Table 5: Diversity indices of IUCN Red List timber species in logged and unlogged areas of FMUs 10-038/10-054

Forest stand	Shannon	Equitabilite de Pielou	Simpson
Logged	$2,03 \pm 0,104^a$	$0,72 \pm 0,015^a$	$0,80 \pm 0,022^a$
Unlogged	$2,50 \pm 0,289^a$	$0,85 \pm 0,061^b$	$0,87 \pm 0,048^a$

^{a,b}: Means in the same column sharing the same letter are not significantly different at $P = 0.05$.

3.6. Diameter structure

Figure 3 shows the stem diameter distribution in the logged and unlogged stands of FMUs 10 038 and 10 054. Both stands exhibited a reverse-J diameter distribution, characterised by an exponentially decreasing stem frequency with increasing diameter. This pattern is characteristic of natural tropical forests and reflects the predominance of small-diameter individuals, particularly in the [10-20[cm and [20-30[cm diameter classes. Across all diameter classes, stem abundance was higher in the unlogged stands than in the logged stands. Timber stems with diameters of 50 cm or greater were also recorded in the logged stands, suggesting that the management measures implemented within the forest concession may contribute to maintaining the timber resource.

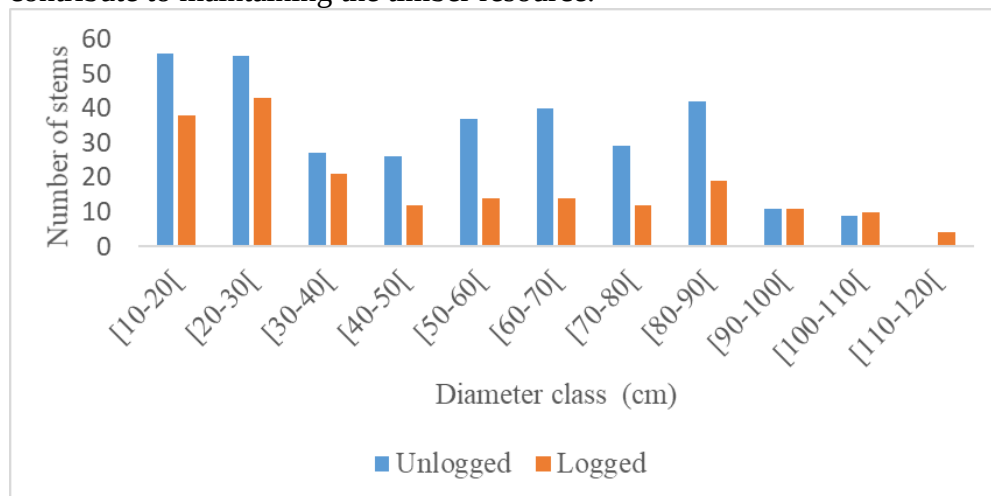


Figure 3: Diameter class distribution of individuals in logged and unlogged stands of FMU 10 038/10 054

4. Discussion

This study was conducted in Forest Management Units (FMUs) 10 038 and 10 054, a forest concession certified for sustainable forest management under the Pan African Forest Certification (PAFC) scheme. The

study examined whether logging practices within this concession could influence the diversity and stand structure of timber species listed on the International Union for Conservation of Nature (IUCN) Red List. The floristic inventory recorded 34 IUCN Red List timber species belonging to 30 genera and 13 botanical families. This species richness exceeds the values reported by Konan (2016) and Ouattara et al. (2019), who recorded 17 and 22 IUCN Red List timber species, respectively, in the Yapo-Abbe forest complex in Ivory Coast. Similarly, Koffi et al. (2018) recorded 16 rare and threatened timber species listed on the IUCN Red List in the Tanoe-Ehy forests of southeastern Ivory Coast. These differences in floristic richness may reflect differences in forest type and environmental conditions. The concession examined in this study consists of evergreen forest on relatively flat terrain, whereas some of the comparison forests contain extensive swamp habitats that may limit the establishment of certain plant species. Adou Yao (2005) reported that swamp habitats generally support comparatively low species richness.

Within the concession, unlogged stands contained more IUCN Red List timber species (29 species) than logged stands (26 species). However, analysis of variance revealed that there is no statistically significant difference in species richness between logged and unlogged stands. This finding may be associated with the sustainable forest management practices implemented within the certified concession, although the absence of a significant difference alone does not establish a causal effect of certification. Sustainable forest management guidelines seek to maintain forest viability and timber production functions while conserving and enhancing biodiversity and supporting the socioeconomic well-being of local populations (Eloundou et al., 2008). Matangaran et al. (2018) reported that timber harvesting had relatively limited effects in concessions applying reduced-impact logging techniques. Reduced-impact logging can improve environmental protection and promote the sustainable management of production forests (Puyz et al., 2008). Directional felling is particularly important for limiting harvesting damage and maintaining the future viability of residual stands (Tavankar et al., 2011; Umunaya et al., 2019). Forest certification promotes responsible management by encouraging improvements in tropical forest management practices (Auld et al., 2008). Blundell et al. (2011) suggested that certified companies should receive preferential consideration when new forest concessions are allocated. Reduced-impact logging practices have been available for several decades and are incorporated into the criteria of most forest certification schemes. When properly implemented, these practices substantially reduce damage to residual trees and soils (Putz et al., 2008).

Fabaceae and Meliaceae were the most represented families in both logged and unlogged stands. The abundance of Fabaceae is a distinguishing feature of African tropical rainforests compared with those of Asia (White, 1986). Similar patterns have been reported in studies conducted within the Lower Guinean (Sonke, 1998; Doucet, 2003; Campbell et al., 2006) and Congolian (Amani et al., 2013; Lisingo et al., 2015) subcentres of endemism. This pattern is consistent with the role of these forests as refuges for the species concerned (Miabangana, 2019). The predominant families identified in this study also correspond to those reported in forest management plans for production forests in eastern Cameroon (SFID, 2012; Anonymous, 2023), as well as those documented by Kenne et al. (2022) in FMU 00 004 in Cameroon's Littoral Region and by Temgoua et al. (2020) in the Cobabe community forests in eastern Cameroon.

Overall, the family composition of IUCN Red List timber species was dominated by Fabaceae and Meliaceae in both logged and unlogged stands. This pattern is consistent with observations from other tropical forests in Cameroon, where these families are among the most species-rich groups of commercial timber trees. For example, Fabaceae was reported as the most represented family in the Cobaba community forest in eastern Cameroon, followed by Malvaceae and Meliaceae (Temgoua et al., 2020).

The density of IUCN Red List timber species was higher in logged stands (28.83 stems ha^{-1}) than in unlogged stands (16.50 stems ha^{-1}). This finding may reflect the influence of factors other than logging alone, including recruitment, growth, mortality, stand age structure, and disturbance history. Trees belonging to species for which there is no commercial demand may remain unharvested within logged stands (Kenne et al., 2022). Mokake et al. (2024), working in tropical forests in eastern Cameroon, showed that post-logging responses vary according to species' ecological characteristics. Several species, including *Terminalia superba*, *Entandrophragma cylindricum*, *Gambeya africana*, *Petersianthus macrocarpus*, and *Pterocarpus soyauxii*, exhibited densities of at least 1 stem ha^{-1} in both logged and unlogged stands. This indicates that some IUCN Red List timber species remain relatively well represented following logging. Hall et al. (2003) reported that selective, reduced-impact logging in Central African forests can alter stand structure without causing immediate, substantial changes in floristic composition.

In logged and unlogged stands, respectively, 81.48% and 79.31% of IUCN Red List timber species had densities below 1 stem ha^{-1} . These low densities represent an important challenge for sustainable management, as sparsely represented populations may be vulnerable to mortality and regeneration constraints. Temgoua et al. (2020) recommended conservation measures for low-density commercial species in the Cobabe community

forests of eastern Cameroon. Bourland et al. (2012) found that, under certain management conditions, species' diameter growth did not differ significantly between logged and unlogged stands.

The results indicated no statistically significant differences between logged and unlogged stands for species classified as Endangered or Vulnerable on the IUCN Red List. This pattern may be associated with the planned management measures implemented within the certified concession. Forest certification encourages responsible management and improvements in tropical forest management practices (Auld et al., 2008). Reduced-impact logging measures, which are incorporated into most forest certification schemes, can substantially reduce damage to residual trees and soils when effectively implemented (Putz et al., 2008).

Species classified as Least Concern were the most represented, whereas Endangered species were the least represented in both logged and unlogged stands. Similar findings were reported by Njinang et al. (2025) in the Ngomedzaz council forests, where Least Concern species predominated and Endangered species were less represented. Priority conservation measures should therefore focus on the most threatened species, including habitat protection, sustainable management, and restoration efforts. Involving local communities in activities that support natural regeneration could further improve conservation outcomes (Droissart et al., 2024; Njinang et al., 2025).

Shannon diversity index values were 2.02 bits in logged stands and 2.50 bits in unlogged stands. These values were interpreted as indicating relatively low diversity within the subset of IUCN Red List timber species examined. The findings are consistent with those of Ouattara et al. (2018), who reported low diversity of IUCN Red List timber species across three habitats in the Yapo-Abbé forest complex. By contrast, Mounmemi et al. (2023) and Nkongmeneck et al. (2003) reported Shannon index values of 3.5 and 4 bits, respectively, in Cameroon's dense semi-deciduous forests. The lower values observed in the present study may partly reflect its restricted focus on IUCN Red List timber species rather than the entire tree community. Comparisons should therefore account for differences in the species groups surveyed and sampling methods. Statistical analysis revealed no significant difference in the Shannon index between logged and unlogged stands. This finding may be consistent with the use of reduced-impact logging in the concession. Selective logging at moderate intensity can have limited effects on woody species richness and diversity over the short to medium term (Hall et al., 2003; Clark and Covey, 2012).

The relatively high Simpson index values recorded in logged (0.80) and unlogged (0.87) stands suggest appreciable diversity, provided that the index was calculated using the $1-D1-D1-D$ formulation. These results are

comparable to those of Ouattara et al. (2018), who reported Simpson index values ranging from 0.6 to 0.9 across three habitats in the Yapo-Abbé forest complex. The absence of a statistically significant difference between logged and unlogged stands suggests that logging was not associated with a detectable difference in the dominance structure of IUCN Red List timber species in the sampled stands. In production forests of the Congo Basin, selective logging may maintain the dominance of certain commercial timber species (Nasi et al., 2012; Gourlet-Fleury et al., 2013; Kenne et al., 2022).

In contrast, Pielou's evenness index differed significantly between logged and unlogged stands. Individuals were more evenly distributed among species in unlogged stands ($E=0.85$ $E=0.85$) than in logged stands ($E=0.72$ $E=0.72$). The lower evenness in logged stands may reflect the removal of large-diameter trees of certain commercially valuable species, such as *Entandrophragma cylindricum* (sapelli), *Entandrophragma utile* (sipo), and assamela, while less heavily harvested species, such as *Desbordesia glaucescens* (alep), remain in the stand. Several authors have shown that selective logging can alter species abundance patterns without necessarily reducing species richness (Hall et al., 2003; Clark and Covey, 2012; Mounmeni et al., 2023). In the semi-deciduous forests of eastern Cameroon, Mounmeni et al. (2023) likewise reported variations in evenness associated with logging.

Both study stands exhibited an inverse-J-shaped diameter distribution, with relatively high numbers of stems in the [10-20[cm and [20-30[cm diameter classes. This pattern indicates a predominance of small-diameter stems and is consistent with ongoing recruitment in both stands, although diameter distributions alone do not demonstrate successful regeneration for every species. An inverse-J-shaped distribution is characteristic of many dense tropical rainforests (Kenne et al., 2022; Njinang et al., 2025). In natural forests where recruitment occurs over extended periods, stem abundance generally decreases with increasing diameter (Djomo et al., 2011).

Conclusion

This study characterized the diversity and stand structure of timber species listed on the IUCN Red List in logged and unlogged stands of FMUs 10 038 and 10 054, a forest concession certified under the Pan-African Forest Certification (PAFC) scheme in Cameroon. A total of 34 IUCN Red List-listed timber species, belonging to 30 genera and 13 botanical families, were recorded. The Fabaceae and Meliaceae were the most represented families in both logged and unlogged stands. Species richness was higher in the unlogged stands (29 species) than in the logged stands (26 species), whereas stem density showed the opposite pattern, with 16.50 and 28.83

stems ha⁻¹ recorded in the unlogged and logged stands, respectively. The results indicated that both logged and unlogged stands exhibited relatively low diversity of timber species listed on the IUCN Red List. In both stands, the diameter-class distribution displayed an inverted J-shaped pattern, characterized by a high proportion of small-diameter stems. Species classified as Endangered (EN) and Near Threatened (NT) were the least represented in both logged and unlogged stands. Overall, low stem densities were recorded for several timber species listed on the IUCN Red List in both forest conditions.

Author contribution

KENNE TENE Lacatuce: Conceptualization, data curation, formal analysis, methodology, supervision, visualization, writing and editing original draft ; **FOMEKONG TSAKEU** : supervision, visualization, and editing original draft ; **MBE TALONG armand** : visualization, and editing original draft ; **TEMGOUA Lucie Félicité** : supervision, visualization, and editing original draft ; **FREDERIC Valentin** : supervision and visualization.

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