Floristic diversity and exploitable potential of commercial timber species in the Cobaba community forest in Eastern Cameroon: implications for forest management

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ABSTRACT

One of the forms of forest management is community forestry which is an alternative to state-managed conservation. Knowledge of the wood potential and exploitable species is a prerequisite for the sustainable management of a community forest. This study carried out in the Cobaba community forest in Eastern Cameroon aimed to assess the floristic diversity and exploitable potential of timber species. A floristic inventory at a sampling rate of 8% was carried out and the volume of trees having reached the minimum exploitable diameter estimated. A total of 7736 commercial trees with dbh ≥20 cm were recorded, belonging to 65 species, 58 genera and 26 families. The Shannon–Weaver diversity index (H’) was 3.61. The density was 42.04 stems ha⁻¹ and the basal area 16.43 m² ha⁻¹. A volume of timber of 31,929.21 m³ has been estimated for trees having reached the minimum exploitable diameter. About 30% of this volume is made up of high and medium commercial value species for which market demand exists. The most abundant species of high commercial value were Triplochiton scleroxylon, Entandrophragma cylindricum, and Milicia excelsa. For sustainable management and species conservation, we recommend that species with very low densities should be excluded from logging and for each species exploited, some well-conformed seed trees with a diameter greater than the minimum exploitable diameter should be left to ensure the renewal of the wood resource.

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Introduction

In Cameroon, tropical rainforest covers 22.5 million hectares or nearly 48% of the national territory (De Wasseige et al. 2009). The forest sector contributes significantly to local and national economies. The contribution of Cameroon’s forest sector is estimated at about 4% of the non-oil gross domestic product. It constitutes the third source of government revenue after agricultural exports and oil (Eba’a Atyi et al. 2013). One of the forms of forest management is community forestry which is an alternative to state-managed conservation. Community forestry is practiced in many countries of the world and several authors have shown that shifting the management of forests from state to local communities could result in more sustainable management of forests, if local communities have an interest in conservation and if it contribute to their socio-economic development (Maryudi et al. 2012; Piabuo et al. 2018; Kimengsi et al. 2019).

The changing concerns of Cameroon and the international community regarding the sustainable management of forest ecosystems have led the Government of Cameroon to review its traditional system of forest management. This was effectively done through the introduction of provisions on community forestry in Forest Law No. 94/01 of 20 January 1994 (Cuny 2011). Community forestry has a dual objective: improving the standard of living of village populations and conserving biodiversity. The aim is to increase the level of involvement and participation of local communities in the conservation and sustainable management of natural resources (Minang et al. 2019). The exploitation of community forests must be subject to the prior elaboration of a simple management plan that allows the community concerned to exploit the forest resources rationally (MINFOF 2009). This simple management plan describes all the activities to be undertaken and allows for resource management planning of the community forest.

A multi-resource inventory is indeed a mandatory element for the validation of the simple management plan (Vermeulen et al. 2006). The objective of this inventory is to have a better knowledge of the wood potential of the forest in order to better plan its exploitation in time and space. Although other resources such as non-timber forest products and wildlife are

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also important for the populations, the most exploited resource in community forests in Cameroon is timber (Cuny 2011). Knowing the volume of harvestable timber is essential for forest managers at various key stages of forest management (Mille and Louppe 2015). In the same way, understanding tree species composition, diversity, and structure is a vital instrument in assessing sustainability of any forest, conservation of species, and management of the ecosystems at large (Addo-Fordjour et al. 2009). The Cameroon Government has allocated the Cobaba community forest to the communities of Zoulabot 1. However, no study had yet been carried out in this forest to assess the timber diversity and exploitable potential. Hence, the need for this study, which aims to assess the floristic diversity and exploitable potential of timber species in this community forest. The goal was to contribute toward the establishment of a simple management plan for the forest.

Materials and methods

Study site

This study was carried out in the Cobaba community forest, located in the Eastern Region, Upper Nyong division and Ngoya sub-division (Figure 1). The Cobaba community forest covers an area of 2300 ha. The study site is characterized by an equatorial climate with a bimodal rainfall regime with four seasons. Rainfall is about 1500 mm/year and monthly average temperatures range from 23.1 to 25°C (WWF 2011). Rainfall is spread throughout the year with two peaks in April and October. The long rainy season extends from September to November while the short rainy season stretches from March to June (Ekobo 1995). The soils are typical ferrallitic soils characterized by iron and aluminum oxides. These soils can be divided into two groups which are red soils derived from the ancient metamorphic and eruptive bedrock and red soils derived from ancient basaltic rocks (Laclavère 1979; Ekobo 1995). The main vegetation type is a semi-deciduous Guineo-Congolian dense forest described by Letouzey (1968, 1985) as rich in Sterculiaceae and Ulmaceae. In the Cobaba community forest, the terra firma forest consisting of primary forest and secondary forest is largely dominant, covering almost 81% of the surface area. It is followed by fallow and farmland (9.05%) and swamps (5.16%). The terra firma forest is dominated by *Triplochiton scleroxylon*, *Terminalia superba* *Antandrophragma cylindricum* and *Desbordesia glaucescens*. Fallow and farmland are characterized by the presence of *Musa* sp, *Elaeis guineensis* and *Musanga cecropioides*. Swamps are located along rivers. They are periodically flooded and are dominated by raffia palms and *Uapaca guineensis*.

The population of the village Zoulabot 1 is composed of Bantu, settled along the roads. This population mainly practises agriculture, fishing, hunting, and the collection of non-timber forest products (WWF 2011).

Data collection

The inventories were carried out according to management inventory standards in Cameroon (ONADEF...
An 8% sampling rate was adopted. The 8% sampling rate was chosen in accordance with the regulations regarding management of community forests, which recommend a sampling rate of 2–10% (MINFOF 2009). Thus, with the Cobaba community forest covering 2300 ha, the area surveyed was 184 ha. The inventory was carried out in 368 contiguous plots of 0.5 ha (20 m × 250 m). In the field, the inventory was carried out following several steps: the demarcation of the boundaries of the community forest; the layering—which involved laying down the network of transects for the sampling plan in the field; and the counting. The plots were systematically laid out along transects in such a way as to represent all vegetation strata. The counting operation was carried out on both sides of the transect. In each plot, all commercial trees with diameter at breast height (dbh) ≥20 cm measured at 1.3 m above the ground were identified, counted, and dbh recorded, following the recommendations of ONADEF (1991) and MINFOF (2019). This inventory was based on the list of commercial forest species established by Cameroonian forest administration. The species were identified according to the Angiosperm Phylogeny Group (APG) IV (2016) classification.

**Data analysis**

Data analysis was performed with TIAMA (Inventory Processing Applied to Forest Management Modelling) software and Microsoft Excel 2016. Floristic characterization was done by determining parameters such as: diversity indices, relative density and dominance of species and families.

Species richness corresponds to the number of species in a community or stand (Ramade 1994). The number of families and the number of species present in the community forest were determined, as well as the number of individuals of each species. The family importance value (FIV) was calculated following Mori et al. (1983) formula:

\[
\text{FIV} = r_{De} + r_{Do} + r_{Di}
\]

where \( r_{De} \) is the relative density (number of individuals of the family considered in relation to the total number of individuals, × 100),

\( r_{Do} \) is the relative dominance (basal area of the family considered in relation to the total basal area of the stand, × 100) and

\( r_{Di} \) is the relative diversity (number of species of the family considered in relation to the total number of species, × 100).

The relative importance of each species was specified by calculating an importance index derived from the Importance value index (IVI) of Curtis and McIntosh (1950) by Pascal and Pélassier (1996) as follows:

\[
\text{IVI} = r_{De} + r_{Do}
\]

where \( r_{De} \) is the relative density (number of individuals of the species in question relative to the total number of individuals, × 100) and \( r_{Do} \) is the relative basal area (basal area of the species in question relative to the total basal area of the stand, × 100).

The Shannon–Weaver diversity index (\( H' \)) is a measure of the potential for interaction between the species that make up a community. This index takes into account the number of species present and the distribution of individuals within those species.

\[
H' = -\sum (n_i/N) \ln(n_i/N)
\]

where \( n_i \) is the number of individuals of a given species \( i \) and \( N \) the total number of individuals.

The Simpson’s diversity index (\( D' \)): is the probability that two randomly selected individuals are of different species. It is represented by the reciprocal of the Simpson’s index (\( D \)). The maximum diversity is represented by the value 1 and the minimum diversity by the value 0.

\[
D' = 1 - \sum (n_i/N)^2
\]

The Pielou’s evenness (\( E \)) expresses the regularity, the equitable distribution of species within a community. This index, which varies from 0 to 1, is maximum when the species have identical abundances in the stand and is minimal when a single species dominates the entire stand.

\[
E = H'/\ln S
\]

where \( S \) is the total number of species surveyed and \( H' \) is the Shannon index.

Vegetation structure was determined by parameters such as density, basal area and distribution of individuals by diameter classes.

Density and basal area was estimated using the formula given by Kent and Coker (1992).

Density (\( D \)): density is the number of individuals per hectare. It was calculated by converting the total number of individuals encountered in all plots to equivalent number per hectare, following this formula:

\[
D = N/S
\]

where \( D \) is the density (stems ha\(^{-1}\)), \( N \) the number of stems present on the considered surface and \( S \) the area considered (ha).

Basal area (\( BA \)) provides information on the area occupied by tree sections at 1.30 m from the ground. The formula is:

\[
BA = \frac{\pi}{4} \sum_{n=1}^{n} (D_i^2)
\]

where \( BA \) is basal area (m\(^2\) ha\(^{-1}\)) and \( D_i \) is diameter (m).

The trees were divided into diameter classes of amplitude equal to 10 cm, and histograms of distribution were developed to characterize the diametric structure of the vegetation.

The gross volume of harvestable timber was calculated based on the volume tables established during the phase 2 of the national inventory (CENADEFOR 1985). The formulas for these volume tables take into consideration the diameter at breast height and are of two types as presented below.
Formula 1: \( V = aD^b \)

Formula 2: \( V = a + bD + cD^2 \)

where \( V \) is volume (m\(^3\)), \( D \) is diameter (cm) and \( a \), \( b \) and \( c \) are the coefficients.

These volume tables by species are given in Appendix 1.

**Results**

**Diversity, species richness and floristic composition**

In the 184 ha surveyed, 7736 trees (dbh ≥ 20 cm) representing 65 species and belonging to 58 genera and 26 families were identified. The Shannon–Weaver diversity index (\( H' \)) was 3.61. The Pielou’s evenness and the Simpson’s diversity index values were 0.86 and 0.95, respectively.

In the Cobaba community forest, the relationship between the number of species and genus was equal to 1.12. This value is very low and shows an average of less than two species per genus. Only 4 genera had more than one species (*Entandrophragma*, *Irvingia*, *Guarea* and *Sterculia*). In term of number of species per family, Fabaceae was the best represented family with 15 species, followed by Malvaceae (8 species, with 6 species of former Sterculiaceae and 2 species of former Bombacaceae), Meliaceae (7 species), Irvingiaceae, Euphorbiaceae and Sapotaceae with 4 species each. Seventeen families were represented by only one species each (Table 1). The Family importance value index of the identified species (50).

The total density of commercial species identified was 42.04 stems ha\(^{-1}\) and the basal area was 16.43 m\(^2\) ha\(^{-1}\). The species with the highest densities and basal areas were *T. superba* (5.16 stems ha\(^{-1}\) and 2.55 m\(^2\) ha\(^{-1}\) respectively), *T. scleroxylon* (4.83 stems ha\(^{-1}\) and 2.55 m\(^2\) ha\(^{-1}\)) and *E. cylindricum* (2.77 stems ha\(^{-1}\) and 1.45 m\(^2\) ha\(^{-1}\)). The rare species (with less than 1 stem ha\(^{-1}\)) made up more than two-third of the identified species (30).

**Diameter class distribution**

The population size class frequency distribution of the community forest stand exhibited a tendency toward a bell-curve distribution (Figure 2). The classes with most abundant individuals were 70–80 cm, 80–90 cm and 60–70 cm with respectively 23.61, 17.55, and 13.94% of individuals. Woody vegetation in the community forest has few trees with diameter larger than 130 cm. If we consider the diametric structures of each species, three types of structures have been identified:

Type 1: Species with a complete or truncated bell-curve distribution (Figure 3). This type characterizes species having a greater number of stems in the medium diameter classes, reflecting a regeneration deficit. Thirty two species showed this type of distribution, including the most dominant species *T. superba*, *T. scleroxylon*, *E. cylindricum*, *A. boonei* and *M. excelsa*.
Type 2: Species with an exponentially decreasing curve distribution (Figure 4). These species have the stems concentrated in the small diameter classes, reflecting constant regeneration over time. Some of these species are: Celtis zenkeri, Irvingia gabonensis, Fagara heitzii, Nauclea diderrichii and Petersianthus macrocarpus.

Type 3: Species with an erratic or limited distribution whose stems are concentrated only in certain diameter classes (Figure 5). Regeneration can be problematic because not all diameter classes are represented. These include: Baillonella toxisperma, Guarea cedrata, Lophira alata, Guibourdia tessmannii, Diospyros crassiflora and Distemonanthus bentamianus.

Harvestable volume of commercial timber

The gross exploitable volume was estimated for commercial species by considering the minimum exploitable diameter (MED) of each species fixed by the forest law of Cameroon. Below this diameter, the exploitation of the tree trunk of a given species is prohibited. Species are grouped into four categories according to their value and commercial importance.
following the Cameroonian forest administration classification (MINFOF 2019). Group 1 species are easy to commercialize due to the existence of a large market and demand. Group 2 includes species with a small market demand. Group 3 includes species that are exploited and marketed on a small scale. Group 4 includes species that can be used but are not yet under use (Table 3).

Table 3 shows that a harvestable volume of 31,929.21 m³ has been estimated for stems that have already reached minimum exploitable diameter. This volume is much higher than the 8540.39 m³ estimated for stems that have not yet reached the minimum diameter. The volume of group 1 species represents 28.40% of the total volume. This percentage is only 1.42% for group 2 species. Group 3 species have the highest proportion of volume (49.75%) and the volume of category 4 species represents 20.43% of the total volume.

Among the 10 species with the highest volumes are two belonging to group 1 (T. scleroxylon and E. cylindricum); six belonging to group 3 (T. superba, P. angolensis and P. soyauxii, D. glaucescens, A. boonei and E. ivorense) and two belonging to group 4 (K. gabonensis and R. heudelotii).

**Discussion**

**Floristic richness and diversity**

A richness of 65 commercial timber species was found in this study. This is lower than that of 74 species found by Durrieu de Madron et al. (1998) in eastern Cameroon. Being in the same ecological zone, this difference can be explained by the smaller area inventoried in our study (184 ha) compared to that of Durrieu de Madron et al. (1998) who did an inventory on 1862 ha. The number of species found in the Cobaba community forest is however much higher than the number of species of 26 and 31 found by Ndebi (2015) and Ghapuen (2014) in other community forests of the Njoya Mintom forest in eastern Cameroon. This difference can also be explained by the higher sampling rate in our study (8%) while the other two authors had sampling rates of 4%.
Forest communities considered rich are characterized by a Shannon diversity value of about 3.5 or higher (Kent and Coker 1992). The Shannon–Weaver diversity index ($H^\prime$) was 3.61, reflected high diversity of study site. The high diversity is also confirmed by a Simpson’s diversity index close to 1 (0.95). The high diversity seems also to derive from a great abundance of rare species: 18 species were represented by less than 10 individuals each and more than two-third of the identified species had a density less than 1 stem ha$^{-1}$.

The total density of commercial species identified was 42.04 stems ha$^{-1}$ and the basal area was 16.43 m$^2$ ha$^{-1}$. This density is higher than those obtained by Ndebi (2015) and Ghapuen (2014) in other community forests in eastern Cameroon, which ranged from 11 to 27 stems ha$^{-1}$. The density of the Cobaba community forest is also higher than that of 30 stems ha$^{-1}$ found
by Abebe and Holm (2003) in the dense rainforest of south-west Ethiopia. However, this density is very low compared to those reported in the semi-deciduous forests of Tené and Mopri in Ivory Coast, where densities of commercial species with diameters greater than 20 cm were estimated at 115 stems ha\(^{-1}\) and 69.75 stems ha\(^{-1}\), respectively (Dupuy 1998). In the Ngombe Forest Management Unit (FMU) in the dense humid evergreen forest of Congo, MEFDD (2007) estimated the density of commercial species at 98.62 stems ha\(^{-1}\) and the basal area at 16.98 m\(^2\) ha\(^{-1}\).

Inventories carried out by several authors in the dense humid forests of eastern and southern Cameroon, all tree species combined, showed a very high specific richness. These authors include Djuikouo et al. (2010) in Dja Biosphere Reserve (207 species), Fongnzossie et al. (2011) in Mengmé gorilla reserve (304), Gnombade et al. (2011) in the Ngoyavang’s lowland forests (293), and Kengne et al. (2016) in the Kompia and Nkolenyeng community forests (214 and 204 species). This very large difference with the number of commercial species (65) recorded in this study confirms the particularity of dense tropical rainforests which are highly diversified, but the number of species exploited as commercial timber remains low (Dupuy 1998). In Cameroon only about 60 species are exploited as timber despite the high natural potential of the forests (FAO 2005).

The Family importance value indicated that Fabaceae was the most important family in the community forest. In term of number of species per family, Fabaceae was also the best represented family followed by Malvaceae, Meliaceae, Irvingiaceae, Euphorbiaceae and Sapotaceae. According to White (1986), one of the fundamental characteristics of African dense forests is their great richness in Fabaceae (Fabaceae-Caesalpinioideae and Fabaceae-Mimosoideae). The families of commercial tree species observed in the Cobaba community forest do not differ from those reported in the management plans of some production forests of southern and eastern Cameroon by SFID (2012, 2013) and FIPCAM (2012).

| Group | Scientific name | MED (cm) | Volume of stems < MED (m\(^3\)) | Exploitable volume >MED (m\(^3\)) | Percentage % |
|-------|----------------|----------|---------------------------------|----------------------------------|--------------|
| I     | *Triplochiton scleroxylon* | 80       | 1282.26                         | 5326.0                           | 16.69        |
|       | *Entandrophragma cylindricum* | 100      | 1944.84                         | 1369.90                          | 4.29         |
|       | *Milicia excelsa* | 100      | 1308.34                         | 902.52                           | 2.83         |
|       | *Entandrophragma utile* | 80       | 179.57                          | 407.74                           | 1.28         |
|       | *Lovoa trichilioides* | 80       | 558.82                          | 358.11                           | 1.12         |
|       | *Entandrophragma candollei* | 80      | 193.90                          | 276.75                           | 0.86         |
|       | *Afzelia polychyla* | 80       | 260.08                          | 250.56                           | 0.78         |
|       | *Nesogordonia papaverifera* | 50     | 0.84                            | 40.78                            | 0.13         |
|       | *Guarea cedrata* | 80       | 38.21                           | 28.40                            | 0.09         |
|       | *Diospyros cassiflora* | 60       | 17.32                           | 24.35                            | 0.08         |
|       | *Lophira alata* | 60       | 0.00                            | 20.89                            | 0.07         |
|       | *Entandrophragma angolense* | 80   | 15.43                           | 20.63                            | 0.06         |
|       | *Pericopsis elata* | 100     | 145.36                          | 12.13                            | 0.04         |
|       | *Syzygium rowlandii* | 80      | 7.43                            | 10.27                            | 0.03         |
|       | *Baillonella toxisperma* | 100    | 1.55                            | 9.10                             | 0.03         |
|       | *Guarea thompsonii* | 80      | 19.77                           | 6.12                             | 0.02         |
|       | *Mansonia altissima* | 60       | 3.02                            | 0.00                             | 0.00         |
|       | Sub-total I |          | 5886.74                         | 9064.25                          | 28.40        |
| II    | *Erythrophleum ornatum* | 60       | 62.33                           | 270.67                           | 0.85         |
|       | *Mitragyna clavata* | 60       | 10.79                           | 87.27                            | 0.27         |
|       | *Fagara hitzë* | 60       | 80.23                           | 34.93                            | 0.11         |
|       | *Guibouria tessmannii* | 80     | 5.50                            | 8.10                             | 0.03         |
|       | *Distemonanthus benthanianus* | 60   | 3.72                            | 34.50                            | 0.11         |
|       | *Gambeya africana* | 60      | 1.09                            | 7.82                             | 0.02         |
|       | *Svatzie fistuloides* | 50       | 0.32                            | 5.66                             | 0.02         |
|       | *Sectulcia rhinopetalà* | 50     | 0.98                            | 5.51                             | 0.02         |
|       | Sub-total II |          | 164.96                          | 454.46                           | 1.42         |
| III   | *Terminalia superba* | 60       | 387.2                           | 4739.55                          | 14.85        |
|       | *Desbordesia glaucescens* | 50    | 140.96                          | 2388.24                          | 7.48         |
|       | *Alstonia boonei* | 50       | 87.56                           | 1852.28                          | 5.80         |
|       | *Erythrophleum ivorense* | 50   | 32.01                           | 150.84                           | 4.71         |
|       | *Pycnanthus angolensis* | 60     | 127.18                          | 1401.31                          | 4.39         |
|       | *Pterocarpus soyauxii* | 60      | 113.23                          | 1084.20                          | 3.40         |
|       | *Celtis penduëndra* | 50       | 4.54                            | 1017.70                          | 3.19         |
|       | *Gilbertiodendron dewveëri* | 60   | 80.45                           | 866.69                           | 2.72         |
|       | *Cylicodiscus gabonensis* | 60 | 15.35                           | 509.89                           | 1.60         |
|       | Others (6 species) | –        | 418.15                          | 1869.02                          | 5.86         |
|       | Sub-total III |          | 1406.63                         | 15,879.72                        | 49.75        |
| IV    | *Klainodoxa gabonensis* | 50       | 10.81                           | 1205.71                          | 3.78         |
|       | *Ricnodendron heudelotii* | 50     | 159.66                          | 1218.74                          | 3.82         |
|       | *Uapaca guineensis* | 50       | 118.96                          | 596.05                           | 1.87         |
|       | *Chrysophyllum lacourtiana* | 50   | 52.98                           | 588.28                           | 1.84         |
|       | *Ceiba zenkeri* | 50       | 149.33                          | 473.46                           | 1.48         |
|       | *Petersianthus macrocarpus* | 50 | 145.67                          | 440.42                           | 1.38         |
|       | Others (19 species) | –        | 444.65                          | 1999.12                          | 6.26         |
|       | Sub-total IV |          | 1082.06                         | 6521.78                          | 20.43        |
| Total | (I + II + III + IV) |          | 8540.39                         | 31,920.21                        | 100          |

MED: minimum exploitable diameter.
The calculated Importance value index (IVI) was between 0.03 and 27.79%. The most important species with an IVI greater than 10% were *T. superba*, *T. scleroxylon*, *E. cylindicum*, *D. glaucescens* and *A. boonei*. These results corroborate those of SFID (2013) who also identified these species among the most abundant in FMU 10,054 in eastern Cameroon. In Crajamal community forest and Mballam community forest in the same region, *T. superba* was also among the most abundant species (Ghapuen 2014; Ndebi 2015). Indeed, *T. superba* is a semi-deciduous dense humid forest species that sometimes forms very extensive stands and is often associated with *T. scleroxylon* (Souane 1983). However, contrary to what we observed in our study, Ghapuen (2014) had found in Crajamal community forest a very low abundance of *T. scleroxylon* (0.03 stems ha$^{-1}$), the most abundant species being *P. macrocarpa* with 6.18 stems ha$^{-1}$.

The IVI is commonly used in ecological studies as it shows ecological importance of a species in a given ecosystem. It is also used for prioritizing species conservation whereby species with low IVI value need high conservation priority compared to the ones with high IVI (Gotelli and Colwell 2011). In Cobaba community forest, 35 species had an IVI less than 1% each. The species with the lowest IVI were: *Staudia kamerunensis*, *Sterculia rhinopetala*, *Mansonia altissima*, *B. toxasperma*, *Swartzia fistuloides* and *Gilbertiodendron brachystegioides*. Therefore, conservation and regeneration priority should be given to those species having low importance value index.

**Diameter class distribution of species**

The diameter structures of the different species have been classified into three groups: species with a complete or truncated bell-curve distribution; species with an erratic or limited distribution; and species with an exponentially decreasing curve distribution. These three types of distribution were also observed by Durrieu de Madron and Forni (1997) in the forests of eastern Cameroon.

Class frequency distribution of 32 species exhibited a tendency toward a bell-curve distribution indicating a regeneration deficit with the largest numbers concentrated above the minimum required exploitable diameter. This type of structure is representative of light species (Rollet 1974) and is found in Cameroon on the scale of several million hectares of the national inventory (ONADEF 1992). Durrieu de Madron and Forni (1997) citing Letouze (1968) explained that, this type of distribution could correspond to a past colonization of the savannah by the forest in the South-East Cameroon zone. Thus, the light-tolerant species that can no longer regenerate in the shade of the understorey present a deficit in numbers in the small diameter classes. Species with an erratic or limited distribution show a total absence of certain diameter classes. Species with an exponentially decreasing curve distribution have a constant regeneration over time and therefore will not cause problems with their exploitation. The management of species with bell-shaped and erratic distribution requires special attention. Indeed, the natural regeneration of these species is problematic and an excessive logging can compromise the recovery potential (Durrieu de Madron et al. 1998; Sepulchre et al. 2008).

**Harvestable volume**

In the production forest, it is important for the manager to know how much harvestable volume is available. The harvestable timber was calculated based on the volume tables established during the phase 2 of the national inventory (CENADEFOR 1985). Although some studies have shown that these volume tables underestimated the volume (Tchatat et al. 2008; Fayolle et al. 2013; Ligot et al. 2019), they are still in force and are those imposed by the Cameroon administration and implemented in the TIAMA software (MINFOF 2019).

A gross harvestable volume of 31929.21 m$^3$ has been estimated for stems that have already reached the minimum exploitable diameter. Considering a 30-year rotation, the annual exploitable volume is 1064.30 m$^3$ per year. This annual volume is slightly higher than that of 902.30 m$^3$ per year estimated by Dethier (2002) in the Kompia community forest in eastern Cameroon. Almost the half of the exploitable volume is made up of group 3 species, for which the market is very limited. Group 1 and 2 species for which there is a large market represent 29.82% of the exploitable volume. *T. scleroxylon* accounts for 16.69% of the harvestable volume. In Cameroon, this species is one of the most exploited forest timber species (Eba’a Atyi et al. 2013; Cerutti et al. 2016; Mahonghol et al. 2016). However, in recent years, its proportion has increased from about 24% of total log exports in 2010 to about 7% in 2015, while some others, such as *E. ivorense*, have increased from about 20 to 31% (Cerruti et al. 2015). *E. ivorense* and *E. cylindicum* which are among the most abundant species in the Cobaba community forest, are also among the five most exploited timber species in Cameroon (Eba’a Atyi et al. 2013). Some abundant species such as *R. heudelotii* and *I. gabonensis* do not produce timber of high value, but do produce non-timber forest products (seeds and fruits) among the most collected by local population in many parts of the country.

**Implications for Forest management**

From the analysis of the number of individuals of each species, it appears that some species (12) are very poorly represented in the community forest (density less than 0.03 stems ha$^{-1}$). In order to preserve them, we recommend banning their exploitation. Among these species are first and second category commercial species such as *B. toxasperma*, *G. cedrata*, *G. tessmannii*, *L. alata*, *M. altissima*, *S. rhinopetala* and *D. benthamianus*. Some of the poorly represented species also have an erratic diameter structure and therefore...
present regeneration problems and a risk of disappearance from the community forest if they are continuously logged. In order to ensure the renewal of the wood resource for each exploited species, a well-conformed seed tree with a diameter greater than the minimum exploitable diameter must be left every 10 ha. The managers of this community forest should respect the minimum exploitable diameter of species and also consider the reforestation of areas disturbed during logging (logging gaps).

Conclusion

This study carried out in the Cobaba community forest in eastern Cameroon identified 65 species of commercial timber, belonging to 58 genera and 26 families. This forest has a high diversity, however many species are very poorly represented with densities below 0.03 stems ha⁻¹. A volume of timber of 31,929.21 m³ has been estimated for trees having reached the minimum exploitable diameter. About 56% of this volume is made up of high and medium commercial value species for which market demand exists. We recommend that species with very low densities be excluded from logging. It is also important that the exploitation of this forest respects the legislation and standards existing in Cameroon and that measures be taken to preserve seed trees and to restore sites that have been degraded by the exploitation.

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Disclosure statement

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### Appendix 1. Volume table for tree species used for estimating harvestable volume \((V = \text{volume}; D = \text{diameter at height breast})\)

| Species                     | Formula                      | \(a\)       | \(b\)       | \(c\)       |
|-----------------------------|------------------------------|-------------|-------------|-------------|
| *Entandrophragma candollei* | \(V = aD^b\)                | 0.154       | 0.0009482   |             |
| *Milicia excelsa*           | \(-0.305\)                  | 0.0009946   |             |             |
| *Pericopsis elata*          | \(-0.609\)                  | 0.0009668   |             |             |
| *Guarea cedrata*            | \(-0.263\)                  | 0.0009067   |             |             |
| *Nesogordonia popaverifera* | \(0.397\)                   | 0.0007066   |             |             |
| *Guarea thompsonii*         | \(-0.263\)                  | 0.0009067   |             |             |
| *Logania alata*             | \(-0.222\)                  | 0.0008664   |             |             |
| *Terminalia superba*        | \(V = a + bD + cD^2\)       | 1.858       | \(-0.03518\)| 0.0010283   |
| *Triplochiton scleroxylon*  | \(-0.044\)                  | \(-0.00162\)| 0.0009825   |
| *Entandrophragma cylindricum* | \(0.215\)           |             |             |             |
| *Desbordesia glaucescens*   | \(-0.263\)                  | \(-0.03518\)| 0.0010283   |
| *Alstonia boonei*           | \(-0.263\)                  | \(-0.03518\)| 0.0010283   |
| *Ricinodendron heudelotii*  | \(-0.263\)                  | \(-0.03518\)| 0.0010283   |
| *Triplochiton scleroxylon*  | \(-0.044\)                  | \(-0.00162\)| 0.0009825   |
| *Entandrophragma candollei* | \(0.154\)                   | 0.0009482   |             |             |
| *Milicia excelsa*           | \(-0.305\)                  | 0.0009946   |             |             |
| *Pericopsis elata*          | \(-0.609\)                  | 0.0009668   |             |             |
| *Guarea cedrata*            | \(-0.263\)                  | 0.0009067   |             |             |
| *Nesogordonia popaverifera* | \(0.397\)                   | 0.0007066   |             |             |
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| *Logania alata*             | \(-0.222\)                  | 0.0008664   |             |             |
| *Triplochiton scleroxylon*  | \(-0.044\)                  | \(-0.00162\)| 0.0009825   |

Source: CENADEFOR 1985
