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DIVERSITY, STRUCTURAL PARAMETERS AND NON-TIMBER FOREST PRODUCTS IN THE FOREST RESERVE OF BONEPOUPA (DOUALA, CAMEROON)

DIVERSIDADE, PARÂMETROS ESTRUTURAIS E PRODUTOS FLORESTAIS NÃO MADEIREIROS NA RESERVA FLORESTAL DE BONEPOUPA (DOUALA, CAMARÕES)

Jean Paul Kamdem[1] Jules Richard Priso[2] Din Ndongo[3]

ABSTRACT

In order to come up with a sustainable use of forest ecosystems in Cameroon, its vegetal diversity has been inventoried; the plant potentials and the structural parameters were studied in the forest reserve of Bonepoupa. Ten non-continuous plots of 200 m² were done and the materialization of the lines was done with a topofil put at the centre of the field with ropes at 5 m each of the topofil. In addition, ninety people were interviewed in order to know the potential use of species in this region. Up to 172 individuals with Diameter at Breast Height (DBH) ≥ 5 cm divided into 27 species, 25 genera and 18 families were inventoried and the coefficient of abundance-dominance was determined. The diversity index of Shannon (H') was $H'_1 = 4.17 \pm 0.45$ with $H'_1 max = 4.75$ and the evenness was $R_1 = 0.88$. Taking into account herbaceous species, H' determined by the coefficient of abundance-dominance was $H'_2 = 4.74 \pm 0.56$ with $H'_2 max = 5.70$ and the evenness was $R_2 = 0.83$. The total basal area was 19.69 m²/ha and the density was 860 individuals/ha. These results indicate that herbaceous significantly modifies the value of the diversity index and that forest reserve of Bonepoupa is experiencing a problem of conservation which is due to a lack of its appropriate management. The knowledge of non-timber forest products and their use as food as well as medicinal resources by local population might be helpful for the sustainable management of resources in this forest reserve.

Keywords: forest reserve; structural parameters; vegetal diversity; non-timber forest products.

RESUMO

A fim de chegar a uma utilização sustentável dos ecossistemas florestais na República dos Camarões, a diversidade vegetal tem sido amostrada com intuito de ressaltar o potencial das plantas; e os parâmetros estruturais que foram estudados na reserva florestal de Bonepoupa. O levantamento foi realizado pelo método de amostragem aleatória, onde foram plotadas dez parcelas de 200 m², distanciadas por uma linha feita com um "topofil" colocado no centro do campo com cordas de 5 m cada uma. Além disso, noventa pessoas foram entrevistadas com o objetivo de conhecer o potencial de uso das espécies nessa região. No total foram amostrados 172 indivíduos com diâmetro a altura do peito (DAP) ≥ 5 cm, distribuídos em 27 espécies, 25 gêneros e 18 famílias. Determinou-se o coeficiente de abundância-dominância. O índice de diversidade de Shannon (H') foi $H'_1 = 4,17 \pm 0,45$ com $H'_1 max = 4,75$ e a equabilidade foi $R_1 = 0.88$. Levando em consideração as espécies herbáceas, o H' determinado pelo coeficiente de abundância-dominância foi $H'_2 = 4,74 \pm 0,56$ com $H'_2 max = 5,70$ e a equabilidade foi $R_1 = 0,83$. A área basal total foi 19,69 m²/ha e a densidade foi 860 indivíduos/ha. Analisando-se os resultados obtidos, pôde-se concluir que as herbáceas modificaram significativamente o valor do índice de diversidade e também que a reserva florestal de Bonepoupa está passando por um problema de conservação por falta de gestão adequada. O conhecimento dos produtos florestais não madeireiros, bem como seus usos alimentares e medicinais pela

1 Botânico e Ecologista, Doutorando do Programa de Pós-Graduação em Ciências Biológicas: Bioquímica Toxicológica, Universidade Federal de Santa Maria, Av. Roraima, 1000, CEP 97105-900, Santa Maria (RS), Brasil. kamdemjeanpaul2005@yahoo.fr / jpkamdem@gmail.com

2 Botânico, Dr., Professor do Departamento de Botânico, Université de Douala, Universidade de Douala, Caixa Postal 24157, Douala, Camarões. r_priso@yahoo.fr

3 Botânico, Dr., Professor do Departamento de Botânico, Université de Douala, Universidade de Douala, Caixa Postal 8948, Douala, Camarões. ndongodin@yahoo.com

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população local, poderia ser útil para a gestão sustentável dos recursos nesta reserva florestal.

Palavras-chave: reserva florestal; parâmetros estruturais; diversidade vegetal; produtos florestais não madeireiros.

INTRODUCTION

The context of biodiversity nowadays appears to be a matter that should be given permanent concern by encouraging and maintaining its conservation. In developing countries, forests provide multiple local, regional and global ecosystem services (CHAZDON, 2008). For instance, at the global scale, they contribute to climate regulation, whereas at the regional scale, they provide water storage capacity and at the local scale they can support pest regulation, pollination, seed dispersal and soil fertility (IIDD, 2005; GUARIGUATA and BALVANERA, 2009). Unfortunately, both the biodiversity and the functioning of these forest ecosystems are under threat from human activities including forest habitat fragmentation through conversion to agriculture as well as other land-use due to overpopulation (OZENDA, 2000; DIN and NGOLLO, 2002; DIN et al., 2002; 2008; DOUMEGNE et al., 2003; PRISO et al., 2010). Such activities contribute for the reduction of biodiversity and could lead to species extinction. PUIG (2001) reported that tropical areas are particularly affected by the reduction in biodiversity which is accentuated in Africa and mostly in coastal evergreen rain forest in Cameroon, at the border of Congolese and Biafraen meridional areas (LETOUZEY, 1968; 1985). RIERA and ALEXANDRE (2004) attest to this matter that 34,000 species are threatened to disappear. This human activity not only leads to the disappearance of some species but also modifies specific diversities. Considering Africa on a small scale, Cameroon has the largest ecosystem of the sub-region and it is among the countries with the richest forest in Africa (FOMETE and TCHANOU, 1998).

Given that loss of biodiversity can have negative impacts on the functioning and stability of ecosystems (DUFFY, 2009; CARDINALE et al., 2011), conservation efforts have increasingly focused on natural recovery and active restoration of degraded ecosystems in order to restore both ecosystem services and biodiversity (CHAZDON, 2008; CHAZDON et al., 2009; REY BENAYAS et al., 2009). However, in Cameroon and in some tropical countries, the identification of areas to be protected is not always preceded by inventories of the biodiversity that will enable the inventory of resources whereas knowing the local flora is a necessity in order to preserve biodiversity (IRM, 2006). Thus, a good knowledge on their composition and their structure is therefore important in order to conceive them for a sustainable use.

This work aims at determining the vegetal diversity, the plant potentials and structural parameters in the forest reserve of Bonepoupa with a view not only to protect the environment but also for a sustainable and effective conservation as well as the management of biodiversity.

MATERIALS AND METHODS

Study area

The forest reserve of Bonepoupa is located in Douala at the Littoral region (4º10' N, 9º 43' E) where we have a tropical climate with two seasons: a dry season from December to February and a rainy season that starts in March and ends in November. Temperatures, relatively elevated, are around 27°C, with the range of temperature slightly varying from 3 to 4°C. The vegetation belongs to the coastal evergreen rainforest (0-100 m altitude), which is characterized by the presence of some species such as *Lophira alata* and *Coula edulis*. Humidity, which is relatively elevated, varies from 80 to 90% in the rainy season and from 50 to 60% in the dry season (MINEPAT, 2002). The site of our study was on the lengthening of the coastal evergreen rainforest. Our study was conducted from October to November.

Realization of the plots

Ten surfaces of 200 m² were plotted in the forest reserve of Bonepoupa. During the survey of the plot, structural homogeneity of the vegetation was taken into account, avoiding shading graduated or farming areas. Ten non-continuous plots of 200 m² were done randomly. The materialization of the lines was carried out with a topofil (a rope field that is used to delineate plots) put at the centre of the field with ropes at 5 m each of the topofil. All

individuals with Diameter at Breast Height (DBH) ≥ 5 cm were marked, counted, identified and measured with a forest ribbon. In each survey, we determined the coefficient of abundance-dominance that determines the number of individual of a species with its degree of recovery (BRAUN-BLANQUET et al., 1952; MASSENS, 1997) with a scale made of six signs that looks as follows:

+ : simple presence, medium size recovery (MSR) = 0.1% ; 1 : less abundant individuals recovering less than 1/20 of the surface where the survey was carried out, MSR = 2.5% ; 2 : very abundant individuals recovering between 1/20 to 1/4 of the surface where the survey was carried out, MSR= 15%; 3 : individuals recovering between 1/4 to 1/2 of the surface, MSR = 37.5% ; 4 : individuals recovering between 1/2 to 3/4 of the surface, MSR = 62.5% ; 5 : individuals recovering more than 3/4 of the surface, MSR = 87.5%. These signs of abundance-dominance have enabled to calculate, for each species, the medium recovery and the mark of presence (MP) that corresponds to the number of the individuals of the species i (Ni) on the total amount of the individuals (N) or the middle recovery of the species i (MSRi) on the total recovery of the individuals (MSR). In other words, MP = Ni/N (woody individuals) or MP = MSRi /MSR (woody + herbaceous species). Therefore, the diversity index of Shannon-wiener (H') (SHANNON, 1948) used in ecology as a measure of specific diversity is:

H' = - ∑ MP x Ln MP. H' varies from 0 (if the stocking is made of only one species or if each species is represented by one individual in the stocking) to H'max (H'max = LnS, with S = total number of species) in the case that all the species in the survey presents similar abundance. Usually, H'= 4.5 to 5 for the most diversified ecosystems as stated by LOBRY et al. (2003); WALA et al. (2005). The advantage of this index is that it takes into account the number of species and the evenness of the species. In our research, however, H'_1 corresponds to the diversity index that uses woody individuals, whereas, H'_2 uses the abundance-dominance coefficient (woody and herbaceous species).

Evenness of Pielou (R) was calculated as follow: R= H'/H'max = H'/LnS. It varies from 0 when only one species is dominant to 1 when all the species have the same abundance (LOBRY et al., 2003; WALA et al., 2005). In other words $0 \leq R \leq 1$. According to PIELOU (1966), it enables us to appreciate the disorder related to the population.

The acquisition of knowledge on plant potential in Bonepoupa´s region

For each identified species, samples were collected in order to constitute a duplicate herbarium of priority. Ninety (90) people were interviewed about the potential use of species in this region. To select respondents, we were interested to holders of traditional knowledge such as parents and other people (who develop plant gardens behind their house). They know and use plants for various uses (medical purposes, feeding, selling, self-protection, house building or any other reason). We were also interested in traditional healers. In addition, it should be mentioned that in order to keep their knowledge secret and the fear of facing competitors made our respondents reluctant to give us some information, which made our investigation difficult. The main purpose of this survey was to collect qualitative data that can be proven through high frequency in use of plants.

Statistical analysis

Values were expressed as mean ± SE (standard error of mean). The diversity index was compared using Student's t-test and the results were considered significantly different with $p < 0.05$.

RESULTS

Structural parameters

Inside the vegetal formation, the environment is made of a population more or less close from place to place and is constituted of ABCD layers. This environment presents some herbaceous species among which we have *Asystasia gangetica* (Acanthaceae), *Cercestis camerunensis* (Araceae), *Costus afer* (Costaceae), *Melastomastrum segregatum* (Melastomataceae), *Liparis nervosa* (Orchidaceae), *Stachytarpheta cayennessis* (Verbenaceae). 172 individuals with DBH ≥ 5 cm divided into 27 species, 25 genera and 18 families were registered in the inventory (Table 1).

The Gentianaceae and Apocynaceae families were the most abundant; with 38 individuals (22.09%) and 24 individuals (13.95%) respectively; therefore, giving a total of 36.04 %. The highest numbers of individuals were *Anthocleista schweinfurthii* (38), *Macaranga heterophylla* (14), *Rauvolfia vomitoria* (12), *Xylopia aethiopica* (10),

xylopia sp. (11). The Gentianaceae, Annonaceae and Apocynaceae families had the most abundant woody individuals. The highest number of individuals per hectare were found in *Anthocleista schweinfurthii* (190 ind/ha), *Macaranga heterophylla* (70 ind/ha), *Garcinia mannii* (55 ind/ha), *Rauvolfia vomitoria* (60 ind/ha), *Xylopia aethiopica* (50 ind/ha), *Xylopia* sp. (55 ind/ha). The density of woody individuals with DBH ≥ 5 cm was 860 ind/ha. The species with the highest diameters were *Anthocleista schweinfurthii* (25.10 cm), *Dichostemma glaucescens* (21.34 cm), *Omphalocarpum* sp. (25.62 cm), *Xylopia aethiopica* (19.47 cm). However, the most important medium size diameters were *Deinbollia maxima* (14.53 cm), *Funtumia elastica* (18.18 cm), *Lophira alata* (15.28 cm), *Tabernaemontana* sp. (14.49 cm).

TABLE 1: Structural parameters (density, diameter and basal area) of species with DBH ≥ 5 cm in the forest reserve of Bonepoupa.

TABELA 1: Parâmetros estruturais (densidade, diâmetro e área basal) das espécies de DAP ≥ 5 cm dentro da reserva florestal de Bonepoupa.

Species	Family	N	Density (ind/ha)	Dm (cm)	St (m^2/ha)
Anthocleista schweinfurthii Gilg.	Gentianaceae	38	190	25.10	9.40
Anthonotha macropylla P.Beauv.	Caesalpiniaceae	3	15	12.74	0.19
Canthium arnoldianum (De Wild. & T. Durand) Hepper.	Rubiaceae	2	10	12.08	0.11
Cola sp.	Sterculiaceae	2	10	8.16	0.05
Deinbollia maxima Gilg.	Sapindaceae	4	20	14.53	0.33
Dialium sp.	Caesalpiniaceae	6	30	11.38	0.30
Dichostemma glaucescens Pierre	Euphorbiaceae	1	5	21.34	0.18
Erythrophleum ivorense A. Chev.	Caesalpiniaceae	7	35	13.27	0.48
Ficus eriobotryoides Kunth & Bouche	Moraceae	5	25	13.63	0.36
Funtumia elastica (P. Preuss) Stapf	Apocynaceae	9	45	18.18	1.17
Garcinia mannii Oliv.	Clusiaceae	11	55	10.42	0.47
Harungana madagascariensis Lam. ex Poiret	Hypericaceae	8	40	12.55	0.49
Lophira alata Banks ex. C.F. Gaertn.	Ochnaceae	3	15	15.28	0.27
Macaranga heterophylla (Müll. Arg.) Müll. Arg.	Euphorbiaceae	14	70	13.18	0.95
Musanga cecropioides R.Br. & Tedlie	Urticaceae	4	20	15.85	0.39
Myrianthus arboreus P. Beauv.	Urticaceae	3	15	11.67	0.16
Omphalocarpum sp.	Sapotaceae	2	10	25.62	0.52
Pausinystalia sp.	Rubiaceae	1	5	11.15	0.05
Piptadeniastrum africanum (Hook.f.) Brenan	Mimosaceae	6	30	9.44	0.21
Rauvolfia vomitoria Afzel.	Apocynaceae	12	60	13.64	0.88
Staudtia kamerunensis Warb.	Myristicaceae	3	15	14.02	0.23
Tabernaemontana sp.	Apocynaceae	3	15	14.49	0.25
Thunbergia vogeliana Benth.	Acanthaceae	1	5	9.24	0.03
Triplochiton scleroxylon K. Schum.	Sterculiaceae	1	5	11.80	0.05
Uapaca guineensis Müll. Arg.	Phyllanthaceae	2	10	7.32	0.04
Xylopia aethiopica (Dunal) A. Rich.	Annonaceae	10	50	19.47	1.49
Xylopia sp.	Annonaceae	11	55	12.13	0.64
Total	-	172	860	-	19.69

N = number of individuals; Dm = arithmetical average of all individuals of species; St = total basal area of the species. The total basal area calculated from the basal area of each species is 19.69 m^2/ha.

The least important ones are *Piptadeniastrum africanum* (09.44 cm) and *Thunbergia vogeliana* (09.24 cm).

The total basal area calculated from the basal area of each species was 19.69 m^2/ha. The diversity index of Shannon-wiener calculated from woody species with DBH ≥ 5 cm gives $H'_1 = 4.17 \pm 0.45$ with $H'_1max = 4.75$ and the evenness is $R_1 = 0.88$. Taking into account herbaceous species, the highest MSR based on abundance-dominance of species were found in *Anthocleista schweinfurthii*, *Erythrophleum ivorense*, *Garcinia mannii, Harungana madagascariensis*. The diversity index of Shannon-wiener calculated gives $H'_2 = 4.74 \pm 0.56$ with $H'_2max = 5.70$ and the evenness was $R_2 = 0.83$.

Non-timber forest products found in the course of the inventories

Table 2 represents the classification in age group of the local people interviewed on the use of the species registered.

Non-timber forest products used for food and craft

Myrianthus arboreus possesses almonds or seeds that are consumed by the local population. The stems of various woody species produce non-timber forest products such as *Xylopia aethiopica* that are used to reinforce constructions. Furthermore, its fruits are used as seasonings in flavouring many local foods. The long roots of *Cercestis camerunensis* are used to tie yams and their fibrous hearts are used as fishing-lines.

TABLE 2: Classification in age group of the local people interviewed on the use of the registered species.

TABELA 2: Classificação por grupo de idade da população local que foi questionada sobre o uso das espécies registradas.

Class centres	Age class intervals	Respondents	Percentage (%)
25	[20-30[	1	1.11
35	[30-40[	15	16.67
45	[40-50[	40	44.44
55	[50-60[	28	31.11
65	[60-70[	6	6.67
TOTAL	-	90	100

Non-timber forest products used as medicinal plants

Table 3 shows the species used for medicinal purposes in the forest reserve of Bonepoupa.

DISCUSSION

The comparison of the diversity index by t-test shows a significant difference ($p < 0.05$) between Bonepoupa-woody ($H'_1 = 4.17 \pm 0.45$) and Bonepoupa-woody + herbaceous ($H'_2 = 4.74 \pm 0.56$). The consideration of herbaceous, did not only influences the value of the maximal diversity (H'max), but also the diversity index (H'). DIBONG et al. (2003) reported H'= 4.54 in the forests located between the plain and southern Cameroon stray, PRISO et al. (2010) reported H'= 4.31 in the forest reserve of « Bois des singes » in Cameroon, SSEGAWA and NKUUTU (2006) reported H'= 4.67 in Ougandan forests, while Ngueguim et al. (2010) reported value of the diversity index in the range of 1.19 to 2.74 in the forest plantation of « Mangombé » at Edea in Cameroon. If we compare with species diversity of riparian forest of Rio Paraguai or with riparian forest in the city of Lages, in Brazil, DAMASCENO-JUNIOR et al. (2005) and NASCIMENTO et al. (2011) found respectively H'= 2.7 and H' = 3.6, whereas TONIATO and OLIVEIRA-FILHO (2004) obtained species diversity ranging from 2.66 to 3.69 in tropical semideciduous southeastern Brazil, which are lower than the diversity index found in the forest reserve of Bonepoupa in Cameroon. The Shannon diversity index (H') usually varies from 1.3 to 3.5 and may exceed 4.0 to reach 4.5 in tropical forest environments (FELFILI and REZENDE, 2003). In this view, our values of diversity index can be considered high. DAJOZ (1995) and NGUEGUIM et al. (2010) stated that an elevated diversity index indicates a high diversity and also a good reconstitution of the flora diversity, thanks to the favourable environment that enables the installation of many species. The presence of Urticaceae, represented by *Musanga cecropioides* which is a pioneering species characterizing secondary forests and emptied forests was observed. Moreover, the high value of evenness when taking into account only woody species ($R_1 = 0.88$) also attests the richness of the floristic vegetation.

TABLE 3: Species used for medicinal purposes in the forest reserve of Bonepoupa.
TABELA 3: Espécies usadas com as finalidades medicinais na reserva florestal de Bonepoupa.

Species	Disease treated	Part used	Preparation	Administration
Anthocleista schweinfurthii	fever	bark leave	decoction	orally
Asystasia gangetica	asthma ease childbirth	leave whole plant	maceration infusion	orally
Costus afer	syphilis	Juice of stem bark	-	application on the chancres
Garcinia mannii	malaria	bark leave	decoction	orally
	antidot against venom	seed	decoction	orally
	constipation	bark	infusion	orally
Harungana madagascariensis	fever	bark	infusion	orally
	mycosis	bark	pounding	on the skin
	anemia	leave	pounding	eye instillation
Lophira alata	tooth decay	bark	decoction	inhalation
Musanga cecropioides	ease childbirth	leave	decoction	orally
	tooth decay	young leave	decoction	inhalation
Omphalocarpum sp.	intestinal worms headache	bark	decoction	orally
Piptadeniastrum africanum	itching skin painful periods	bark	maceration	skin washing orally
Rauvolfia vomitória	malaria	leave	decoction	orally
Staudtia stiputata	Hemorrhoid	Root	maceration	Orally
Tabernaemontana Montana	Malaria	leave	decoction	Orally
Xylopia aethiopica	Hemorrhoid Rheumatism	Root	Burn	scarification

The distribution of individuals into classes of diameter (Figure 1) revealed that species with weak diameters are the most represented ones, characterizing therefore dynamic forest which is in reconstitution and rejuvenation (FRONTIER and PICHOD-VIALE, 1998), as a result of several incursions, and this represents 76.74% of the total amount of the individuals.

They are easy to cut and use to build houses as well as firewood. Moreover, the barks of some of these species are sold in order to spice palm wine like the case of *Garcinia mannii*. On the order hand, some rare trees on this field can be those that are not useful in forest activities or those which are useful for traditional healing. The analysis of the distribution of individuals in classes of diameter in the forest reserve of Bonepoupa (Figure 1) showed a population in course of reconstitution, demonstrating the presence of secondary species that appeared after the destruction of the forest, tending to restore the floristic and the structural characteristics of the former ecosystem.

The value of total basal area calculated from the basal area of each species is 19.69 m^2/ha. Sunderland et al. (2003) reported a total basal area varying from 18.6 to 42.1 m^2/ha in forest reserve of Takamanda. PRISO et al. (2010) reported 25.7 m^2/ha in the forest area of Bangue, while ADOU et al. (2005) reported 31.7 m^2/ha in the national park of Taï. In the same scheme, DIBONG et al. (2003) reported 21.2 m^2/ha in the forests located between the littoral plain and the south Cameroonian stray. The weak value of the total basal area might not be due only to the high density

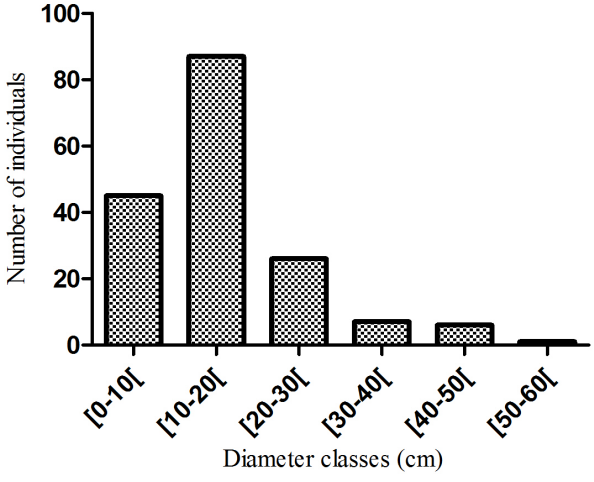

FIGURE 1: Distribution of individuals and diameter classes in the forester reserve of Bonepoupa.

FIGURA 1: Distribuição dos indivíduos por classe de diâmetro na reserva florestal de Bonepoupa.

of some species like *Anthocleista schweinfurthii* (190 ind/ha), *Macaranga heterophylla* (70 ind/ha), *Garcinia mannii* (55 ind/ha), *Rauvolfia vomitoria* (60 ind/ha), *Xylopia aethiopica* (50 ind/ha), *Xylopia* sp. (55 ind/ha), but also to the abundance of species that are weak in diameter (Table 1).

Several studies have helped to identify medicinal plants in Cameroon (ATANGANA, 1998; MBITA, 1999; GUEDJE and FANKAP, 2001; JIOFACK et al., 2008; NDUMBE et al., 2009) and in Democratic Republic of Congo, a neighbouring country to Cameroon (IRM, 2006). In these studies, all stock-lists and harvests of these researchers, in association with traditional healers, have been collected in almost all through Cameroon wide. Non-timber forest products are a great source of income in developing countries as well as they constitute an efficient means of conservation and also of valorisation of biodiversity. They generate income to people living around forest and are used in order to satisfy needs concerning food, traditional medicine, craft, ornament, and also for religious and sociocultural activities (FOMETE and TCHANOU, 1998; TCHATAT et al., 1999; TCHATAT and NDOYE, 2006, NOUBISSIE et al., 2008). In this view, oleaginous seeds of *Myrianthus arboreus* are very rich in linoleic acids (93.50%). However, they contain relatively balanced quantities of amino acid (BUSSON, 1965). They are particularly rich in cystine (9.5%) and can therefore repair a chronic deficiency of sulphur amino acid that some people can eventually suffer from.

CONCLUSION

Overall, it appears that the diversity is high in the forest reserve of Bonepoupa and that herbaceous species significantly modifies the value of the diversity index. Structural parameters (density, diameter and basal area) have shown a population in course of reconstitution, tending to restore the floristic and structural characteristics of the former ecosystem. However, the number of inventoried species was low (27), nevertheless, knowing their structural parameters is essential for their conservation. Non-timber forest products in Cameroon contribute in food security and also to the well-being of those who exploit them. More efforts should be undertaken at the national level to implement conservation, management and sustainable use of this forest reserve, which is the safest place to conceive genetic resources and that can be used as an open-air laboratory.

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