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Regulation of the diametric structure of the Miombo Woodland using the *De Liocourt* method in Mozambique

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ABSTRACT: The aim of this work was to apply the *De Liocourt quotient* in diametric structure evaluation of the Miombo woodland in Mocuba district, in central Mozambique, in order to subsidize logging regulation actions and management. The study was carried out in an area of 4.0 ha, divided into 16 plots of 50 x 50 m, where the CBH ≥ 31.5 cm and total height of all trees were measured and distributed in diametric classes. There were 2075 individuals, distributed in 41 species, 31 genera and 12 families. Fabaceae was the most ecologically important family. The woodland had a density of 519 trees per hectare and a basal area of 27.48 $m^2.ha^{-1}$. The value of the '*q*' quotient for the Miombo woodland was 1.48, indicating that mortality and recruitment rates are not in equilibrium. The logging regulation allowed the withdrawal of 15 trees per hectare in the frequency classes as a whole, to a minimum diameter cutting limit (MDC) of 40.0 cm with a reduction of 2.42 $m^2.ha^{-1}$ of basal area, thus avoiding stagnation of woodland, as well as 2 trees per hectare for a MDC of 50.0 cm with a reduction of 0.45 $m^2.ha^{-1}$ of basal area.

Keywords: floristic, phytosociology, logging, forest management.

Regulação da estrutura diamétrica de uma Floresta de Miombo usando o método *De Liocourt* em Moçambique

RESUMO: Este trabalho teve como objetivo aplicar o método de *De Liocourt* na regulação da estrutura diamétrica de uma floresta de Miombo no distrito de Mocuba, na região central de Moçambique, a fim de subsidiar ações de regulação do corte de madeira e manejo. O estudo foi realizado em uma área de 4,0 ha, dividida em 16 parcelas de 50 x 50 m, onde foram mensuradas as variáveis CAP ≥ 31,5 cm e a altura total dos indivíduos, e distribuídos em classes de diâmetro. Foram registrados 2075 indivíduos, distribuídos em 41 espécies, 31 gêneros e 12 famílias. A Fabaceae foi a família de maior importância ecológica. A floresta apresentou uma densidade de 519 árvores por hectare e área basal de 27,48 $m^2.ha^{-1}$. O valor do quociente '*q*' para a floresta foi de 1,48, indicando que as taxas de mortalidade e recrutamento não se encontram em equilíbrio. A regulação do corte possibilitou a retirada de 15 árvores por hectare no conjunto das classes de frequência, para um diâmetro mínimo de corte (DMC) de 40,0 cm com redução de 2,42 $m^2.ha^{-1}$ de área basal, evitando-se assim a estagnação da floresta, bem como 2 árvores por hectare para um DMC de 50,0 cm com redução de 0,45 $m^2.ha^{-1}$ de área basal.

Palavras-chave: florística, fitossociologia, exploração florestal, manejo florestal.

1. INTRODUCTION

Miombo woodlands are the most disseminated vegetation typology that predominate in the Southern and Eastern regions of Africa, covering approximately 10% of the forest environments of the African continent (DEWEES et al., 2010). This biome had originally 2.7 million km^2, extending from the extreme west in the Atlantic Ocean to the extreme east near the Indian Ocean, between the parallels 3°S and 26°S (MALMER, 2007), being the main forest phytophisiognomy of countries such as Angola, Botswana, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe (CHIDUMAYO, 2013). The Miombo woodlands distinguish from other forest biomes in Africa due to the marked occurrence of species of the genera *Brachystegia* ("miombo" in local languages), *Julbernardia* and/or *Isoberlina*, all belonging to the family Fabaceae (RIBEIRO et al., 2008), in association with species such as *Afzelia quanzensis* Welw., *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon, *Millettia stuhlmannii* Taub., *Parinari curatellifolia* Planch. ex Benth, *Pseudolachnostylis maprouneifolia* Pax, *Pterocarpus angolensis* DC, *Swartzia madagascariensis* Desv., (MARZOLI, 2007; KALABA et al., 2013).

In Mozambique, forest resources from Miombo woodlands are highly relevant socioeconomically as well as environmentally, being the main source of timber that drives the local economy (DNTF, 2010; MATE et al., 2014), in addition to being used as construction material, for non-timber forest products such as fibres, medicinal plants and food; for energy purposes as well as subsistence agriculture (FALCÃO et al., 2007), mainly in the rural areas where 80% of the population is concentrated and have low per capita income (SHACKLETON et al., 2007; FALCÃO et al., 2010).

However, there has been an increase in the pressure on the biome, mainly for timber resources, which has been highly exploited for several purposes, including commercial purposes (timber, fibres and fuel wood), with no concerns regarding conservation and the sustainability of extraction processes (MACKENZIE, 2006; MACKENZIE, RIBEIRO, 2009; EIA, 2014).

As a result of the current model of forest exploitation, the Mozambican Miombo woodland structure has been recording deep changes such as the drastic reduction of several vegetable communities, earth degradation, overexploitation of a reduced number of forest species, specially *Millettia stuhlmannii, Afzelia quanzensis, Pterocarpus angolensis* and *Swartzia madagascariensis*, which represent 78% of timber production in the country (DNTF, 2010; EKMAN et al., 2014). This fact has negatively affected the biome, compromising the growth, sustainability and management of these species (HOFIÇO; FLEIG, 2015; REMANE; THERRELL, 2015). For this reason, the populations of these species are at risk of extinction in the region, being *Swartzia madagascariensis* the most threatened due to the drastic reduction caused by the overexploitation associated to illegal logging (EIA, 2014; EKMAN et al., 2014).

Thus, studies about forest structure, floristic composition and forest dynamics are important steps to subsidize the management of the Miombo biome and allow the development of conservation programs for diversity in Mozambique (HOFIÇO; FLEIG, 2015; RIBEIRO et al., 2017). In this context, Angers et al. (2005) affirmed that diameter distribution assumes particular importance in mapping the horizontal structure of a forest by allowing the characterization of a forest typology. The diametric structure is a powerful indicator of the forest growing stock, in addition to providing resources for decision-making and the management plan to be performed in a given area (MACHADO et al., 2010). It allows to use the diametric structure to help achieve the concept of balanced forest by identifying classes where there is either tree deficit or surplus (RUBIN et al., 2006).

According to Kershaw Jr et al. (2016), the diameter distribution of individuals in balanced forest formations occurs in an exponentially negative way, i.e., corresponding to a decreasing geometric progression (A; Aq^{-1}; Aq^{-2} …; $Aq^{(1-n)}$), where “*A*” represents the number of trees in the lowest diameter class; “*q*” is the *De Liocourt* quotient that determines the curve shape; and “*n*” represents the number of diameter classes. The histogram of frequency of individuals resembles a reverse *J*, with the highest frequency of individuals found in the smallest diameter classes (ANGERS et al., 2005; MACHADO et al., 2010).

According to the concept of balanced forest, or “*De Liocourt*” approach, trees of higher diameter classes must be eliminated since their increment is under the rate of trees of smaller classes (HESS et al., 2014). The application of this management method is directly related to the knowledge of floristic composition, phytosociological structure and diameter and spatial distribution of species (CABACINHA; CASTRO, 2010; HESS et al., 2014). Thus, the integration of these knowledges is essential to manage the Miombo woodlands aiming to a balanced structure and, at the same time, the harmonization of concepts of ecological interactions, functional groups, and phytosociology with sustainable timber production.

In this context, the present study aims to use the *De Liocourt* “*q*” quotient to assess the diametric structure of a Miombo woodland in Mocuba district, Zambézia province, in central Mozambique, for future regulation actions for logging and sustainable management of species.

2. MATERIAL AND METHODS

2.1. Study area

The study was performed in a forest concession area owned by Indústria e Construções Sotomane Limitada. The area comprises 40.000 ha and is located at the Namanjavira Administrative Post, in Mocuba district, Zambézia province, Mozambique, between the geographical coordinates 16°33'58"S and 16°49'22"S South latitude, and 36°32'57"E and 36°47'39"E East longitude, with average altitude 280 m above sea level (Figure 1).

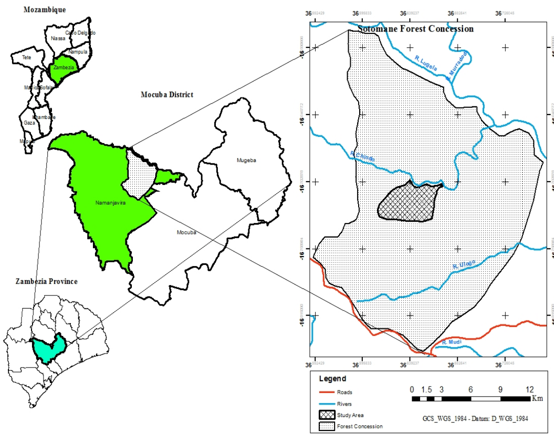

Figure 1. Location of the study area in Mocuba district, Zambézia province, Mozambique.

Figura 1. Localização da área de estudo, no distrito de Mocuba, na província da Zambézia em Moçambique.

According to Köppen classification, the climate in the region is *Aw*, defined as hot tropical, with two distinct seasons, rainy summer and dry winter. The average annual temperature varies between 22 ºC and 27 ºC and the average annual precipitation is 1200 mm, between October and March (PEREIRA, 2006). Soils are predominantly dystrophic red-yellow Latosol, with flat topography varying between 200 and 400 m, and declivity around 5% (IBRAIMO, 2004). The typical phytoecology is the Miombo woodland, in a primary succession stage as predominant physiognomy (GELDENHUYS, 2005; HOFIÇO; FLEIG, 2015). This phytophisiognomy forms a mosaic in the vegetation cover of the study area according to the environmental variations (humidity, temperature and precipitation), microclimate and the occurrence of fire (ZOLHO, 2005; RIBEIRO et al., 2008; RYAN; WILLIAMS, 2011). The area has a history of disturbance by timber exploitation, fire and the common practice of shifting cultivation, being all these factors observed in the data collection.

2.2. Sampling design and data collection

A sampling grid of 16 units x 2500 m^2 (50 m x 50 m) was installed in the 100-ha area, distanced 50 m between lines and 50 m between plots, aiming to incorporate possible variations in the vegetation cover. All timber individuals with diameter at breast height (1.30 m above ground) equal to or above 31.5 cm were measured with measuring tape, georeferenced with GPS and individually identified through a plate for higher practicality in future measurements. The botanical material was collected, and expert literature was used for species identification: *Field guide to trees of Southern Africa* (VAN WYK; VAN WYK, 2011). Species nomenclatures followed the classification of *Angiosperm Phylogeny Group* version III (APG, 2009).

2.3. Data analysis

The horizontal structure was characterized by the calculation of phytosociological absolute and relative parameters of density, dominance, and frequency of species, as well as the value of importance, a parameter resulting from the sum of the three previously cited parameters (KENT; COKER, 2011). Diversity was estimated with the Shannon–Wiener index (H') in the logarithmical scale, and equity was estimated according to Pielou (J') (KENT; COKER, 2011).

In order to assess the diametric structure, a histogram of the frequency of distribution of individuals was developed in diameter classes with 5.0 cm range (ISANGO, 2007; SHIRIMA et al., 2011). Subsequently, diameter distribution was adjusted to the negative exponential model of Meyer (KERSHAW JR et al., 2016) (Equation 1).

$$Y_j = exp^{(\beta 0 + \beta 1.Dj)} + \varepsilon_j \qquad \text{(Equation 1)}$$

where: Y_j is the estimator of the number of trees per hectare in the *j*th DBH class; β_0 and β_1 are the equation coefficients that express the structure of the vegetation according to diameter distribution; D_j, is the diameter corresponding to the central *j*th DBH class; and ε_j is the random error.

After the coefficients β_0 and β_1 were obtained, the *De Liocourt* "*q*" constant was calculated for the evaluation of the diametric structure, its regulation and subsequent forest management (CABACINHA; CASTRO, 2010; HESS et al., 2014) (Equation 2).

$$q = \frac{e^{(\beta 0 + \beta 1.Dj)}}{e^{(\beta 0 + \beta 1.Dj + 1)}} \qquad \text{(Equation 2)}$$

where D_j, is the diameter corresponding to the central *j*th DBH class; and D_{j+1}, the diameter corresponding to the central *j*th DBH class immediately above.

After obtaining the value of *q*, the equation coefficients β_0 and β_1 and respective adjustments were calculated. With the value of *q*, the curve of difference between the diameter frequencies (observed and estimated) $\hat{\beta}1$ was generated by recalculating the value of Equation 3, indicating which diameter classes had a tree surplus, so they could be removed (ANGERS et al., 2005; HESS et al., 2010). Hess et al. (2014) stated that the minimum diameter cutting limit must be determined by adopting the maturity criterion, i.e., the age at which a tree reaches the growth asymptote, or the exploitation condition.

$$\hat{\beta}1 = \frac{\ln(q)}{D_j - D_{j+1}} \qquad \text{(Equation 3)}$$

The characteristic of this diameter must allow the future volume of periodical removal of the stand to reach a maximum result (HESS et al., 2010). Thus, based on the diameter distribution and the cutting cycle, the minimum cutting diameters were determined at 40.0 and 50.0 cm, established by the Forest and Wild Fauna Law Regulations of the Republic of Mozambique (Decree nº 12/2002). The regulation of number of trees and basal area that can be removed was established to provide the adjustment in the curve of frequency distribution in the forest.

To calculate phytosociological parameters and floristic diversity, the *Mata Nativa 2* software (CIENTEC, 2006) was used, and for the adjustment of the model to describe the diameter distribution the *Statistical Analysis System 9.2* software (SAS Institute, 2011) was used.

3. RESULTS

3.1. Phytosociological and floristic composition

A total of 2075 trees were recorded, and 41 species, 12 families and 31 genera were identified in the study area. *Brachystegia spiciformis* was the most abundant species with 338 individuals corresponding to 22.97% of the value of importance (VI), followed by *Ficus ingens* with 149 individuals (5.21% VI), *Diplorhynchus condylocarpon* with 134 individuals (5.09 VI), *Julbernadia globiflora* with 124 individuals (4.83% VI), and *Pseudolachnostylis maprouneifolia* with 104 individuals (3.8% VI). These five species represented 27.49% of the total number of species found in the study area, and 41.78% of the total value of importance (Table 1).

The families with the highest number of species were Fabaceae (25), Euphorbiaceae (4) and Combretaceae (3). Nine other families showed individuals of only one species. These three main families represented 78% of the specimens listed, and the nine remaining families represented 22% of the total, evidencing the low relative abundance of individuals in these families. The floristic diversity estimated by the Shannon-Wiener index (H') was high, equal to 3.21 $nats.ind^{-1}$, and Pielou's equity (J') was 0.85.

3.2. Diametric structure

The diameter distribution of the forest can be observed in Figure 2. The curve of the observed frequency has a reverse *J* shape, which is typical of native forests. The total density of this vegetation was 519 $ind.ha^{-1}$ with a basal area of 27.48 $m^2.ha^{-1}$. However, there is an irregular distribution of individuals, with a variation between classes and tree deficit, which is reflected on the initial diameter classes of 10 to 15 cm, 20 to 25 cm, as well as in the intermediate diameter class of 50 to 55 cm, evidencing an unbalanced forest.

3.4 Regulation of diametric structure and timber

The value of the *De Liocourt* "*q*" quotient for the studied forest, calculated by equation 2, was 1.48; the adjusted equation coefficients of distribution of frequency were β_0 = 6.180, β_1 = -0.079; the adjusted coefficient of determination ($R^2_{aj.}$= 0.946), the mean error of estimates (S_{yx} = 0.2962), and the value of *F* 195.32.

In this study, the alternative to regulate the diametric structure and cutting by the *De Liocourt* method established two minimum diameters cutting limit of 40.0 cm and 50.0 cm according to the Decree nº 12/2002 from the Forest and Wild Fauna Law Regulations of the Republic of Mozambique. For the calculation of the estimated frequencies, the *Meyer* equation coefficients were recalculated, with the results β_0 =

6.069 and β_1 = -0.0789 for the minimum diameter of 40.0 cm, and β_0 = 5.992 and β_1 = -0.789 for the minimum diameter of 50.0 cm. It was also observed that the diameter distribution behaved as expected for uneven-aged heterogeneous forests, with the reverse *J* shape.

Table 2 shows the estimation of basal area for trees that can be removed in each diameter class for the minimum cutting diameters of 40.0 cm. Thus, the management of trees with minimum diameters cutting of 40.0 cm allowed the removal of 15 trees with diameters 40 to 45 cm, and 55 to 60 cm, which represented 15 trees per hectare, basal area 2.42 $m^2.ha^{-1}$, totalling 9.68 m^2 of basal area to be removed, corresponding to 8.81% of cutting intensity of basal area per hectare.

Table 3 shows the estimation of basal area for trees that can be removed in each diameter class for the minimum cutting diameter of 50.0 cm. In this sense, for the management with minimum cutting diameters of 50.0 cm, it was observed that 2 trees could be removed per hectare, distributed in the diameter class 55 to 60 cm, which represented the basal area of 0.45 $m^2.ha^{-1}$, totaling 1.81 m^2 basal area to be removed, corresponding to 1.64% of cutting intensity of basal area per hectare.

Table 1. Phytosociological parameters of the Miombo woodland, in Mocuba district, in Zambézia province, Mozambique.
Tabela 1. Parâmetros fitossociológicos da floresta de Miombo, no distrito de Mocuba, na província da Zambézia em Moçambique.

Species / Families	N	UA	DA	g	VI%
Brachystegia spiciformis Benth. / Fabaceae	338	16	84.50 ± 9.32	5.01 ± 0.07	22.97
Ficus ingens Miq. / Moraceae	149	16	32.25 ± 1.12	2.16 ± 0.11	5.21
Diplorhynchus condylocarpon (Müll.Arg.) Pichon / Apocynaceae	134	16	31.01 ± 0.39	2.04 ± 0.09	5.09
Julbernardia globiflora (Benth.) Troupin / Fabaceae	124	16	31.00 ± 0.97	1.90 ± 0.08	4.83
Pseudolachnostylis maprouneifolia Pax / Euphorbiaceae	104	16	24.25 ± 1.21	1.25 ± 0.09	3.68
Piliostigma thonningii (Schumach.) Milne-Redh. / Fabaceae	86	16	19.00 ± 3.78	1.28 ± 0.07	3.37
Brachystegia boehmii Taub. / Fabaceae	78	16	17.00 ± 1.32	0.94 ± 0.19	2.86
Pterocarpus angolensis DC. / Fabaceae	66	16	14.50 ± 0.89	0.96 ± 0.09	2.72
Parinari curatellifolia Planch. ex Benth. / Chrysobalanaceae	53	15	13.25 ± 0.13	0.80 ± 0.01	2.41
Pteleopsis myrtifolia Engl. & Diels / Combretaceae	52	15	13.00 ± 1.89	0.77 ± 0.07	2.41
Bridelia micrantha Baill. / Euphorbiaceae	49	14	12.25 ± 0.51	0.78 ± 0.04	2.28
Afzelia quanzensis Welw. / Fabaceae	44	12	11.00 ± 0.98	0.84 ± 0.03	2.11
Balanites maughamii Sprague / Balanitaceae	40	15	11.01 ± 1.63	0.63 ± 0.02	2.02
Brachystegia manga De Wild. / Fabaceae	39	15	10.75 ± 0.69	0.61 ± 0.02	1.98
Millettia stuhlmannii Taub. / Fabaceae	40	12	10.00 ± 0.78	0.68 ± 0.08	1.94
Burkea africana Hook. /Fabaceae	34	15	9.50 ± 0.71	0.61 ± 0.06	1.92
Albizia adianthifolia W. Wight / Fabaceae	30	13	8.50 ± 0.97	0.66 ± 0.04	1.79
Deinbollia xanthocarpa Radlk. /Sapindaceae	49	15	12.25 ± 0.31	0.27 ± 0.02	1.78
Brachystegia bussei Harms / Fabaceae	34	13	9.50 ± 0.41	0.51 ± 0.04	1.71
Acacia tortilis Hayne / Fabaceae	35	11	9.75 ± 1.23	0.55 ± 0.06	1.67
Albizia glaberrima Benth. / Fabaceae	30	12	8.50 ± 2.11	0.55 ± 0.02	1.66
Dalbergia melanoxylon Guill. & Perr. / Fabaceae	55	11	13.75± 2.21	0.23 ± 0.01	1.66
Dichrostachys cinerea (L.) Wight & Arn. / Fabaceae	32	11	9.00 ± 1.63	0.54 ± 0.03	1.61
Pericopsis angolensis (Baker) Meeuwen / Fabaceae	28	13	8.50 ± 0.78	0.47 ± 0.03	1.55
Bauhinia tomentosa L. / Fabaceae	28	14	8.00 ± 0.91	0.39 ± 0.02	1.52
Bauhinia galpinii N.E.Br. / Fabaceae	28	11	7.00 ± 2.21	0.42 ± 0.03	1.41
Combretum imberbe Wawra / Combretaceae	27	10	7.75 ± 1.58	0.46 ± 0.04	1.39
Brachystegia longifolia Benth. / Fabaceae	31	8	7.75 ± 0.93	0.42 ± 0.07	1.38
Pseudobersama mossambicensis (Sim) Verdc. / Meliaceae	22	11	6.50 ± 1.09	0.39 ± 0.05	1.28
Cassia abbreviata Oliv. / Fabaceae	19	11	5.75 ± 0.09	0.39 ± 0.03	1.23
Kirkia acuminata Oliv. / Simarobaceae	20	12	6.01 ± 0.27	0.31± 0.06	1.21
Cleistanthus schlechteri Hutch. / Euphorbiaceae	22	8	5.50 ± 0.89	0.41 ± 0.07	1.17
Uapaca nitida Müll.Arg. / Euphorbiaceae	22	7	5.50 ± 1.12	0.39 ± 0.06	1.12
Swartzia madagascariensis Desv. / Fabaceae	22	10	5.25 ± 1.01	0.30 ± 0.01	1.05
Erythrophleum suaveolens (Guill. & Perr.) Brenan / Fabaceae	20	8	5.00 ± 0.69	0.29 ± 0.02	1.02
Combretum apiculatum Sond. / Combretaceae	20	8	5.00 ± 0.46	0.25 ± 0.01	0.96
Berchemia discolor Hemsl. / Rhamnaceae	16	7	4.00 ± 0.09	0.27 ± 0.01	0.88
Faurea speciosa Welw. / Proteaceae	16	7	4.00 ± 0.29	0.25 ± 0.02	0.85
Albizia versicolor Welw. ex Oliv. / Fabaceae	14	9	3.50 ± 0.94	0.18 ± 0.02	0.83
Acacia nigrescens Oliv. / Fabaceae	15	8	3.75 ± 0.11	0.19 ± 0.03	0.81
Acacia sieberiana DC. / Fabaceae	10	8	3.15 ± 0.07	0.25 ± 0.04	0.79
Total	2075	16	518.75 ± 14.12	27.48 ± 6.05	100

where: decreasing values according to *VI* (Value of Importance); *N* = number of found individuals of the species; *UA* = number of sampling units where the species occurs; *G* = species basal area ($m^2.ha^{-1}$) ± standard deviation; *DA* = absolute density of species (average number of individuals.ha^{-1} ± standard deviation); *VI%* = species value of importance.

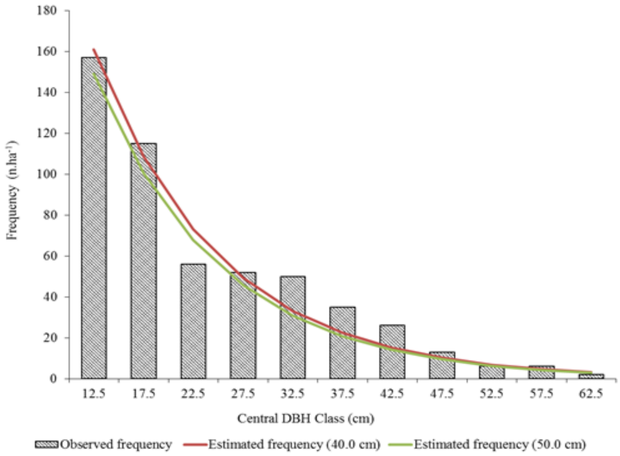

Figure 2. Observed frequency and estimated for the minimum diameters cutting (MDC) of 40.0 cm and 50.0 cm for Miombo woodland in the study area in Mocuba district, Zambézia province, Mozambique.
Figura 2. Frequência observada e estimada para os diâmetros mínimos de corte (DMC) de 40,0 cm e 50,0 cm, para a Floresta de Miombo, no distrito de Mocuba, província da Zambézia em Moçambique.

Table 2. Distribution of the number of trees ($n.ha^{-1}$) and basal area ($m^2.ha^{-1}$) of the observed, estimated frequency and removal (exploitation estimates) by central diameter class, for the minimum diameter cutting (MDC) of 40.0 cm in Mocuba district, Zambézia province, Mozambique.
Tabela 2. Distribuição do número de árvores ($n.ha^{-1}$) e área basal ($m^2.ha^{-1}$) da frequência observada, estimada e da remoção (estimativas de corte), por centro de classe de diâmetro, para o diâmetro mínimo de corte (DMC) de 40,0 cm, no distrito de Mocuba, província da Zambézia em Moçambique.

Central class (cm)	Observed frequency		Estimated frequency		Exploitation estimates	
	$n.ha^{-1}$	$m^2.ha^{-1}$	$n.ha^{-1}$	$m^2.ha^{-1}$	$n.ha^{-1}$	$m^2.ha^{-1}$
12.5	157	1.927	161	1.9760	-	-
17.5	115	2.766	108	2.6091	-	-
22.5	56	2.227	73	2.9056	-	-
27.5	52	3.089	49	2.9240	-	-
32.5	50	4.148	33	2.7513	17	1.3966
37.5	35	3.866	22	2.4677	13	1.3980
42.5	26	3.688	15	2.1353	*11*	*1.5531*
47.5	13	2.304	10	1.7969	*3*	*0.5068*
52.5	6	1.299	7	1.4788	-	-
57.5	6	1.558	5	1.1950	*1*	*0.3630*
62.5	2	0.614	3	0.9512	-	-
Total	519	27.48	487	23.19	45	5.22

where: values in italics represent the number of trees and the basal area to be removed for the MDC of 40.0 cm

4. DISCUSSION

The phytosociological parameters evidenced a community characterized by the predomination of the species *Brachystegia spiciformis*, which showed the highest VI%. These results are lower than the ones obtained by Ribeiro et al. (2008) in a Miombo woodland in the Niassa National Reserve, north of Mozambique, who found 79 species, 29 families and density of 548 individuals per hectare. However, a similarity was found considering species, with the prevalence of *Brachystegia spiciformis, Julbernardia globiflora, Pseudolachnostylis maprouneufolia, Diplorhynchus condylocarpon* e *Piliostigma thonningii*. Dewees et al. (2010) affirmed that *B. spiciformis* follows the floristic pattern typical of this biome. The remarkable presence of species of the family Fabaceae when considered as only one taxon is associated to the capacity to compete with species of other families in low fertility soils (GELDENHUYS, 2005; ISANGO, 2007; RYAN et al., 2011; KALABA et al., 2013; CHYDUMAYO, 2013).

Table 3. Distribution of the number of trees ($n.ha^{-1}$) and basal area ($m^2.ha^{-1}$) of the observed, estimated frequency and removal (exploitation estimates) by central diameter class, for the minimum diameter cutting (MDC) of 50.0 cm in Mocuba district, Zambézia province, Mozambique.
Tabela 3. Distribuição do número de árvores ($n.ha^{-1}$) e área basal ($m^2.ha^{-1}$) da frequência observada, estimada e da remoção (estimativas de corte), por centro de classe de diâmetro, para o diâmetro mínimo de corte (DMC) de 50,0 cm, no distrito de Mocuba, província da Zambézia em Moçambique.

Central class (cm)	Observed Frequency		Estimated frequency		Exploitation estimates	
	$n.ha^{-1}$	$m^2.ha^{-1}$	$n.ha^{-1}$		$n.ha^{-1}$	$m^2.ha^{-1}$
12.5	157	1.9267	149	1.8295	-	-
17.5	115	2.7661	100	2.4157	-	-
22.5	56	2.2266	68	2.6902	-	-
27.5	52	3.0886	46	2.7073	-	-
32.5	50	4.1479	31	2.5474	19	1.6005
37.5	35	3.8656	21	2.2848	14	1.5808
42.5	26	3.6884	14	1.9770	12	1.7114
47.5	13	2.3037	9	1.6637	4	0.6400
52.5	6	1.2989	6	13692	-	-
57.5	6	1.5580	4	1.1065	*2*	*0.4516*
62.5	2	0.6136	3	0.8807	-	-
Total	519	27.48	451	21.47	51	5.98

where: values in italics represent the number of trees and the basal area to be removed for the MDC of 50.0 cm.

The considerable occurrence of individuals of the genus *Combretum* was evidenced in the study area. Ribeiro et al. (2008) and Ryan; Williams (2011) suggested that the occurrence of a considerable number of species of the genus *Combretum* in this biome is related to the successional stage of the forest, the associated occurrence of anthropic disturbances in the past caused by fires commonly used for farmland expansion related to migratory agriculture and energy production from the forest biomass. On the other hand, the remarkable occurrence of *Pseudolachnostylis condylocarpon* and *Piliostigma thonningii* can be related to sites that are unsustainable for agriculture, and rarely affected by fire (ZOLHO, 2005; HOFIÇO; FLEIG, 2015; GONÇALVES et al., 2017).

The reduced number of individuals of *Millettia stuhlmannii*, *Afzelia quanzensis*, *Pterocarpus angolensis* and *Swartzia madagascariensis* found in the study area is explained by their importance as commercial timber and their associated value. These species are referenced as the most constrained timber species regarding cutting in the region (MACKENZIE, 2006; MACKENZIE; RIBEIRO, 2009; MATE et al., 2014; EIA, 2014; EKMAN et al., 2014; MITADER, 2016). However, the studied area evidenced a high floristic diversity and showed a homogeneous species distribution. It is important to highlight that the vegetation in the study area is characterized by the occurrence of few dominant species, in a way that uncommon or rare species have low contribution in the occupation of the area. By crosschecking the number of individuals with other studies in the same biome (ISANGO, 2007; RIBEIRO et al., 2008; GILIBA et al., 2011; CHIDUMAYO, 2013; HOFIÇO; FLEIG, 2015), it was observed that the sampled area has a lower species density per hectare. Nevertheless, the low density resulted in a high floristic diversity, as observed in other studies in the region (RYAN; WILLIAMS, 2011; KALABA et al., 2013). This fact may be related to higher density when one or more species are locally favoured by anthropic disturbances such as deforestation and degradation caused by fires, as reported by other authors such as Ryan et al. (2010) and Shirima et al. (2011), as well as the sampling effort made (KERSHAW JR et al., 2016).

The decreasing behaviour of the diameter distribution curve clearly indicated the anthropic pressure on the forest environment with the occurrence of surplus (trees to be removed) or deficit trees. The anthropic pressure can be determined by the low number of species in the initial classes and the low density of species of higher commercial interest in the listed area, mainly for *Millettia stuhlmannii*, *Afzelia quanzensis*, *Pterocarpus angolensis* and *Swartzia madagascariensis*. Such fact is related to the timber exploitation activity, being associated with management practices adopted in the area (HOFIÇO; FLEIG, 2015). According to Pereira (2006), part of the regional population lives within the limits of this forest biome, and uses it as part of livelihood strategies, source of fibre, construction material, as well as a food alternative in times of prolonged drought.

At the same time, the absence of individuals in certain classes or a lower density in intermediate classes can explain the value of "*q*" being around 1, which is influenced by the frequencies of all diameter classes, according to Hess et al. (2014). This fact makes feasible the simulation of the diametric structure regulation of a forest in the long term, allowing the use of alternative ways to enrich and manage the forest (CABACINHA; CASTRO, 2010; HESS et al., 2010). Consequently, one must be aware that clearings, even though small, will emerge when considering the removal of individuals, since it is a low impact technique that will allow the canopy opening, increasing the intensity of light. In this case, the number of pioneer species as well as the number of individuals of these species can increase considerably, influencing the results following cutting (KALABA et al., 2013). Kershaw JR et al. (2016) suggested that the regulation of diametric structure can contribute to species regeneration, decrease in competition, and the recovery of possible diameter and volume increments, thus leading to a stability of the remaining vegetation throughout the cutting cycle. Therefore, the ideal growth of most species in the Miombo woodland is reached with the adequate exposition of crowns to sunlight, being possible to obtain profits up to 50% in relation to the periodic annual increment in diameter (MWAVU; WITKOWSKI, 2009). Chidumayo (2013) comments about the need for thinning interventions, aiming to maintain the canopy opening, in order to keep the positive reaction of the forest to luminosity. This opinion emphasizes the importance of silvicultural treatments of remaining forests in management areas. In this sense, this management approach will provide the forest with a balanced structure, in case it undergoes cuttings (HESS et al., 2010).

However, it is important to highlight that forest exploitation leads to changes in the canopy structure as well as in the floristic composition of the stand, decreasing the number of species tolerant to shade and stimulating the occurrence of heliophytic species (HIGGINS et al., 2007; MWAVU; WITKOWSKI, 2009). Therefore, the recommendation for cutting, i.e., the canopy opening for a higher incidence of light to favour growth, must be used in a correct way, since the wrong thinning can promote the proliferation of pioneer species that most of times have an unknown economic value, and will compete with desired tree species (CHIDUMAYO, 2013; GONÇALVES et al., 2017).

5. CONCLUSION

The studied forest management unit is characterized by the concentration of a large number of individuals and species in few botanical families, as well as by a large number of species locally rare. Also, it shows a high floristic diversity in the tree component, what indicates the preservation of the number of species after the regulation of the diametric structure.

The diametric structure evidenced an unbalanced vegetation and, by the simulation of the diametric structure regulation with the *De Liocourt* method, it has shown to be efficient, suggesting that the conduction of the forest stock based on the basal area, minimum diameters cutting limits and *De Liocourt* quotient can be a management alternative for the Miombo woodlands studied.

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