

## Technical feasibility of forest management: a case study in a cerrado *sensu stricto* Legal Reserve in northern Minas Gerais, Brazil

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### Abstract

The Cerrado domain is considered as one of the global hotspots, although studies upon management in this vegetation type have many gaps in the forest literature. Thus, it's important to propose viable alternatives to its use. This study aimed to evaluate the technical feasibility of forest management in a legal reserve of cerrado *sensu stricto* in Minas Gerais state, as support to the local increased demand for firewood. A forest inventory was applied from systematic samplings of 10 plots, based on the diameter criteria at 0.30 m above ground (DAG)  $\geq$  than 5 cm. The Shannon diversity index ( $H'$ ) and Pielou's equability ( $J$ ) were used. Furthermore, diametric distribution models and the diameter classes were evaluated by De Liocourt quotient. We observed that the Shannon diversity was 2.61 nats.ind<sup>-1</sup> and the Pielou ( $J$ ) equability was 0.74. The De Liocourt quotient showed a non-constant mean value of 1.97 between the diameter classes. None of the fitted models showed results likewise the frequency observed in the study. The total wood volume estimated was 2,189.6765 m<sup>3</sup>. The study area possibly suffered anthropic interventions, resulting both low volumetric yield and species diversity. Thus, the forest management to the legal reserve area was considered unfeasible, as it does not present technical sustainability.

**Keywords:** Sustainable management. Forest structure. Firewood demand. Brazilian savanna.

## Viabilidade técnica de manejo florestal: um estudo de caso em uma reserva legal de cerrado *sensu stricto* no norte de Minas Gerais, Brasil

### Resumo

O Cerrado é considerado como um dos hotspots mundiais, no entanto, estudos em manejo sustentável nesse domínio são escassos na literatura florestal. Assim, é importante propor alternativas viáveis para a utilização de seus recursos. Esse estudo objetivou avaliar a viabilidade técnica de manejo florestal em uma reserva legal de cerrado *sensu stricto* em Minas Gerais, como suporte a demanda de lenha para a comunidade rural. Realizou-se o inventário florestal a partir da amostragem sistemática de 10 parcelas, utilizando o critério de inclusão diâmetro à 0,30 m do solo (DAS)  $\geq$  de 5 cm. Calculou-se o índice de diversidade de Shannon ( $H'$ ) e equabilidade de Pielou ( $J$ ). Realizou-se o ajuste de modelos de distribuição diamétrica e verificou o balanceamento a partir do quociente de De Liocourt. A diversidade

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de Shannon ( $H'$ ) foi 2,61  $\text{nats.ind}^{-1}$  e a equabilidade de Pielou ( $J$ ) de 0,74. O quociente de De Liocourt apresentou um valor médio não constante entre as classes de 1,97. Nenhum dos modelos ajustados se aderiu à frequência observada no estudo. O volume de madeira estimado foi de 2.189,6765  $\text{m}^3$ . A área de estudo possivelmente sofreu intervenções antrópicas, resultando em um baixo rendimento volumétrico e diversidade de espécies. A implementação do manejo florestal para a área de reserva legal foi considerada inviável, pois não apresenta sustentabilidade técnica.

**Palavras-chave:** Manejo sustentável. Estrutura florestal. Demanda de madeira. Cerrado.

## Introduction

The Cerrado (Brazilian savanna) covers more than 2 million  $\text{km}^2$ , around 22% of the Brazilian territory and is known for its high fauna and flora diversity, as well as large amount of endemic species (Strassburg et al., 2017). Among its main phytophysiognomies, the Cerrado domain include riparian forest, grasslands, woodlands and rupestrian grasslands, being considered as one of the world hotspots for conservation (Myers et al., 2000). Also, it harbors a diversity of woody, medicinal and fruit species, which together with its fauna, contribute to the environmental balance. Moreover, the domain has great importance to water resources conservation (Durigan et al., 2011; Ferreira et al., 2016; Oliveira-Filho, 2009).

The devastation of Cerrado areas for economic purposes, due to the constant and growing demand for timber and non-timber products, implies in the need to propose viable alternatives to natural resources in a long-term use (Paparelli and Henkes, 2012; Pereira et al., 2012). Hence, sustainable forest management plan has been considered as the main alternative to ensure an adequate exploration, ensuring the biodiversity conservation and preservation (Scarano et al., 2014). In other words, the management plan enables the use of available resources in the native forests through mitigating alternatives which may imply in a low-impact generation, as well as achieving economic, social and environmental success. Therefore, protected areas such as the Legal Reserve can be used to timber and non-timber products extraction, as long as it is based on a sustainable management plan approved by the competent authority (Brasil 2012; Braz et al., 2012; Kanashiro, 2014; Minas Gerais, 2013).

The Legal Reserve area (LR) was instituted in national level by the Forest Code, being regulated Federal Law 12651/2012 and, for Minas Gerais state, by State Law 20922/2013. The LR is considered a legally protected area that aims to maintain biodiversity and ensure the environment balance (Brasil, 2012; Minas Gerais, 2013). Considering properties with Cerrado vegetation which are not in the Legal Amazon, the area destined to the Legal Reserve must be equal to or greater than 20% of the property total area (Brasil, 2012; Borges and Rezen-de, 2011). Further, the Legal Reserve has specifications regarding its exploitation, in which clearcutting and land use for non-conservation purpose are prohibited. However, it is possible to manage the LR sustainably, as long as authorized by the competent authority considering

establishment of guideline and consistent techniques (Froufe and Seoane 2011; Oliveira and Wolski, 2012).

The natural resources provided by native forests subsidize the rural communities demand that live in their surroundings. In this way, the timber and non-timber products are sources of income for the population. However, in most cases these resources are used in a predatory practice, without a professional assistance, management plan and environmental permits (Costa and Mitja, 2010; Pereira et al., 2012). Besides that, there is a lack of information in the literature on the Cerrado management, especially regarding the technical feasibility of sustainable wood harvesting.

In this sense, the decision-making regarding forest resources requires knowledge about the forest structure and composition, thus performing technical analyses from the floristic, phytosociology, horizontal, vertical, parametric and diametric structures of the forest community (Calegari et al., 2010; Chaves et al., 2013; Klauberg et al., 2010). Thus, the study aimed to evaluate the implementation of sustainable management to a legal reserve with cerrado *sensu stricto* vegetation, as support to the energy demand of a rural community in the municipality of Montes Claros, Minas Gerais state, Brazil.

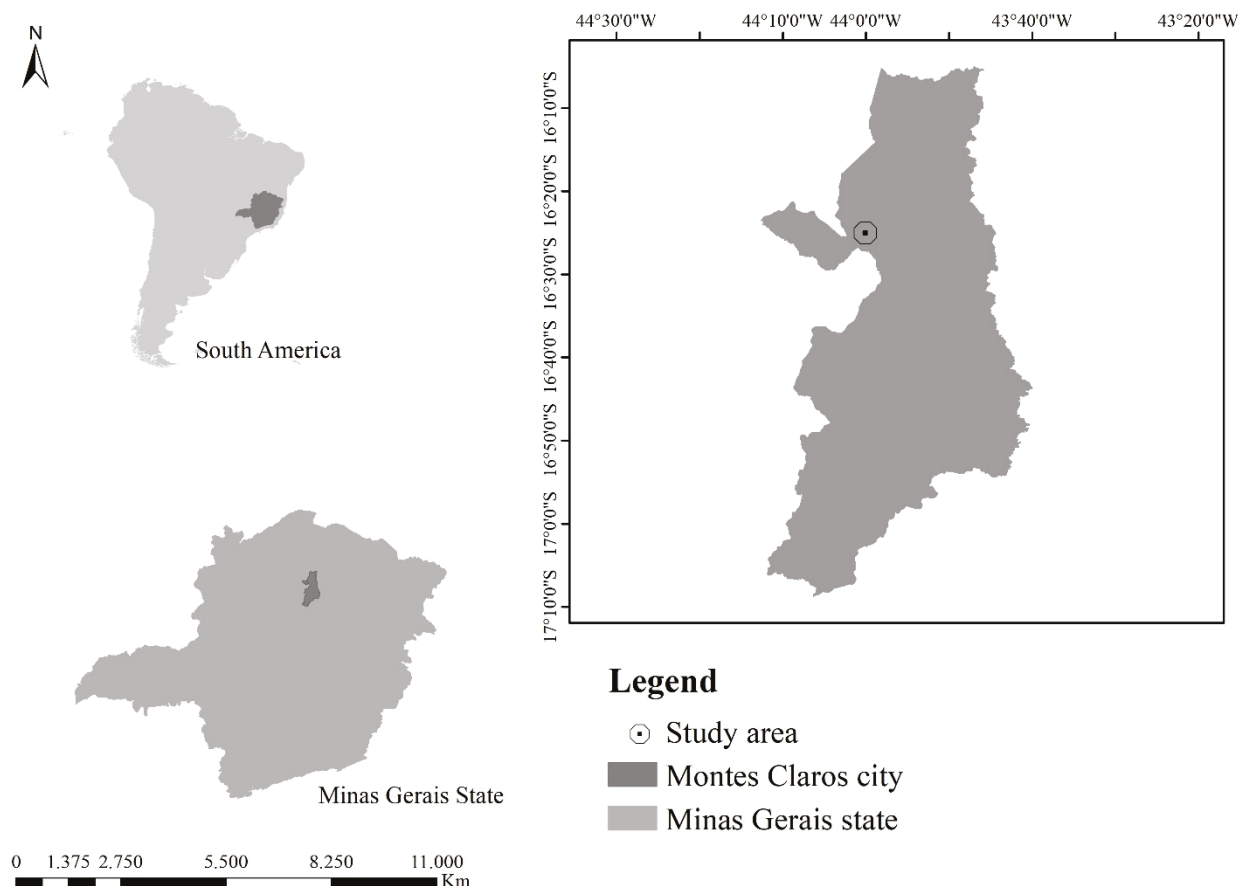
## Materials and methods

The data of this study is from a Legal Reserve area with cerrado *sensu stricto* vegetation, which has an extension of 27.4 hectares, and is located at a rural area called Camelas. Nowadays, about 70 families live in the community. Therefore, there is a demand of approximately 10.67  $\text{m}^3 \cdot \text{month}^{-1}$  of firewood and a representative amount is removed from the nearby native vegetation. The firewood is used to supply energy to the manufacturing process of “rapadura”, a kind of Brazilian dessert.

The Camelas community, which has agriculture as predominant activity, is located 50 km from the municipality of Montes Claros - Minas Gerais state, Brazil, under the coordinates -16.416168° latitude and -44.003954° longitude (Figure 1). According to Köppen and Geiger classification, the region climate is Aw, tropical with a dry season. The mean annual temperature is 22.7°C, mean

annual precipitation of 1,029 mm and an altitude of 906 m (Alvares *et al.*, 2013).

Figure 1 – Study area located in the Camelas community Legal Reserve in Montes Claros city, Minas Gerais state, Brazil.



In order to achieve previous information from the area, the forest inventory was carried out from systematic samplings of 10 plots of 10 x 100 m (1000 m<sup>2</sup>), totaling one hectare sampled (Moro and Martins, 2011). All trees with diameter at 0.30 meters above ground (DAG) greater than 5 cm were measured. In addition, tree heights were measured with telescopic measuring stick and the botanical material were collected to later identification through specialists, specific literature (Silva-Júnior, 2012) and virtual herbaria (Flora do Brasil, 2019; JBRJ, 2019). Hence, it was considered the *APG IV classification system*

(2016). All measured trees were labeled with metal tags describing the plant and plot number.

Afterwards, it was calculated the wood volume, Shannon and Weaver diversity index ( $H'$ ), Pielou equability ( $J$ ) (Magurran, 2011) and phytosociological parameters (species richness, absolute and relative density, relative frequency, relative dominance and importance value index) (Mueller-Dombois and Ellenberg, 1974).

The following equation (Eq. 1), proposed by Rezende *et al.* (2006), was used to estimate the wood volume to the Legal Reserve.

$$V = 0.000109 * DAG^2 + 0.000451 * DAG^2 * H \quad R^2 = 98.02\% ; S_{yx} = 25\% \text{ (Eq. 1)}$$

Where: DAS: Diameter at 0.30 meters above ground (cm); H: Tree height (m); V: Volume (m<sup>3</sup>); R<sup>2</sup>: Coefficient of determination; S<sub>yx</sub>: Residual standard error.

In order to assess the diameter heterogeneity, the trees were distributed in twelve diametric classes, considering an amplitude of 3 cm (Scolforo and Thiersch, 2004). Then, the De Liocourt quotient ( $q$ ) (De Liocourt, 1898) was calculated using the ratio between the number of individuals in successive classes after determining the frequency (Hess *et al.*, 2014).

To assess the diametric distribution pattern of trees per hectare ( $Y_j$ ) by diameter class ( $X_i$ ), it was fitted the models of Meyer, Mervart and Weibull (Scolforo, 1998) (Table 1). The use of probability density function, like the models fitted to this study, allows to achieve information that may lead to the planning of vegetation yield as well as to simulate thinning procedures and ensure the sustainable forest management. Thus, the chi-square

test, with a significance level of 95%, was applied to the frequencies found searching to analyze the adjusted

models adherence by exponential distribution (Souza and Soares, 2013).

Table 1 – Diametric distribution models used to estimate the expected frequency in the Legal Reserve area in Montes Claros city, Minas Gerais state, Brazil.

Model	Equation
Meyer's exponential	$N_j = \beta_0 e^{\beta_1 D_j} \cdot \epsilon_j$
Mervart's potential	$N_j = \beta_0 D_j^{\beta_1} \cdot \epsilon_j$
Weibull with two parameters	$F(D_j) = 1 - \exp^{-(D_j/b)^y}$

Where:  $N_j$  is the number of trees per hectare in the  $j$ -th diameter class at 0.30 meters above ground (DAG);  $\beta_0, \beta_1, y$ : parameters to be estimated;  $F(D_j)$  is the accumulated probability up to the  $j$ -th DAG class;  $\epsilon$ : error for the  $j$ -th DAG class.

Lastly, regarding the individuals heights stratification, they were split into nine classes with an amplitude of one standard deviation (sd) (Souza and Soares, 2013).

## Results and discussion

Considering the forest inventory procedure, it was measured a total of 512 individuals, distributed in 34 species and 13 families. The population mean DAG was equal to 7.87 cm and the maximum equal to 40.67 cm. In addition, the mean height of the individuals was 3.5 m and the maximum height was 12.0 m. The total absolute density was 512 trees.ha<sup>-1</sup> and the basal area of 3.72 m<sup>2</sup>.ha<sup>-1</sup>, values lower than those found in other studies of cerrado *sensu stricto*.

The horizontal structure to our study presents an unusual pattern to the vegetation type, when compared to other studies, in which it is expected to find a balanced diametric structure (Costa et al., 2010; Giacomo et al., 2013). This result may be linked with possible anthropic interventions such as agricultural and cattle raising activities in which justifies the low intensity of individuals (Paula et al., 2007).

As regard to the floristic aspects, the Combretaceae family presented the highest number of individuals (153), due to successive occurrence of the *Terminalia fagifolia* Mart. species. However, the Fabaceae family was the one that had the largest number of species (14). The five species with highest importance value index (IVI) in decreasing order were *Terminalia fagifolia* Mart.; *Caryocar brasiliense* Cambess.; *Vatairea macrocarpa* (Benth.) Ducke; *Qualea multiflora* Mart. and *Hymenaea stigonocarpa* Mart. ex Hayne (Table 2).

High density of *T. fagifolia* was detected in the area, which may be associated with the morphology of its fruit characterized as winged, allowing anemochory dispersion, as well as by its irregular spatial distribution (Ribeiro et al., 2018; Soares Neto et al., 2014). This species is commonly found in the Cerrado, with its occurrence in the Brazil southeast region being only in Minas Gerais state. The *T. fagifolia* is a relevant species due its intrinsic characteristics such as high wood density and durability,

as well as medicinal properties (Araújo et al., 2012; Flora do Brasil, 2019; Mota et al., 2014). The second species with great importance value index, *C. brasiliense*, has great relevance for the Cerrado due to its economic and cultural value. Nevertheless, this species is protected by Law, being its suppression allowed only in specific cases such as social interest, urban area and anthropized rural area until July 22, 2008 (Afonso et al., 2015; Minas Gerais, 2012).

Species that have a relative density (RD) less than or equal to 1% are considered rare (Almeida et al., 1993; Pereira-Silva et al., 2004). We found in the area 20 species with RD less than 1%, not being able to be management (Minas Gerais, 2013; Reis et al., 2013). The Shannon diversity index ( $H'$ ) was 2.61 nats.ind<sup>-1</sup> and the Pielou equability index ( $J$ ) was 0.74. Also, the studied area showed a species diversity minor than in other studies in the same vegetation type, thus allowing to infer that the legal reserve may have been explored by the surrounding community (Silva Neto et al., 2016; Costa et al., 2010).

Regarding the diametric distribution, the area presented 80.47% of the individuals concentrated at the first class, in which the central value is 6.5 cm in diameter (Figure 2). As for the De Liocourt quotient, it showed a non-constant value between classes (9.16; 3.75; 1.71; 1.17; 0.86; 0.88; 1.14; 2.33; 0.00; 0.00; 0.67), resulting an average value of 1.97.

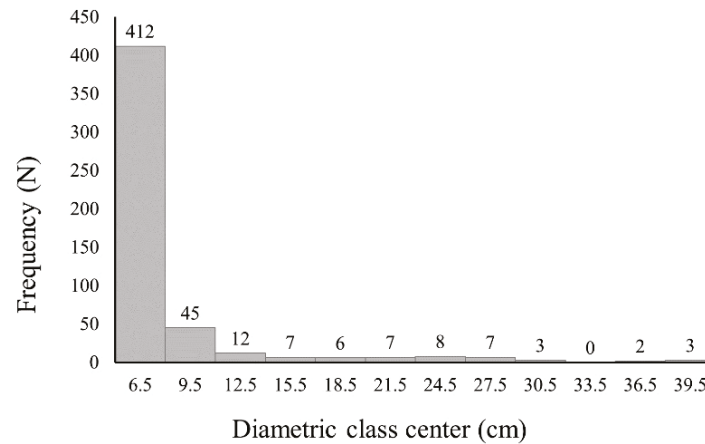
The diametric distribution presented the J - inverse pattern, which is expected for heterogeneous forests in Brazil (Silva Neto et al., 2016). However, a minimal number of trees was observed in the largest DAG classes, besides to their absence in the 33.5 cm class of central value. Similar results were found by Oliveira et al. (2015) whom analyzed the cerrado *sensu stricto* vegetation in western Bahia. The authors found a concentration of 96.33% of individuals in the first three diametric classes. Considering the same vegetation in an area located in Sete Lagoas - MG, 68% of the sampled individuals were distributed in the first class (Pereira et al., 2013).

Table 2 – Species phytosociology in the cerrado *sensu stricto* area located in the municipality of Montes Claros - Minas Gerais, Brazil, in decreasing order of IVI.

Species	N	RD	RF	RDo	IVI
<i>Terminalia fagifolia</i> Mart. et Zucc	153	29.88	7.35	42.55	79.79
<i>Vatairea macrocarpa</i> (Benth.) Ducke	52	10.16	5.88	4.20	20.24
<i>Qualea multiflora</i> Mart.	50	9.77	5.88	4.80	20.45
<i>Caryocar brasiliense</i> Cambess.	45	8.79	7.35	23.25	39.39
<i>Eriotheca pubescens</i> (Mart. & Zucc.) Schott & Endl.	33	6.45	5.88	3.25	15.58
<i>Aspidosperma macrocarpon</i> Mart.	20	3.91	4.41	1.76	10.08
<i>Aspidosperma subincanum</i> Mart.	19	3.71	5.88	2.15	11.74
<i>Dalbergia miscolobium</i> Benth.	19	3.71	5.15	1.32	10.18
<i>Hymenaea stigonocarpa</i> Mart.ex Hayne	18	3.52	5.15	3.63	12.30
<i>Bowdichia virgilioides</i> Kunth	17	3.32	4.41	1.34	9.07
<i>Qualea grandiflora</i> Mart.	13	2.54	3.68	0.91	7.13
<i>Eugenia dysenterica</i> DC.	6	1.17	3.68	0.45	5.29
Indeterminate	6	1.17	2.21	0.56	3.94
<i>Vochysia thyrsoidea</i> Pohl.	6	1.17	1.47	0.83	3.47
<i>Machaerium opacum</i> Vogel	5	0.98	2.94	0.61	4.53
<i>Machaerium acutifolium</i> Vogel	5	0.98	2.94	0.41	4.33
<i>Pouteria ramiflora</i> (Mart.) Radlk.	5	0.98	2.21	0.39	3.57
<i>Enterolobium gummiferum</i> (Mart). J.F Macbr.	5	0.98	2.21	0.34	3.53
<i>Dimorphandra mollis</i> Benth.	4	0.78	1.47	3.43	5.68
<i>Hancornia speciosa</i> Gomes	4	0.78	2.21	0.52	3.50
<i>Plathyenia reticulata</i> Benth.	4	0.78	2.21	0.28	3.27
<i>Stryphnodendron adstringens</i> (Mart.) Corville	3	0.59	1.47	0.27	2.33
<i>Copaifera langsdorffii</i> Desf.	3	0.59	1.47	0.18	2.23
<i>Aspidosperma tomentosum</i> Mart.	2	0.39	1.47	0.53	2.40
<i>Annona emarginata</i> (Schltdl.) H. Rainer.	2	0.39	1.47	0.32	2.18
<i>Miconia ferruginata</i> DC.	2	0.39	1.47	0.19	2.05
<i>Strychnos pseudoquina</i> A. St.-Hil.	2	0.39	1.47	0.18	2.04
<i>Couepia grandiflora</i> (Mart. & Zucc.) Benth	2	0.39	1.47	0.17	2.03
<i>Schefflera macrocarpa</i> (Cham. & Schltdl.) Frodin	2	0.39	1.47	0.15	2.01
<i>Himatanthus obovatus</i> (Müll. Arg.) Woodson	1	0.20	0.74	0.74	1.67
<i>Handroanthus ochraceus</i> (Cham.) Mattos	1	0.20	0.74	0.09	1.02
<i>Salvertia convallariaeodora</i> A.St.-Hil.	1	0.20	0.74	0.08	1.01
<i>Machaerium vilosum</i> Vogel.	1	0.20	0.74	0.06	0.99
<i>Chamaecrista</i> sp. H.S. Irwin & Barneby	1	0.20	0.74	0.06	0.99

Where: N= number of individuals; RD = relative density (%); RDo = relative dominance (%); RF = relative frequency (%); IVI = importance value index (%).

Figure 2 – Diameter classes (cm) of individuals sampled in the cerrado *sensu stricto* Legal Reserve area located in Montes Claros, Minas Gerais state, Brazil.



Where: N= number of individuals.

The community absence of balance is reflected in the mean value of the De Liocourt quotient (Alves Júnior *et al.*, 2010; Hess *et al.*, 2014). Thus, the values discrepancy can mean the presence of a high mortality rate and low recruitment between classes, especially regarding the lack of individuals in the largest diametric classes (Cunha and Silva Júnior, 2012). It is expected an imbalance between the diameter classes to native forests, with a high concentration of individuals in the lower classes (Calixto Júnior *et al.*, 2011; Silva Neto *et al.*, 2016). However, areas with a higher degree of conservation tend to be in close proximity to balanced distribution. Instead, the study region is characterized by not favorable edaphoclimatic conditions, and this fact may be not allowing a greater increment in the area, thus justifying the presence of a greater number of individuals

in the first classes and resulting in a low volumetric yield (Ávila *et al.*, 2014; Lima *et al.*, 2013).

According to the diametric distribution models fitted using the observed frequency (OF) within each class, it is observed that the Meyer model presented the lowest frequencies in relation to the frequencies observed in the study, since all results were statistically significant, presenting p-values <0.05. Thus, the model does not describe the tree community behavior, as it presents a discrepancy regarding the observed frequency, which results in an unfeasible forest management implementation. Moreover, none of the models represents correctly the vegetal formation behavior, and therefore did not present an efficient precision in adjusting distributions (Table 3). This result may be associated with the heterogeneity of diameters present in the sample (Barros *et al.*, 1979) (Figure 3).

Table 3 – Chi-square test for the diametric distribution models used in the study in the cerrado *sensu stricto* Legal Reserve area located in Montes Claros, Minas Gerais state, Brazil.

Model	$\chi^2$ test
Meyer	2,190.12*
Mervart	554.36*
Weibull	37.64*

Where: \* significant Chi-square ( $\chi^2$ ) test for  $\alpha = 0.05$ .

Concerning to the height stratification, it is possible to observe that 80.86% of the trees are concentrated in the first and second classes. Thus, the stratification of height allowed to predict about the height dominance in lowest classes and this result is not an expected distribution pattern for cerrado *sensu stricto*, since it is usual to find a normal distribution (Pereira *et al.*, 2013) (Figure 4).

The estimated wood volume per hectare was 79.9152 m<sup>3</sup> and considering the total Legal Reserve

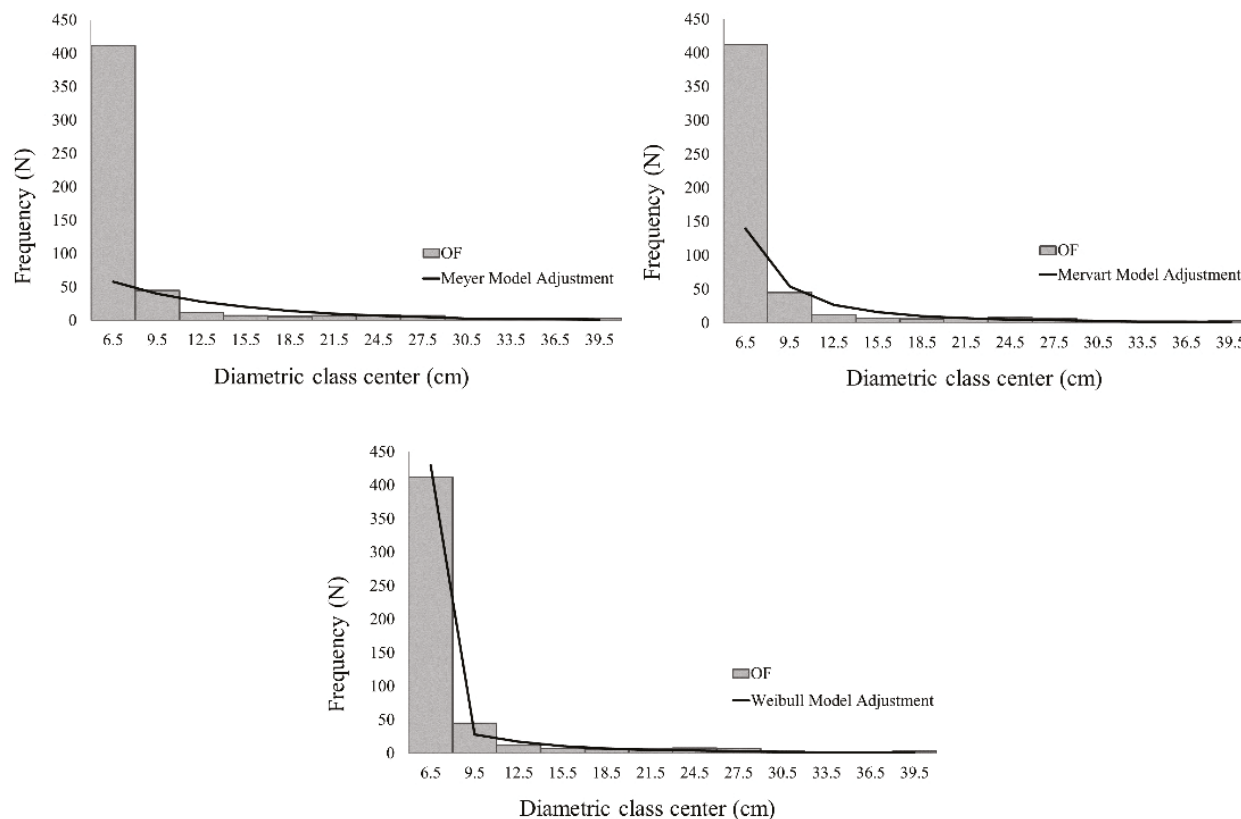
area, it was 2,189.6765 m<sup>3</sup>. Nevertheless, the estimated wood volume includes individuals of the species *Caryocar brasiliense* Cambess and Ipê Amarelo of the genus *Handroanthus*, which are protected by Law and their suppression is not allowed (Minas Gerais, 2012). It also includes species whose occurrence in the studied area is considered rare.

Based on the results, Cerrado management legislation of the state of Minas Gerais state and aiming to meet the wood demand to the community in the generation of

energy, it can be inferred that initially there is a need to implement conservation and restoration measures for the Legal Reserve area, since this possibly suffered pressures imposed by the surrounding community. Thus,

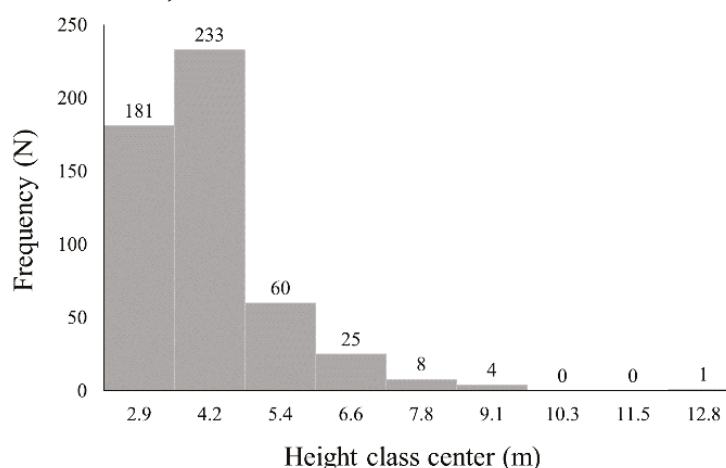
the implementation of sustainable management aiming at the wood extraction to energy supply energy in the process of manufacturing “rapadura”, becomes unfeasible.

Figure 3 – Observed frequency according to the adjustment of the diametric distribution models for the cerrado *sensu stricto* Legal Reserve located in Montes Claros city, Minas Gerais state, Brazil.



Where: OF is the observed frequency.

Figure 4 – Height classes (m) of individuals sampled in the cerrado *sensu stricto* Legal Reserve area located in Montes Claros city, Minas Gerais state, Brazil.



Where: N= number of individuals.

Considering the current volumetric stock (2,189.6765 m<sup>3</sup>) and a 10-year cycle for wood harvesting (as established by law), there is a gross supply of 18.2473 m<sup>3</sup>. month<sup>-1</sup> of firewood. According to the Cerrado management legislation, it is prohibits the clearcutting of the

rare species as well as seed-bearing trees because they must be protected so the environmental sustainability of forest management, since the Cerrado requires a longer time for its recovery (Líbano and Felfili, 2006; Rezende *et al.*, 2005). Thus, when considering that in this gross

monthly volumetric stock, there are species that are not allowed to be cutting according to the law, it appears that this volumetric stock is not enough to sustainably meet the demand ( $10.67 \text{ m}^3 \cdot \text{month}^{-1}$  of firewood) informed by the rural community.

## Conclusion

The implementation of a forest management to the Legal Reserve area is not viable, as it does not present sustainability for the objective. Among the species identified, approximately 59% are considered as rare species, which do not allow to proceed a clearcut of them. In addition, the basal area indicates a low degree of site occupation and a structure unable to provide the necessary wood turnover. The selective cutting would interfere in the community's resilience, affecting its dynamics and

ecological processes, generating an imbalance in the vegetation.

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