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Artigo Científico

Estimate of the diameter distribution in Mixed Ombrophylous Forest fragment with the Meyer's function

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Abstract

Evaluate the diameter distribution of a fragment of Ombrophyllous Mixed Forest, located in São Francisco de Paula, Rio Grande do Sul. The data was collected in 10 permanent sampling units of 1ha each, established in the São Francisco de Paula's National Forest, RS, Brazil.For analysis of the diameter structure was considered the frequency of diameters in successive classes of range of 10cm, and the intervals diameters ranging from 9.5 to 149.5 cm. For data processing was used SADEF *software*. The frequencies observed by diameter class were divided into plots and adjusted as a function of the center class through of the Meyer`s equation, where was obtained value of 1.63 for the *Liocourt* quotient. We observed a total of 803 trees per hectare, distributed in 107 species belonging to 41 families. The most abundant species was the Araucaria angustifolia, with 97.1 individuals per hectare. The number of trees per hectare adjusted by the Meyer`s equation was 467.85, being lower than the observed, but basal area observed (46.18 m^2ha^{-1}) was lower than the adjusted (47.74 m^2ha^{-1}), with a deficit of 1.56 m^2ha^{-1}. Through analysis of data from distributions diameter, it was verified that the ratio of Liocourt showed a range between 1 and 3.078. The data analysis indicates that the forest is still not in equilibrium, this disequilibrium in the frequencies of the diameter class occurs mainly in the classes with largest DBH, which may have been caused by selective extraction of some species.

Keywords: Diameter distribution, Meyer's Equation, Ombrophyllous Mixed Forest, *Liocourt* quotient

Estimativa da distribuição diamétrica em fragmento de Floresta Ombrófila Mista com a função de Meyer

Resumo

O objetivo do estudo foi avaliar a distribuição diamétrica de um fragmento de Floresta Ombrófila Mista, localizada na região nordeste do estado do Rio Grande do Sul, no município de São Francisco de Paula. Os dados utilizados foram coletados em 10 unidades amostrais permanentes de 1ha cada, instaladas na FLONA de São Francisco de Paula, RS, Brasil. Para a análise da estrutura diamétrica considerou-se a frequência dos diâmetros em classes sucessivas de amplitude de 10cm, sendo que os intervalos diamétricos variaram de 9,5 a 149,5cm. Para o processamento dos dados foi utilizado o programa SADEF. As frequências observadas por classe de diâmetro foram divididas por parcelas e ajustadas como uma função do centro de classe pela equação de Meyer, sendo obtido valor de 1,63 para o quociente de *Liocourt*. Foi observado um total de 803 árvores por hectare, distribuídas em 107 espécies, pertencentes a 41 famílias. A espécie mais abundante foi a *Araucaria angustifolia*, com 97,1 indivíduos por hectare. O número de árvores, por hectare, ajustado pela equação de Meyer foi de 467,85, sendo inferior ao observado, porém a área basal ajustada (47,74 $m^2 ha^{-1}$) foi superior a observada (46,18 $m^2 ha^{-1}$) apresentando um déficit de 1,56 $m^2 ha^{-1}$. A análise dos dados indica que a floresta ainda não está em equilíbrio, esse desequilíbrio nas frequências das classes diamétricas ocorre principalmente nas classes de maior diâmetro, que pode ter sido causado pela extração seletiva de algumas espécies.

Palavras-chave: distribuição diamétrica, Equação de Meyer, Floresta Ombrófila Mista, quociente de *Liocourt*.

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Estimación de la distribución Diamétrica en un fragmento de Bosque Ombrófilo Misto con la función de Meyer

Resumen

El objetivo del estudio fue evaluar la distribución del diámetro de un fragmento de Bosque Ombrófilo Misto, ubicado en la región nordeste del Estado de Rio Grande do Sul, municipio de São Francisco de Paula. Los datos fueron recolectados en 10 unidades de muestreo de 1 ha cada uno, establecidas en el Bosque Nacional de San Francisco de Paula, RS, Brasil . Para el análisis de la estructura de diámetro se consideró la frecuencia de los diámetros en las clases sucesivas de amplitud de 10 cm, en que los intervalos de diámetros se presentaron desde 9,5 hasta 149,5 cm. Para el procesamiento de los datos se utilizó el software SADEF. Las frecuencias observadas por clase de diámetro fueron divididas en parcelas y ajustadas en función del centro de la clase a través de la ecuación de Meyer, donde se obtuvo el valor de 1,63 para el coeficiente *Liocourt*. Se observó un total de 803 árboles por hectárea, distribuidos en 107 especies pertenecientes a 41 familias. La especie más abundante fue la Araucaria angustifolia, con 97,1 individuos por hectárea. El número de árboles por hectárea, ajustado por la ecuación de Meyer fue 467,85, siendo más bajo que el observado, pero el área basal ajustado (47.74 m^2ha^{-1}), fue menor que el observado (46.18 m^2 ha^{-1}) con un déficit de 1.56 m^2 ha^{-1}. El análisis de los datos indica que el bosque aún no se encuentra en equilibrio, este desequilibrio de las frecuencias de la clase de diámetro se produce principalmente en las clases con mayor diámetro, que puede haber sido causado por la extracción selectiva de algunas especies.

Palabras clave: distribución del diámetro, ecuación de Meyer, Bosque Ombrófilo Mixto, cociente de *Liocourt*.

Introduction

The natural forest management requires knowledge of the structure of the forest which will be managed. The knowledge of the diameter distribution is a tool that helps in this work, being an indicator of the stocktaking of forests. The diameter is a variable obtained by direct measurement of trees and the volume can be estimated from it by means of regression equations. Therefore, with diametric measurement data can be obtained an important set of information about the forest, allowing the performance of conclusions such as: cutting cycle, indicative of anthropic action and the current stage of development of the forest (UMAÑA and ALENCAR, 1998).

The Diameter distribution is the tool more simple and powerful for characterizing the structure of a forest. In a general way, the diameter correlates very well with other important variables such as height, volume, value, conversion cost and typification of products (ARCE, 2004).

SCHAAF et al. (2006) stated that the most appropriate way to understand the development of the Diameter distribution of forest is to monitor it consistently and for long periods. The methodology more suitable for this purpose is the installation of permanent sample units. However, the installation and especially the monitoring of these sample units can be considered recent facts in Brazil, especially if compared with the speed with which the dynamic processes and the elimination of forests occur.

The distribution of frequency of diameters, by successive classes in natural forest is of decreasing tendency and can be described in the form of "inverted J", being indicated for its adjustment a curve of the exponential type. This class frequency varies according to the type of forest, which can be described by the quotient of Liocourt - "q". The quotient "q" expresses the relation between the number of individuals in a class of diameter and number of individuals in an adjacent diameter class. The value is based on an assumed decline in the number of individuals between subsequent diameter classes (OLIVER and LARSON, 1996).

The first studies of diameter distributions in mixed forests were performed by Liocourt in 1898, which stated that the distribution in this type of forest formation was behaving in the shape of "inverted-J". According to Liocourt, to avoid the imbalance of the forest would be necessary to establish guidelines for their management, trying to lead the diametric structure to a "balanced distribution" in order to reach a level of sustained production (CAMPOS et al., 1983).

In this same line of study, MEYER (1952) introduced the concept of "balanced forest" or "balanced Diameter distribution." The concept of balanced forest went on to describe the current growth which could be periodically removed, without modifying the structure and initial stocktaking, thus providing a sustainable income. The Diameter distributions remained virtually unchanged in

primary forests and those managed appropriately. This happens mainly by the balance between growth and mortality.

The model for determining the balanced structure of the forest proposed by Meyer is the Meyer equation (SCHNEIDER et al., 1988) being expressed by the equation 1:

$$\ln N_i = b_0 + b_1 . di \qquad (1)$$

Where:

Ni = natural frequency per hectare in the diameter class i;

di = center of diameter class;

b_o e b_1 = parameters which express the vegetation structure in relation to the distribution of diameters.

When comparing the frequencies desired with those estimated from a forest stocktaking, is determined by subtracting the diameter classes which require cutting of selection, and those where there is occurrence of deficit, and therefore should not be subject to cuts (CAMPOS et al., 1983).

Therefore we intend to evaluate, using the Meyer function, the Diameter distribution of arboreal individuals in a fragment of the Ombrophyllous Mixed Forest.

Materials and Methods

Characterization of the Study area

The data used in this study were collected in 2008 coming from permanent sample units of the National Forest of São Francisco de Paula - SFP FLONA. The SFP FLONA was installed by a team of researchers from the Department of Forest Sciences of the Federal University of Santa Maria - UFSM in July of 2000.

The FLONA SFP is located in the northeastern of the state of Rio Grande do Sul, between coordinates 29º23'and 29º27'S and 50º23' and 50º25'W, covering areas of Ombrophyllous Mixed Forest (OMF) which are in different stages of succession and states conservation.

The area is classified, according to the Köppen climate classification as climatic type "Cfb" temperate, with cold winters and rains every month. The temperature of the warmest month is below 22 ºC and the coldest month between -3 °C and 2.18 °C. The average annual rainfall is 2,468mm, and the annual average temperature is below 18.5 °C (MORENO, 1961).

The soils found in the FLONA SFP, according to the Brazilian System of Soil Classification – SBCS, are Humic Aluminic Cambisol, Argiluvic Ferric Chernosol and Litholic Eutrophic Fluvic Neosol (EMBRAPA, 2006; STRECK et al., 2002).

Based on the classification proposed by IBGE (1992), the dominant vegetation in the area is the Mixed Ombrophylous Forest, lying in different stages of succession, having sites with small changes until places where there was selective extraction of commercial species (LONGHI et al. 2008).

The FLONA, with total area of 1606.69 hectares, has a strongly undulated relief in the northern part, with 930m of altitude and rugged in the south, forming canyons with more than 100m deep.

Obtaining of data and analysis

The study was based on data collected in ten sample units of the project PELD in the year 2008, considering all individuals with DAP>9.5 cm. All trees of the sampling units were identified being collected also exsiccates for botanical identification, with the Herbarium of the Department of Forest Sciences (HDCF) of UFSM, for individuals who could not be identified in the field.

The sampling units, named 1537, 1538, 1539, 1540, 1541, 1542, 1543, 1544, 1545 and 1546, were demarcated of square shape, with 100m x 100m wide, with a total area of 1 ha each, which were divided in 100 subunits, samples of 10m x 10m wide, forming an area of 100m^2.

To analyze the diameter structure, it was considered the frequency of diameters with amplitude of classes of 10cm. The analysis of diameter distribution was performed using the 10 sample units, considering the observed frequencies individually for sampling units. The estimated frequency was obtained using the equation of adjustment of Meyer.

The information obtained in the stocktaking were processed by the software SADEF (GARDIN, 2011), where was obtained the information of distribution frequency, by diameter class, observed and estimated, the value of the constant "q" Of Lioucourt, the adjusted equation of Meyer and the graphical representations of the observed and estimated frequencies distributions.

Results and Discussion

Using the observed frequencies by diameter class and by sampling units, was determined the adjusted frequencies depending on the center class by the use of the adjusted equation of Meyer expressed in Equation 2. The reason for the use of the frequencies of diameter classes divided by sampling unit and not just their average was that, this is a procedure adopted to avoid losing the specific characteristics of the sample units, making the adjusted equation more loyal to forest analyzed.

$$Ni = e^{5,9098 - 0,0489 \cdot di} \quad (2)$$

Where:

di = center of diameter class;

Ni = frequency by hectare in the diameter class i.

This equation showed a standard error in the estimation of 87.62 tress by hectare and a coefficient of determination of 0.87. This high number of errors was due to the initial classes present an elevated number of individuals observed, however for the greater diameter classes the observed frequency and the adjusted approached. Figure 1 shows the distribution of frequency by observed diameter class and the adjusted by Meyer's equation.

According with the data collected in 2008, 96.11% of the individuals are located in the classes of 9.5 to 49.5 cm, characterizing the distribution of frequency in negative exponential form, characteristic of natural forests, where there is higher concentration of individuals in the smaller diameter classes. In the first class of diameter, with DAP of 9.5 to 19.5 cm, the FLONA presented a density of 481.3 individuals by hectare, totalizing 59.44% of all individuals.

As observed by SOUZA and SOUZA (2005) this occurrence of great quantity of small and thin individuals can indicate in the diameter structure of the forest a tendency of equilibrated distribution, although, NUNES et al. (2003) state that a great quantity of individuals with low DAP can indicate the occurrence of severe disturbing in the past. Agreeing with this indicative, SOLIGO (2009) in a research in the very same FLONA related that 34.80% of the 1,606.70 hectares are planted forests, many of them in the past already suffered shallow cut, formed basically by *Araucaria angustifolia* (318.6 ha), *Pinus taeda* (36.8 ha), *Pinus elliottii* (154.9 ha) e *Eucalyptus sp*. (34.1 ha). As this areas of planted forest are close to some sample units used in this study, it maybe interfered in the quantity of individuals with greater diameters. LONGHI (2008) also argues that climatic variations occurred during 2004-2006 maybe influenced the occurrence of structural changes in the forest

In table 1 is present the value of the basal area and the relative percentage, both by hectare, of the arborous species found in the FLONA, which if of 46.18m^2 ha^{-1}. The basal area of the FLONA presented 45.26% above average of the Rio Grande do Sul state, which was of 31.79 m^{2}ha^{-1}, varying from 5.32 m^{2}ha^{-1} to 61.18 m^{2}ha^{-1} (RIO GRANDE DO SUL, 2002).

Among the species that present greater basal area are the A*raucaria angustifolia, Ilex brevicuspis* and *Blepharocalyx salicifolius*, respectively. The *Araucaria angustifolia* compose 16.49 m^{2}ha^{-1} of the forest, representing 36% of the total. The species that had basal area (G) smaller than 0.1m^{2}ha^{-1} were not included.

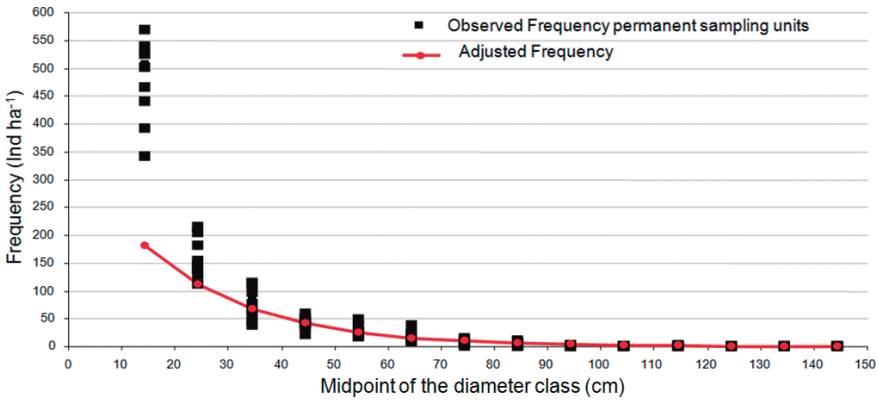

Figure 1. Distribution of frequency by classes of observed diameters by sample unit and the adjusted equation of Meyer for DAP > 9.5 cm, of trees found in the forest stocktaking done in 2008, in the FLONA of São Francisco de Paula, RS, Brazil.

Table 1. Basal area per hectare and relative percentage per hectare of the tree species found in forest stocktaking conducted in 2008, the FLONA of São Francisco de Paula, RS, Brazil.

Species	G/ha (m^2)
Araucaria angustifolia (Bertol.) Kuntze	16.49
Ilex brevicuspis Reissek	3.37
Blepharocalyx salicifolius (Kunth) O. Berg	3.33
Cryptocarya aschersoniana Mez	2.26
Sebastiania commersoniana (Baill.) L. B. Sm. et Downs	1.83
Ocotea pulchella Mart.	1.35
Casearia decandra Jacq.	0.64
Vernonia discolor (Spreng.) Less.	0.60
Eugenia uruguayensis Cambess.	0.58
Cinnamomum glaziovii (Mez) Kosterm.	0.55
Eugenia psidiiflora º Berg	0.50
Matayba elaeagnoides Radlk.	0.48
Luehea divaricata Mart. et Zucc.	0.45
Sapium glandulatum (Vell.) Pax.	0.44
Sebastiania brasiliensis Spreng.	0.42
Campomanesia xanthocarpa º Berg	0.37
Campomanesia rhombea º Berg	0.36
Roupala brasiliensis Klotzsch	0.31
Prunus myrtifolia (L.) Urb.	0.30
Ilex microdonta Reissek	0.29
Ocotea indecora (Schott) Mez	0.29
Prunus myrtifolia (L.) Urb.	0.30
Ilex microdonta Reissek	0.29
Ocotea indecora (Schott) Mez	0.29
Myrceugenia cucullata D. Legrand	0.24
Weinmania paulliniifolia Pohl ex Ser.	0.22
Lonchocarpus campestris Mart. ex Benth.	0.21
Myrsine umbellata Mart.	0.20
Eugenia involucrata DC.	0.19
Citronella gongonha (Mart.) Howard	0.19
Scutia buxifolia Reissek	0.19
Lithraea brasiliensis Marchand	0.18
Inga vera Willd.	0.18
Dasyphyllum spinescens (Less.) Cabrera	0.16
Myrciaria floribunda (West ex Willd.) O. Berg	0.14
Xylosma pseudosalzmannii Sleumer	0.14
Gordonia acutifolia (Wawra) H. Keng	0.13
Zanthoxylum rhoifolium L.	0.11
Myrcianthes gigantea (D. Legrand) D. Legrand	0.10
Calyptranthes concinna DC.	0.10
Cupania vernalis Cambess.	0.10
Total	46.18

In the Central-South region of the state of Parana, SANQUETTA et al. (2001) found the *Araucaria angustifolia* was the dominant specie, in which the basal area between 1995 and 1998 vary from 15.77 m^2ha^{-1} to 16.32 m^2ha^{-1}. In Nova Prata, RS, NASCIMENTO et al. (2001) found 4.15 m^2ha^{-1} for the *Araucaria angustifolia*. SEGER et al. (2005) in the city of Pinhais, PR found 17.10 m^2ha^{-1} of basal area for the *Araucaria angustifolia.*

The adjusted value of the quotient of Lioucourt, by Meyer's equation, presented the value of 1.63, a value close to that expected for this type of forest. This value implies that the difference in percentage between the frequencies of two successive diameter classes is 63%.

HESS et al. (2010), in the city of Lages, SC, found the value of 1,33 for the adjusted quotient of Lioucourt, in FOM. GLUFKE et al. (1994), in the city of Santa Maria, RS, found the value of 1.72.

Values close to 1 indicate that the frequencies of the successive diameter classes have values that do not alter often, that is, the forest do not possess the common distribution pattern in tropical forests, which is the distribution in negative exponential, the shape of "inverted J".

In table 2 are presented the data of frequency and the basal area by observed diameter class, adjusted and the difference between then. The total frequency observed was of 803 individuals per hectare and the adjusted by Meyer's equation was of 467.85 trees per hectare. Although the quantity of observed trees is superior in 335.25 units per hectares, representing 41.74% of the total observed frequency, yet is verified a deficit of 1.56 m^2ha^{-1} in relation to the adjusted area. Even that this deficit represents only 3.38% of the total basal area it can be noted that this value presents itself reduced, due to the large number of individuals observed in the initial classes. Considering for issues of forest handling, only the classes above 39.5 cm this deficit would be of 7.8 m^2ha^{-1}, representing 16.83% of the total basal area observed. The classes observed with more deficit are between 39.5 to 49.5 cm and between 69.5 to 119.5 cm.

In general terms, the forest showed the greatest concentrated basal areas in the classes of diameter below and averages and this occurred due to a larger concentration of trees in these classes. The trees with DAP between 9.5 to 69.5 cm constitute 84.09% of the whole basal area observed. In the diameter classes superior to 99.5 cm were found only six trees in all of the ten hectares analyzed, constituting less than 3.90% of the total basal area, being nominated by *Araucária angustifolia*.

Figure 2 presents the distribution of basal area per diameter classes of the trees observed and estimated.

Analyzing the Figure 2 there is a steeper decrease in the basal area observed of the classes above 69.5 cm, that is, a lower percentage of trees are passing to the upper classes, making these classes deficient. Further studies should be conducted in this area to verify that is occurring transition of the trees to the classes above of 69.5 cm

Table 2. Frequency and basal area per class of observed diameter, adjusted and its differences in forest stocktaking done in 2008, in the FLONA of São Francisco de Paula, RS, Brazil.

Class of diameter (cm)	Frequency (ha)			Basal Area (m^2)		
	Observed	Estimated	Difference	Observed	Estimated	Diference
9.5 -19.5	481.3	181.28	300.02	6.98	2.99	3.99
19.5-29.5	156.4	111.11	45.29	7.12	5.24	1.88
29.5-39.5	73.7	68.11	5.59	6.71	6.37	0.34
39.5-49.5	39.5	41.75	-2.25	6.06	6.49	-0.43
49.5-59.5	27.3	25.59	1.71	6.3	5.97	0.33
59.5-69.5	17.7	15.68	2.02	5.66	5.12	0.54
69.5-79.5	7.9	9.61	-1.71	3.4	4.19	-0.79
79.5-89.5	3.5	5.89	-2.39	1.93	3.3	-1.37
89.5-99.5	1.4	3.61	-2.21	0.94	2.53	-1.59
99.5-109.5	0.4	2.21	-1.81	0.34	1.9	-1.56
109.5-119.5	0.2	1.36	-1.16	0.19	1.4	-1.21
119.5-129.5	0.2	0.83	-0.63	0.23	1.01	-0.78
129.5-139.5	0.1	0.51	-0.41	0.15	0.72	-0.57
139.5-149.5	0.1	0.31	-0.21	0.17	0.51	-0.34
Total	803.1	467.85	335.25	46.18	47.74	-1.56

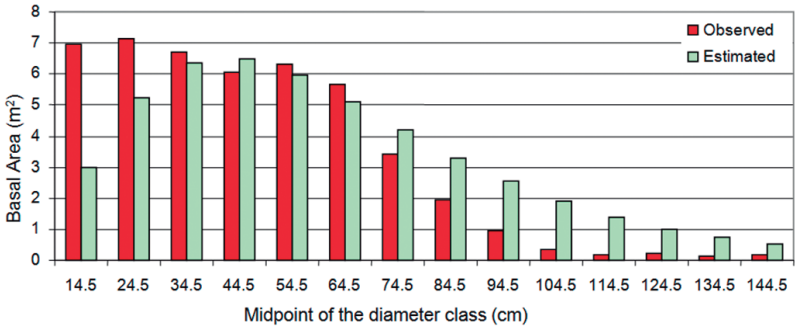

Figure 2. Distribution of basal area per diameter class of the trees observed and as estimated by Meyer's equation, found in the forest stocktaking conducted in 2008, the FLONA of São Francisco de Paula, RS, Brazil.

Conclusions

The data analysis indicates that the forest is not yet in balance, this imbalance in the frequencies of diameter classes occurs mainly in classes with higher DAP, which could have been caused by selective logging of some species.

The adjusted value of the quotient of Lioucourt, by Meyer's equation, presented the value of 1.63, which is expected for the Mixed Ombrophylous Forest.

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