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Influence of forest gaps on the density of cedar population in Silveira Martins-RS

Influência de clareiras florestais sobre a densidade da população de cedro em Silveira Martins-RS

Lilian Daniel PEREIRA[1]; Camila Elizabete SEVERIANO[2]; Evandro Alcir MEYER[3]; Karina LANZARIN[2]; Karina Marques WOLF[2]; Frederico Dimas FLEIG[4]

[1] Autora para correspondência" Doutora em Engenharia Florestal, Universidade Federal de Santa Maria, Av. Roraima nº 1000, Cidade Universitária, Bairro Camobi, Santa Maria – RS, CEP: 97105-900. liliandapereira@yahoo.com.br

[2] Programa de Pós-graduação em Engenharia Florestal, Universidade Federal de Santa Maria elizabeth.camila@gmail.com; karinalanzarin@gmail.com; dimasfleig@uol.com.br

[3] Doutor em Engenharia Florestal, Universidade Federal de Santa Maria. eam.meyer@gmail.com

[4] Engenheira Florestal e Especialista em Gestão, Auditoria e Licenciamento, Universidade Federal de Santa Maria. karina-mw@hotmail.com

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Abstract

The objective of this study is to analyze the influence of gaps on the density of cedar population (*Cedrela fissilis* Vell.) and characterize the total diameter distribution and size class of this species. The study area is located in the municipality of Silveira Martins (state of Rio Grande do Sul), where a census was conducted by walking through 5.54 hectares. The area was divided and characterized into A (0.36 ha), more intensive use of soil; B (0.10 ha), gap with a radius of approximately 17.5 m; C (0.08 ha), gap with radius of approximately 16 m; and D (5.0 ha), intermediate regeneration. All cedar individuals with a total height greater than 15 cm were measured and classified as adults (diameter at breast height - DBH > 10 cm), young (0 < DBH <10 cm), and seedlings (total height - Ht < 1.30 m). The density per area and the Chi-square test for the different areas were calculated. In addition, a diameter distribution histogram was constructed for each size class and area. The negative exponential shape of diametric distribution histograms evidences that the areas with gaps present a higher frequency of young individuals and seedlings; however, there was no difference between the gaps (areas B and C) and the area at an initial regeneration stage (area D).

Additional keywords: *Cedrela fissilis* Vell.; distribution in diameter; histograms of frequency.

Resumo

O objetivo deste estudo foi analisar se há influência das clareiras sobre a densidade da população de cedro (*Cedrela fissilis* Vell.) e caracterizar a distribuição diamétrica total e por classe de tamanho da espécie. A área de estudo localiza-se no município de Silveira Martins (RS), onde foi realizado um censo por caminhamento em 5,54 hectares. A área foi dividida e caracterizada em: A (0,36 ha) uso mais intenso do solo; B (0,10 ha) clareira com raio aproximado de 17,5 m; C (0,08 ha) clareira com raio aproximado de 16 m; e D (5,0 ha) regeneração intermediária. Todos os indivíduos de cedro com altura total superior a 15 cm foram mensurados e classificados em: adultos (diâmetro à altura do peito - DAP > 10 cm), jovens (0 < DAP < 10 cm), e plântulas (altura total - Ht < 1,30 m). Calcularam-se a densidade por área e o teste qui-quadrado para as diferentes áreas. Também, foi construído para cada classe de tamanho e área um histograma de distribuição diamétrica. A forma exponencial negativa dos histogramas de distribuição diamétrica indica que as áreas com clareiras apresentam maior frequência de indivíduos jovens e plântulas, entretanto não houve diferença entre as clareiras (áreas B e C) e a área em estágio inicial de regeneração (área D).

Palavras-chave adicionais: *Cedrela fissilis* Vell.; distribuição em diâmetro; histogramas de frequência.

Introduction

The characterization of diameter distribution is essential for forest research and practice (Jaworski & Podlaski, 2012; Reis et al., 2014) even though ecosystems rarely achieve a steady state in relation to diameter distribution, this characterization has a large importance for maintaining the forest structure through a sustainable management (Rubin et al., 2006), and may also be useful in growth and production models (Jaworski & Podlaski, 2012).

Different forest species may present different diametric distributions (Souza et al., 2012) influenced by their ecological characteristics (Orellana et al., 2014). Species tolerant to shading have a continuous regeneration and a negative exponential diameter distribution (Batista, 1989). On the other hand, regeneration is discontinuous in species intolerant to shading, and therefore have a diametric distribution tending to normal. In addition, the use of a diameter frequency histogram may evidence the current vegetation situation and indicate possible past disturbances (Souza et al., 2012).

The distribution of diameter in native forests is usually negatively exponential (Souza et al., 2010; Cabacinha & Castro, 2010), which generally indicates a good forest maintenance capacity since the high frequency of individuals in the smallest dimensions guarantees the perpetuation of the species (Orellana et al., 2014). However, there are also other diametric distribution models, such as normal or asymmetric, which do not necessarily indicate a low regeneration capacity of a species. This is the case of heliophilous species, which need gaps for regeneration (Souza et al., 2012). There are also other factors that may influence the recruitment process of a species and, consequently, its diameter distribution, such as the presence of fire, rainfall, topography, among others (Prior et al., 2010). It is worth noting that the negative exponential distribution is not always related to the presence of individuals at an initial stage of development, but rather to edaphic constraints (Cabacinha & Castro, 2010).

Therefore, studies aiming to record diameter distribution by species are important, since they allow evaluating natural regeneration and help to define exploration criteria aiming a sustainable management (Orellana et al., 2014). One of the species that has a high commercial value and multiple uses is cedar (*Cedrela fissilis* Vell.). It belongs to the Meliaceae family and presents a wide geographic distribution in South America, demonstrating the high tolerance to local environmental variations (Carvalho, 2003). Cunha et al. (2013) described it as a deciduous species. As for its ecological classification, there is no consensus. Reitz et al. (1983) consider this species as a pioneer, as it is found in virgin forests, secondary forests or semi-devastated forests. On the other hand, Vaccaro et al. (1999) classify this species as initial secondary because, although they found some individuals in virgin forests, the species presented an expressive amount of individuals in secondary forests. There are also authors who consider it a late secondary or climactic species demanding in light because it has a high longevity and may reach up to 40 m in height (Budowski, 1965; Carvalho, 2003).

In this context, this study has the objective to characterize the diameter distribution of *Cedrela fissilis* Vell. in a regeneration area and analyze the influence of gaps on its density.

Material and methods

The study area is located in Val Feltrina, municipality of Silveira Martins, central region of the state of Rio Grande do Sul, at an altitude of 431 m above sea level. According to the classification of Köppen, the mesothermic and humid climate of the region is Cfa, characterized as subtropical humid, with hot summers without a defined dry season (Alvares et al., 2013). The authors also described temperatures at annual average of 19 ºC, average of the hottest month exceeding 22 ºC, average of the coldest month exceeding 3 ºC, and average annual rainfall of 1,769 mm. The predominant soil in the region is typical Humic Litholic Neosol (Embrapa, 2006), which is a shallow, well-drained soil found between the wavy surfaces of the beginning of the Plateau. Pastures, annual crops and areas of secondary vegetation predominate in the use of these soils. They are suitable for less intensive uses, mainly forestry (Dalmolin et al., 2008).

The forest formation of the region is classified as Seasonal Decidual Forest (IBGE, 2012). The forest object of this study is secondary with an initial to intermediate regeneration variation and approximately 20 years of age without anthropic intervention. As the forest presents variations between regeneration stages, the area was characterized and divided into four categories: Area A - 0.36 hectare - more intensive soil use and absence of gaps; Area B - 0.1 hectare - presence of a gap with a radius of approximately 17.5 m; Area C - 0.08 hectare - presence of a gap with a radius of approximately 16.0 m; Area D - 5.0 hectares - a mosaic of vegetation at different ages, intermediate regeneration and absence of gaps (Figure 1). That is, it was an abandoned farm area whose canopy had an average height of 10 m, and areas with older vegetation and a canopy larger than 15 m.

A census was conducted by walking through a total area of 5.54 hectares. All cedar specimens with a total height greater than 15 cm had their positions referenced geographically using a GPS. Information on diameter at breast height (DBH) and total height (Ht) was collected. In small trees, to which DBH did not apply, the plant base diameter and total height were measured. The trees were classified according to the size class as adult (DBH > 10 cm), young (DBH <10 cm and Ht ≥ 1.30 m) and seedlings (Ht <1.30 m). In order to evaluate whether gaps in the canopy of the areas influenced the development of individuals, the cedar population density in the areas (A, B, C and D) was calculated by size classes and per hectare, and a Chi-square with complete randomness was applied for different areas. For the characterization of diametrical distribution, histograms were constructed for each class size and area. All analyses were performed using the software R, version 3.3.1 (R CORE TEAM, 2016).

Results and discussion

413 cedar specimens were divided into the following size classes: 42 adult trees, 225 young trees

and 146 seedlings, that is, 75 plants ha^{-1}. The height of the plants sampled varied between 0.15 and 23.00 m, with a mean of 3.4 m and a standard deviation of ± 3.7 m. The plants classified as adults presented a mean DBH of 21.8 cm ± 13.3 cm and a mean height of 12.1 ± 3.7 m; young plants presented a mean DBH of 3.2 cm ± 3.4 cm and a mean height of 3.4 ± 2.0 m; and seedlings had an average plant base diameter of 1.8 cm ± 1.2 cm and a mean height of 1.1 m ± 1.7 m. The number of trees in each size class and the respective densities were different for each area analyzed (Table 1).

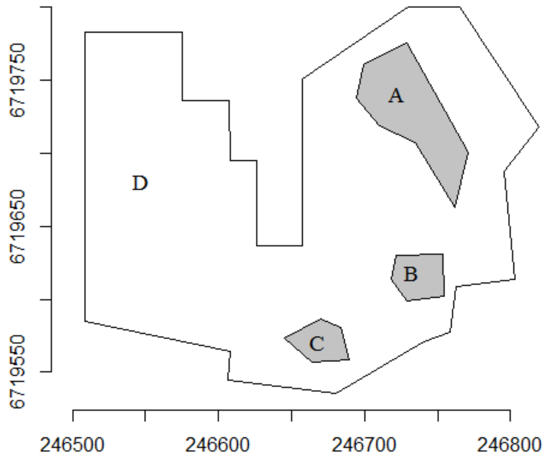

Figure 1 - Sketch of the area under study, the forest in the initial regeneration stage are the gray-filled polygons (A, B and C) and intermediate regeneration forest (D).

Table 1 - Number of trees in each study area and in parenthesis the number of trees per hectare of individuals of *Cedrela fissilis*, in a Secondary Seasonal Deciduous Forest, Silveira Martins-RS.

Classes	Areas				
	A	B	C	D	Total
Adult tree	04 (11.10)	04 (40.00)	00 (00.00)	34 (06.80)	42 (07.60)
Young tree	14 (38.80)	58 (580.0)	09 (112.5)	144 (28.80)	225 (40.90)
Seedling	19 (52.70)	15 (150.0)	09 (112.5)	103 (20.60)	146 (26.50)
Total	37 (102.8)	77 (770.0)	18 (225.0)	281 (56.20)	413 (75.10)

Adult tree (χ^2= 16,06, Pr.< 0,01), Young tree (χ^2= 775,81, Pr.< 0,01) and seedling (χ^2= 98,52, Pr.< 0,01).

The density of adult cedar trees in the Deciduous Seasonal Forest varied from 1.9 seedlings/ha (Farias et al., 1994) to 6.43 seedlings/ha (Hack et al., 2005). When sampling a DBH from 5 cm, the density varied from 5.6 seedlings/ha (Longhi et al., 1999) to 9 seedlings/ha (Scipioni et al., 2011). In other formations, the density of seedlings/ha of this species has a wide variation: 2.85 (Troian et al., 2011), 13.10 (Santos et al., 2012) and 15 (Orellana et al., 2014). The density of seedlings/ha found in this study is higher than that found in a Deciduous Seasonal Forest fragment at an advanced stage of succession: 62.5 seedlings/ha (Longhi et al., 2000).

The diametric distributions of each size class had a negative exponential shape (Figure 2), also known as an inverted "J". This distribution is typical of unequal forests (Callegaro et al., 2016; Cabacinha & Castro, 2010), and indicates that the species presents a good regeneration capacity and maintains itself in the environment (Orellana et al., 2014). However, other studies have shown that cedar may have an asymmetric unimodal diametric distribution (Machado et al., 2009; Figueiredo Filho et al., 2010; Orellana et al., 2014).

The higher frequency of individuals with intermediate dimensions may indicate a low establishment of new individuals, and that the species needs gaps for regeneration (Souza et al., 2012). There is also the hypothesis that this occurs due to an anthropic factor: selective cuts (Orellana et al., 2014). This is consistent with this study's species, which is semi-heliophilous, that is, it needs light for its initial development, but tolerates certain levels of shading; it is characterized as an opportunistic species that regenerates preferentially in gaps, or in areas abandoned by other activities (Carvalho, 2003).

According to Tonhasca Jr. (2005), after the occurrence of a disturbance, the affected area, depending on the degree of degradation, is colonized by pioneer species, which typically present a fast growth, high reproductive power, short longevity and are adapted to unstable environments. Over time, pioneers are gradually being replaced for species with a slower growth, less reproductive capacity, longer longevity, more competitive power and adapted to more stable environments. Therefore, it is expected that cedar present a variable diameter distribution according to the characteristics of the analyzed vegetation, mainly its degree of disturbance. In a forest inventory in the central region of Rio Grande do Sul, known as Fourth Colony, Brena and Longhi (2002) observed a negative exponential diameter distribution. The authors sampled individuals with more than 10 cm of DBH and, within this sampling limit, they found 13.35 specimens of cedars/ha.

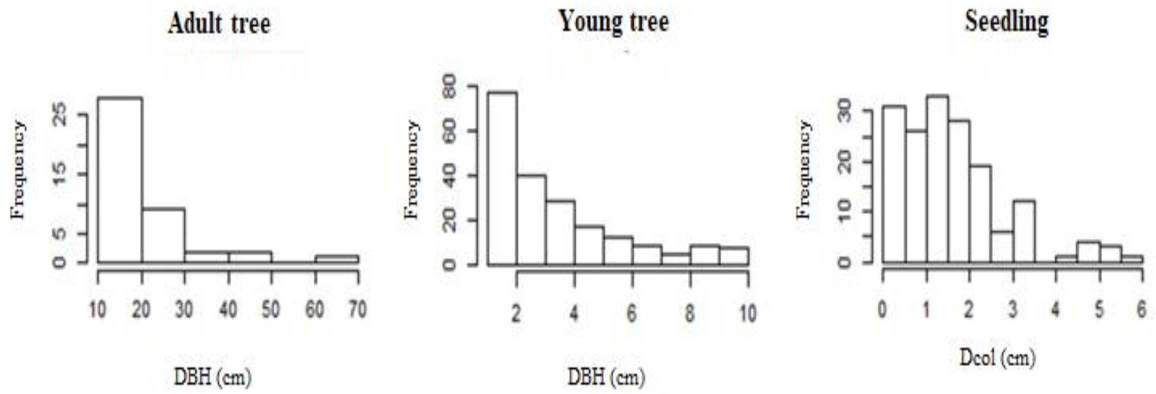

Figure 2 - Total diametric structure of individuals of *Cedrela fissilis*, in a Secondary Decidual Seasonal Forest, Silveira Martins-RS. DBH - diameter at breast height; Dcol - collar diameter.

Knowledge of theoretical diameter distributions at different stages is essential for the construction of forest dynamics models for forest management and protection (Jaworski & Podlaski, 2012). Thus, the distribution in "inverted J" obtained in this study may be due to the successional stage the area is at, that is, the area is at a regeneration stage. Moreover, it should be noted that the negative exponential shape does not always mean that the species is in equilibrium (Rubin et al., 2006). In a study on forest dynamics conducted by Sterba (2004), the author considered that, for an area to be stable, it does not need to present a negative exponential function, but it should be capable of, upon suffering interferences (anthropogenic or not) in a specific diameter class, maintaining the number of trees in that class equal to or greater than the number of the subsequent class. If this condition is satisfactory, the number of individuals in each class may be kept constant over time and the distribution will remain stable.

The histogram of seedling diameter did not present a typical inverted J shape, tending more towards an asymmetric shape, which may indicate variations in fruiting year and, consequently, in the dispersion and germination of the species (Grau, 2000). There is a strong relation between phenology and climate, but the fruiting phase presents complex interactions since it involves biological development besides those related to climate such as insect predation and contamination by pathogens (Alberti, 2002). Moreover, there is also the occurrence of moth caterpillars (*Hypsipyla grandella* Zell.) in fruits (Corvello et al., 1999), which may also influence the distribution and germination of seeds besides the climatic conditions that influence germination.

In general, the forest under study showed a high density of cedar specimens, both in the regeneration class and in the mature tree class. This is due to the seed source in nearby forest formations, as well as to the current vegetation stage, which provided ideal conditions for the establishment of individuals. Thus, we return to discussing succession category according to the characteristics obtained in this study based on Budowski (1965) and Carvalho (2003), suggesting that cedar is a late or climactic secondary species, since it is of high longevity and demanding in light. Another result that confirms this idea is the difference in the number of trees according to the sub-area (Figure 3 and 4) by size class, be it young trees or seedlings. It is observed that the highest densities of young trees and seedlings occurred in areas (B and C) formed by gaps. Therefore, cedar survival is higher in areas with gaps and consequently growth presents a superior performance under high luminosity (Santos et al., 2006). Between areas (B and C) with formation of gaps, there is also a difference in the sense that the area B presents a higher plant density due to the proximity with a source of propagules.

It should be noted that, by observing the total number of cedar specimens in each size class, there is a decrease in the number of seedlings in relation to the young class. This shows that the regeneration of this species is becoming discontinuous, proving that it needs light for its germination and establishment. According to Prior et al. (2010), the lowest density of seedlings in relation to young trees may indicate that in the past a climatic condition was more favorable for the recruitment of the species. Another hypothesis for the lowest seedling density in relation to young trees is that gaps are already being colonized by juvenile trees and present reduced spaces for the regeneration of seedlings.

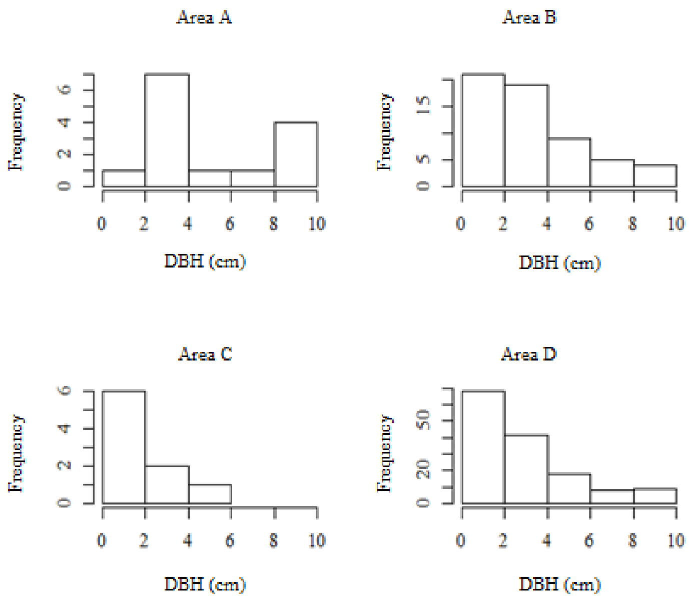

Figure 3 - Diameter structure of young trees of *Cedrela fissilis*, in a Secondary Decidual Seasonal Forest, Silveira Martins-RS. DBH - diameter at breast height.

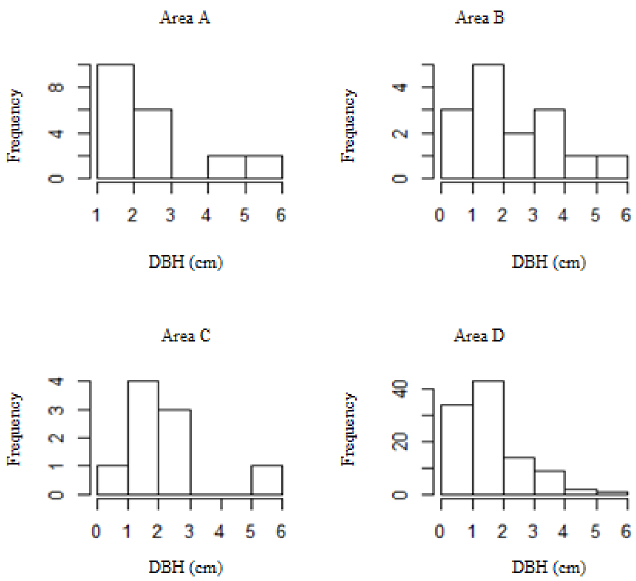

Figure 4. Diametric structure of *Cedrela fissilis* seedlings in a secondary Decidual Seasonal Forest, Silveira Martins-RS. DBH - diameter at breast height

Conclusions

The diameter distribution of cedar in a Deciduous Seasonal Forest area was negatively exponential.

The diameter distribution was the same for the initial stage of regeneration and gaps, differing from the initial regeneration area with an intensive use of soil, indicating that the establishment of regeneration, besides depending on the presence of luminosity, depends on the quality of the site.

Cedar regeneration is slower in areas with a more intensive soil use.

Gaps that have already been colonized by juvenile cedar plants have reduced spaces for the establishment of new species regenerators.

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