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Original Article

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Growth Dynamics of Araucaria after Management Interventions in Natural Forest

Régis Villanova Longhi[1], Paulo Renato Schneider[1], Solon Jonas Longhi[2], Gabriel Paes Marangon[3], Emanuel Arnoni Costa[1]

[1]Departamento de Ciências Florestais, Universidade Federal de Santa Maria – UFSM, Santa Maria/RS, Brazil
[2]Universidade Tecnológica Federal do Paraná – UTFPR, Dois Vizinhos/PR, Brazil
[3]Centro de Ciências Agrárias, Universidade Federal de Alagoas – UFAL, Rio Largo/AL, Brazil

ABSTRACT

The objective of this study was to evaluate the effect of selective logging on the growth dynamics of *Araucaria angustifolia* in a natural forest of Rio Grande do Sul state, Brazil. Treatments were based on percentage reduction of the basal area per DBH class, namely, T0 (control) = 0%; T1 (light selective logging) = reduction of 20-30%; T2 (moderate selective logging) = reduction of 40-50%. Data were obtained prior to the management interventions and four, eight and 13 years after selective logging. Changes between treatments were assessed using the following parameters: absolute density, absolute dominance, importance value index, and growth rates. Results show that population reduction and canopy opening provided greater recruitment and higher growth rates for araucaria in the management treatments (T1 and T2) compared with those of the control treatment (T0). These results reinforce that management practices are necessary for the continuous development of araucaria in this forest formation.

Keywords: increment, selective logging, mixed forest.

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1. INTRODUCTION

Araucaria angustifolia (Bertol.) Kuntze (Brazilian pine; araucaria) is a tree species characteristic of Mixed Ombrophilous Forests (MOF), also known as Forests with Araucaria (IBGE, 2012). In Brazil, this formation occurs in the southern states located below the Tropic of Capricorn, having a humid subtropical climate, within latitudes 19 and 31° S and longitudes 41 and 54° W (Cabral & Cesco, 2008), 500 to 1200 m above sea level (Guerra et al., 2002).

It was estimated that there was approximately 25 million hectares of Forest with Araucaria at the beginning of the 20th century (Ribeiro et al., 2009). During the wood cycle however, in the 1950s and 60s, there was intense exploitation of timber species such as Araucaria (*Araucaria angustifolia* (Bertol.) Kuntze) and Brazilian walnut (Imbuia) (*Ocotea porosa* (Mez) L.Barroso), and non-timber species such as Xaxim (*Dicksonia sellowiana* Hook.) (Higuchi et al., 2012). This reduced the Forests with Araucaria to 12.6% of their original extension (Ribeiro et al., 2009). In the state of Rio Grande do Sul, of the 25.0% of the previously existing original area (Carvalho, 1994), only 10.6% is still covered with MOFs (Cordeiro & Hasenack, 2009), and these are at initial, intermediate and advanced stages of succession, highly decharacterized compared with their original structure.

As a result of these intense exploitation pressures in the past, *Araucaria angustifolia* was included in the vulnerable category in the official list of Brazilian flora species threatened with extinction (IBAMA, 1992), and more recently in the IUCN Red List of Threatened Species (Thomas, 2013) as critically endangered. Felling of araucaria in natural forests is currently prohibited by law. However, history shows that restrictions on the use of a natural resource are rarely observed by the general population, especially when the resource is a raw material or source of income. In these cases, protection through prohibition means devaluation of the good, which quite often leads to a loss of interest in its conservation (Nutto, 2001).

In addition, what has been observed in the understory of Forests with Araucaria at advanced stages of development and with high density of trees is a high mortality rate combined with low natural regeneration of this species, leading to uncertainties in terms of its capacity for regenerative and continuous development in the forest. Some studies have reported low regeneration capacity under developed forest (Soares, 1979; Narvaes et al., 2005; Souza et al., 2008; Beckert et al., 2014).

According to Rosot (2007), an effective way to revert the trend of fragmentation and degradation of Forests with Araucaria is the adoption of multiple-use forest management, which requires research to be conducted into Araucaria Forest management that goes beyond a merely academic focus and formulates an effective technical-scientific basis capable of creating legal instruments to regulate the use of forest resources, as well as to underpin policy to encourage these measures.

According to Smith (1986), one of the purposes of forest management is to maximize sunlight availability for natural regeneration and for commercial species remaining in the forest, aiming to increase the growth rate of trees and, consequently, have shorter logging cycles. However, in the domain of Mixed Ombrophilous Forest, there is a lack of studies on the behavior of remaining vegetation after management controlled interventions, so that the benefits of this practice for the restructuring of altered forests and/or sustainable forest use could actually be confirmed.

In this context, the objective of this study was to evaluate the growth dynamics of *A. angustifolia* after 13 years of application of different intensities of selective logging in a Mixed Ombrophilous Forest located in the upper slope of northeastern Rio Grande do Sul state, Brazil. To this end, two hypotheses were made: i) Selective logging of leafy species of high density and dominance benefit the recruitment of *A. angustifolia* in the forest; ii) Controlled reductions of population density in the forest, through selective logging, increase *A. angustifolia* growth rates compared with those of unexploited areas.

2. MATERIAL AND METHODS

This study was conducted in the “Fazenda Tupi”, which belongs to “Paludo Agropecuária S.A.”, a company of the VIPAL group, located in the municipality of Nova Prata, Rio Grande do Sul state (28° 40’ and 28° 43’ S; 51° 38’ and 51° 36’ W). The total area of the farm is 962 ha, with 784 ha of Mixed Ombrophilous Forest, according to IBGE (2012). This area presents a history of intensive exploitation, which started in the 1970s culminating in indiscriminate exploitation of *Araucaria angustifolia* in the mid 80s, when most of the larger individuals present on the property were logged. This exploitation modified the structure of the forest fragment both through the intensive logging of the araucarias as well as through the damage caused to the remaining trees. Recently, in a forest inventory with a large sampling effort (7.1 ha) conducted on this farm, Callegaro et al. (2016) observed mean density for *Araucaria angustifolia* of 14.5 ind.ha^{-1}, and mean values for density, basal area, height, and diameter for the forest in general of 600 ind.ha^{-1}, 32.08 m^2.ha^{-1}, 13.9 m, and 22.2 cm, respectively; which characterizes this vegetation as secondary, at an advanced stage of natural regeneration, according to the resolution no. 33/94 by CONAMA (Brasil, 2012).

The relief of the region is predominantly undulating, with occurrence of Nitosols and Neosols (Streck et al., 2008). According to the Köppen classification, climate in the study area is Cfa, humid subtropical with hot summers (Alvares et al., 2013), mean annual temperature of 17.0 °C, and rainfall distributed throughout all months of the year, with annual precipitation of approximately 1900 mm.

In 2001, a management experiment was initiated at the MOF of "Fazenda Tupi" aiming to test different selective logging intensities compared with a silvicultural treatment applied to the forest. Six sample units of 50 m × 100 m (0.5 ha) were established, divided into plots of 10 m × 10 m for spatial control of the individuals, comprising a total sample area of 3.0 ha. The units were spaced approximately 30 m from each other and were at least 100 m distant from the forest edge, thus avoiding border effects. At that time, all trees with circumference at breast height ≥31.4 cm (DBH ≥10.0 cm) present in each management unit were identified and numbered using aluminum plates; a 2 cm-wide yellow strip was also painted at measurement height (1.30 m) to avoid errors in subsequent measurements.

In 2002, the interventions were designed and conducted in the study by Borsoi (2004). They consisted of reducing the adjusted frequency distribution curve per DBH class at different percentage levels of basal area. One of the following treatments was applied to each of the sample units: T0 – control: unlogged area; T1 – light selective logging: reduction of the adjusted frequency distribution curve with logging of approximately 20-30% of the total basal area per DBH class; T2 – moderate selective logging: reduction of the adjusted frequency distribution curve with logging of approximately 30-40% of the total basal area per DBH class. The frequencies were adjusted based on the model by Meyer (1952), considering diameter classes with amplitude of 10.0 cm.

At the time of the selective logging interventions, trees of all diametric classes were felled, covering a range of 10.0 to 80.0 cm in diameter. According to each selective logging intensity, preference was given to hardwood species with higher absolute density (especially *Matayba elaeagnoides*) and to defective, dead and damaged individuals. This logging preference aimed, for the next intervention, to obtain individuals with regular stems, well distributed canopies and, consequently, a more productive forest with regular distribution of species. Felling of trees was semi-mechanized, with cleaning of lianas off the selected ones, and logging was performed so that the felling of the trees affected the minimum number of individuals possible, both adults or from natural regeneration, as highlighted by Borsoi (2004). It is worth noting that, in this first management intervention, *A. angustifolia* trees were not felled due to the logging prohibition in force at the time.

The data used in this study was obtained from the inventory conducted prior to the management interventions (2001) and at three monitoring times, namely, the inventories conducted in 2006, 2010, and 2015, after four, eight and 13 years of selective logging, respectively. Changes in the horizontal structure of each management treatment were evaluated prior to the selective logging intervention and four and thirteen years after the application of forest management. To this end, traditionally used phytosociological parameters were estimated: absolute density, absolute dominance, and importance value index (Mueller-Dombois & Ellenberg, 1974).

The growth rates of *A. angustifolia* between the different management treatments, at each time of assessment, were represented by the relative annual diameter increment (ADI%) instead of the absolute increment, considering that the capacity of a tree to gain increment in diameter is related to its initial diameter. For comparison between the growth rates, a completely randomized design (CRD) with a different number of observations (unbalanced) was used, considering the trees present in each selective logging intensity as repetitions. Data resulting from the ADI% were submitted to analysis of variance (ANOVA) and means were discriminated by the Tukey-Kramer test at the significance level of $\alpha = 0.05$. To ensure the application of significance tests based on the *F* distribution, tests of normality and homogeneity of variances were applied for the response variable - ADI%. To this end, the Levene test was used to verify homogeneity, whereas the Shapiro-Wilk test was applied for normality. In order to comply with the assumptions, the method proposed by Box & Cox (1964) was used to stabilize the variance by means of a lambda power (λ) estimated by maximum likelihood.

3. RESULTS AND DISCUSSION

Table 1 shows the participation of *A. angustifolia* in the horizontal structure of the forest fragment in each management treatment and for each measurement time, considering the 10 species of highest importance value (IV%) 13 years after the interventions. In all treatments, *Matayba elaeagnoides* was the species with the highest IV%, confirming the current stage of secondary development of the forest, not presenting *A. angustifolia* as the most important species of the canopy, which was cited by many authors, including Reitz et al. (1983) and Kanieski et al. (2010), as a species of constant and dominant presence in the domains of the Mixed Ombrophilous Forest.

The forest showed good restructuring capacity in its parameters for the selective logging treatments (T1 and T2), considering that the logging preference for individuals of high absolute density and low commercial interest at the time of the interventions (*M. elaeagnoides* in the present study) resulted in a positive change in the analyzed phytosociological parameters, which increased the participation of species of greater economic value/importance, such as *A. angustifolia*. Prior to the management interventions (2001), this species occupied the fourth position in the ranking of importance value in the light selective logging treatment (IVI% = 4.96%), the third position in the ranking in the moderate selective logging treatment (IVI% = 5.91%), and the sixth position in the control treatment (IVI% = 6.60%). Thirteen years after the interventions, greater increase in the importance value index for this species was observed in the selective logging treatments (T1 and T2) compared with the control treatment (T0). This index showed values of 7.98% (third position in the IVI% ranking) and 8.73% (second position in the IVI% ranking) for the light (T1) and moderate (T2) selective logging treatments, respectively, with both values higher than those for the control treatment (T0), which was 7.20%.

Despite the intense logging to which *M. elaeagnoides* was submitted due to its presenting the highest absolute density and dominance values in the area at the time of the interventions, it was still the most important species in the forest thirteen years after the selective logging interventions in the analysis of both management treatments. However, decreases in the importance value indices of 27.50% (IVI% = 23.53%) for the light selective logging treatment (T1) and of 32.1% (IVI% = 29.20%) for the moderate selective logging treatment (T2) were observed compared with those found prior to the management interventions (IVI% = 34.66% in T1 and IVI% = 40.29% in T2).

Analysis of the behavior for the absolute density and absolute dominance variables per hectare showed that, among the selective logging treatments, only T1 (light selective logging) was able to recover the initial density and basal area thirteen years after the management interventions, presenting absolute values of 684 $ind.ha^{-1}$ and 29.59 $m^2.ha^{-1}$, respectively. Additionally, these values correspond to increases of 44 $ind.ha^{-1}$ and 2.80 $m^2.ha^{-1}$ compared with those observed prior to the interventions.

Regarding the control treatment (T0), a decrease of 71 $ind.ha^{-1}$ was observed in absolute density, with an increase of only 1.39 $m^2.ha^{-1}$ in the basal area, compared with the first measures taken in 2001. This observation shows the high degree of competition in the forest, considering that the high density of trees reflects the lower availability of resources (sunlight, nutrients, etc.), mainly in the lower strata of the forest, thus leading to low growth rates and high natural mortality rates of individuals.

Highlighting *A. angustifolia*, Table 2 shows the changes that occurred over time in the absolute density, mean diameter, mean height and basal area variables in each management treatment applied in the forest. Prior to the interventions (2001), the absolute density of *A. angustifolia* was similar between the treatments, presenting the following values: 22 ind. ha^{-1} for T0 (control), 17 $ind.ha^{-1}$ for T1 (light selective logging), and 23 $ind.ha^{-1}$ for T2 (moderate selective logging). Thirteen years after the forest management, it was possible to verify that the selective logging interventions, in addition to stimulating recruitment, caused no mortality of individuals during this period.

Total recruitment was 24 $ind.ha^{-1}$ in T1 and 7 $ind.ha^{-1}$ in T2. Of these, greater recruitment was observed between eight and 13 years after the selective

Table 1. Phytosociological parameters of the 10 species of highest Importance Value Index (IVI%) in each management treatment and time of measurement.

Species	2001 (-1 year)				2006 (+4 years)				2015 (+13 years)			
	P	AD	ADo	IVI%	P	AD	ADo	IVI%	P	AD	ADo	IVI%
T0 – Control (unlogged)												
Matayba elaeagnoides	1	122	4.48	13.78	1	112	4.52	14.22	1	107	4.85	14.19
Zanthoxylum kleinii	2	67	4.01	9.95	2	64	4.24	10.57	2	60	4.65	10.38
Myrciaria floribunda	4	88	1.58	8.18	3	88	1.66	8.84	3	80	1.71	8.52
Araucaria angustifolia	6	22	4.35	6.60	7	21	4.56	7.01	4	21	5.02	7.20
Erythroxylum deciduum	3	72	2.16	8.29	4	61	2.09	7.98	5	50	1.95	7.05
Lithraea brasiliensis	5	55	3.31	7.66	5	47	3.23	7.44	6	40	3.14	6.69
Blepharocalyx salicifolius	7	40	1.56	5.31	8	37	1.63	5.52	7	35	1.86	5.50
Cupania vernalis	9	39	1.06	4.37	9	36	1.06	4.52	8	40	1.25	5.07
Campomanesia xanthocarpa	10	34	0.67	3.69	11	36	0.76	4.26	9	40	0.90	4.64
Myrcia obtecta	8	46	1.14	4.94	10	38	1.01	4.43	10	37	1.04	4.44
Other species		201	7.48	27.23		178	6.18	25.21		184	6.82	26.32
TOTAL		786	31.80	100		718	30.93	100		694	33.19	100
T1 – Light selective logging (reduction of 20-30% of basal area)												
Matayba elaeagnoides	1	271	10.59	34.66	1	171	6.69	25.86	1	183	7.88	23.53
Cupania vernalis	2	70	1.75	9.75	2	71	1.92	11.02	2	88	2.60	11.18
Araucaria angustifolia	4	17	2.12	4.96	3	24	2.59	6.76	3	41	3.57	7.98
Myrciaria floribunda	7	26	0.40	3.80	5	33	0.51	5.02	4	41	0.71	5.43
Luehea divaricata	6	14	1.69	3.82	6	16	1.87	4.74	5	21	2.20	4.75
Casearia decandra	3	37	0.74	5.43	4	33	0.63	5.10	6	34	0.69	4.69
Ilex paraguariensis	8	15	1.31	3.66	7	17	1.28	4.22	7	26	1.60	4.60
Ocotea pulchella	9	10	1.24	2.95	8	10	1.35	3.39	8	10	1.53	2.99
Solanum mauritianum	13	15	0.21	2.11	11	19	0.35	2.67	9	23	0.60	2.93
Campomanesia xanthocarpa	12	14	0.31	2.18	13	15	0.36	2.52	10	19	0.49	2.68
Other species		143	6.26	26.68		148	5.81	28.70		181	7.15	29.24
TOTAL		638	26.62	100		557	23.38	100		667	29.02	100
T2 – Moderate selective logging (reduction of 40-50% of basal area)												
Matayba elaeagnoides	1	298	14.22	40.29	1	165	7.95	34.05	1	164	8.87	29.20
Araucaria angustifolia	3	23	2.80	5.91	2	23	3.19	8.63	2	30	3.84	8.73
Myrciaria floribunda	5	35	0.53	4.89	4	37	0.53	6.70	3	56	0.84	7.74
Erythroxylum deciduum	2	52	2.09	7.75	3	37	1.61	8.05	4	32	1.55	5.96
Casearia decandra	18	9	0.18	1.47	7	13	0.20	2.68	5	29	0.42	4.65
Lithraea brasiliensis	4	36	1.51	5.63	5	22	1.05	5.06	6	17	1.13	3.69
Nectandra megapotamica	9	14	0.42	2.27	8	12	0.43	2.66	7	20	0.69	3.37
Campomanesia xanthocarpa	7	21	0.36	3.09	6	16	0.31	3.18	8	20	0.41	3.24
Ilex paraguariensis	32	2	0.04	0.33	26	4	0.08	0.74	9	16	0.31	2.51
Cupania vernalis	24	6	0.09	0.86	17	7	0.12	1.35	10	13	0.22	2.12
Other species		147	6.72	27.51		108	4.90	26.90		146	6.07	28.79
TOTAL		643	28.94	100		444	20.36	100		543	24.34	100

AD = Absolute density (no. $ind.ha^{-1}$); ADo = Absolute dominance ($m^2.ha^{-1}$); P = Position in the ranking of highest Importance Value Index; () = Time elapsed in relation to the selective logging interventions.

Table 2. Absolute density, mean diameter, mean height, and basal area for *Araucaria angustifolia* for each measurement time and management treatment applied in the forest.

Treatment	Variable	Time of measurement			
		2001	2006	2010	2015
T0 Control	No. ind.ha^{-1}	22	21	21	21
	Mean DBH (cm)	48.3	51.1	52.1	53.6
	Mean height (m)	19.0	19.6	20.1	20.6
	BA (m^2.ha^{-1})	4.34	4.56	4.73	5.02
T1 Light selective logging	No. ind.ha^{-1}	17	24	29	41
	Mean DBH (cm)	34.9	31.3	29.9	27.2
	Mean height (m)	18.5	16.0	15.5	15.0
	BA (m^2.ha^{-1})	2.12	2.59	2.91	3.57
T2 Moderate selective logging	No. ind.ha^{-1}	23	23	24	30
	Mean DBH (cm)	35.9	38.4	38.9	35.1
	Mean height (m)	19.3	18.8	18.4	17.4
	BA (m^2.ha^{-1})	2.80	3.19	3.47	3.84

2001 = 1 year prior to management intervention; 2006, 2010, 2015 = 4, 8, and 13 years after management intervention.

logging in both treatments, with absolute values of 12 ind.ha^{-1} and 6 ind.ha^{-1} for T1 and T2, respectively. The recruitment of these smaller individuals contributed to reductions in the mean diameter and mean height variables in these management treatments 13 years after the selective logging interventions.

With respect to the control treatment (T0), higher absolute values were found for the basal area, mean diameter and mean height variables for all measurement times, suggesting that this forest fragment is in a more advanced stage of development owing to the absence of selective logging. Nevertheless, a deficit of 1 ind.ha^{-1} was verified in the analyzed period for this treatment, with no recruitment of araucaria trees. This finding reinforces the low potential of *A. angustifolia* individuals, present in the understory of highly dense forests, to develop and reach classes of adult vegetation (DBH≥10 cm), being naturally substituted by the advance of broad-leaved species. This has already been referenced in several studies which reported the low regeneration capacity of araucaria under developed forest (Souza et al., 2008; Paludo et al., 2009; Callegaro & Longhi, 2013; Beckert et al., 2014; Ebling et al., 2014).

The increase in *A. angustifolia* density in the management treatments (T1 and T2) indicated that, regardless of selective logging intensity, canopy opening with reduction of competition for space, light, nutrients, etc. benefited the recruitment of individuals that were in the forest understory and presented sufficient growth (DBH≥10 cm) to enter the forest growing stock. It is worth emphasizing that, due to *A. angustifolia* being a heliophic species when adult (Carvalho, 2003), and its benefitting from dim shading during germination and in the growing stage up to two years (Reitz & Klein, 1966), lack of sunlight associated with thickening of the forest canopy and competition with the hardwood species prevent araucaria from finding favorable conditions for regeneration (Lingner et al., 2007), or even leading to individuals in the forest understory presenting stagnant growth, with small dimensions and susceptible to natural mortality if no sunlight is available.

One hypothesis for *A. angustifolia* distribution is the formation of demographic units by a group of trees recruited over the same time interval, constituting cohorts. According to Ogden & Stewart (1995), current knowledge regarding the life history and mode of regeneration of forests with dominance of large conifers in the Southern Hemisphere was summarized in the conceptual model by Lozenge. According to this model, also known as "cohort structure", a group of conifers (cohort) of large size and demanding light (pioneers) establishes itself after severe disturbances. These groups are followed by cohorts of angiosperm (hardwood) species that dominate the forest understory and suppress the recruitment of conifers, which is restricted to the formation of clearings caused by the fall of trees. According to Souza (2007), if applicable for South American conifers, this model would characterize *A. angustifolia* as a pioneering, long-lived species with populations dominated by adults and dependent on disturbances for effective regeneration and long-term maintenance.

Higher recruitment rates of *A. angustifolia* have also been observed in areas with different exploitation histories. Sanquetta et al. (2003) analyzed growth, mortality and recruitment in two Forests with Araucaria in the state of Parana, and found higher *A. angustifolia* recruitment rates in an area that had undergone systematic understory thinning for yerba mate (*Ilex paraguariensis*) management and selective logging for timber, compared with that of another area that had been kept undisturbed for over 25 years, presenting low recruitment owing to high density forest and fiercer competition.

The growth of *A. angustifolia* trees observed in the present study evidenced the positive response of annual diameter increment (ADI) to the selective logging interventions, considering that both management treatments (T1 and T2) presented higher values compared with those of the control treatment (T0), which obtained the smallest increments, with values of 0.25 $cm.year^{-1}$ in Period 1 (2006-2010) and 0.31 $cm.year^{-1}$ in Period 2 (2010-2015). The light selective logging treatment (T1) showed the highest rates of diameter growth, with values of 0.62 $cm.year^{-1}$ and 0.80 $cm.year^{-1}$ for Periods 1 and 2, respectively (Table 3).

The high diameter growth rate for *A. angustifolia* observed in T1 for the period between eight and 13 years after the management interventions is mostly attributed to the larger number of individuals recruited in the re-measurement of 2010 (eight years after the selective logging interventions), and presented a high growth rate due mainly to the favorable conditions that canopy opening provided to these individuals that were in the lower forest stratum. In a study on the growth dynamics of a Mixed Ombrophilous Forest, Beckert et al. (2014) verified mean annual diameter increment of 0.33 $cm.year^{-1}$ for *A. angustifolia*, and concluded that the low increment rates were due to intense competition and little available sunlight in the lower forest strata. The authors also emphasize that the higher mortality rates compared with those of recruitment indicate a trend for this species to disappear if no silvicultural intervention is conducted.

Furthermore, when studying the remaining *A. angustifolia* trees in a 20-year-old logged forest area, Nogueira (1989) compared the radial increments prior to and after reaction to logging intervention for three types of canopy and clearly verified a large difference between them following reactions caused by logging. The radial increment was over twice as much as that found before the reaction for all types of canopy. The author also notes that this fact is the result of some treatment applied to the forest, attributed to canopy opening provided by selective logging, which significantly improved growth conditions, resulting in a greater diameter increment.

To compare the incremental rates between the treatments, verified by the relative annual diameter increment (ADI%), after the Box-Cox transformation having indicated a lambda value (λ) of zero within the

Table 3. Annual diameter increment for *Araucaria angustifolia* by management treatment.

Treatment	Variable	Time of measurement	
		1 (2006-2010)	2 (2010-2015)
T0 Control	N	21	21
	ADI (cm)	0.25	0.31
	ADI%	0.52 **b**	0.60 **b**
T1 Light selective logging	N	24	29
	ADI	0.62	0.80
	ADI%	3.14 **a**	4.03 **a**
T2 Moderate selective logging	N	23	24
	ADI	0.45	0.40
	ADI%	1.57 **a**	1.35 **b**

N = number of observations; ADI = annual diameter increment; ADI% = relative annual diameter increment; (2006-2010) = Period between four and eight years after the selective logging interventions; (2010-2015) = Period between eight and thirteen years after the selective logging interventions. Means followed by the same letter in the same column do not differ statistically by the Tukey-Kramer test, α = 0.05.

confidence interval in both assessment periods, it was assumed that application of logarithmic transformation would be the best way to fit with the assumptions of ANOVA.

Table 3 shows that, in Period 1 (between four and eight years after the selective logging interventions), the mean relative diameter increment for *A. angustifolia* was higher for all selective logging treatments compared with those of the control treatment, presenting a statistically significant difference at 5% probability level. This result indicates that araucaria growth was positively influenced by the management interventions regardless of selective logging intensity.

As for Period 2 (between eight and 13 years after the selective logging interventions), it was possible to observe that the light selective logging treatment (T1) presented higher growth than the others, showing a statistically significant difference. This fact may be related to the significant recruitment of *A. angustifolia* in this treatment, therefore presenting a larger proportion of smaller individuals with increased growth potential. This behavior was observed to a lesser extent in the moderate selective logging treatment (T2), considering that the greatest recruitment occurred in 2015 and that these individuals were not included in the calculation of the mean increment rates.

In addition, reduction in competition and the consequent increase in availability of resources (sunlight, nutrients, etc.) that was provided to the remaining araucaria individuals contributed to the high diameter increment rates in the selective logging treatments (T1 and T2). Similarly, a study conducted by Nogueira (1989) reported that canopy opening, promoted by selective logging of the larger diameter araucarias, influenced the growth of the remaining trees, considering that reaction was observed in the radial growth of most trees.

According to Soares (1979), *A. angustifolia* is dependent on some level of disturbance to regenerate and remain dominant in its habitat. Based on what has been previously presented, this first management intervention at experimental level conducted in an MOF fragment located in the "Fazenda Tupi", municipality of Nova Prata, Rio Grande do Sul state, proved to be effective for both management intensities assessed. Nevertheless, light selective logging (reduction of approximately 20-30% in basal area) allowed for total recovery of the forest stock in a shorter time (less than 13 years), and it is therefore recommended as an alternative to reduce natural mortality (recruitment and increment) of *A. angustifolia* individuals present in forest understory and facing competition from broad-leaved species.

4. CONCLUSIONS

After thirteen years of application of different intensities of selective logging, it was possible to verify that the removal of hardwood species of low commercial value and high absolute density, mainly *Matayba elaeagnoides* - a common and dominant species in disturbed Forests with Araucaria - induce *Araucaria angustifolia* recruitment and growth in these environments. This finding reinforces that management of Mixed Ombrophilous Forests should be considered as a frequent and necessary practice for the perpetuation of *Araucaria angustifolia* in these stagnant forests which have undergone past disturbance.

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CORRESPONDENCE TO

Régis Villanova Longhi
Departamento de Ciências Florestais, Centro de Ciências Rurais, Universidade Federal de Santa Maria – UFSM, Avenida Roraima, 1000, Camobi, CEP 97105-900, Santa Maria, RS, Brazil
e-mail: regislonghi@yahoo.com.br

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