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Wood production from a *Pinus taeda* L. stand attacked by *Sapajus nigritus*

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ABSTRACT: This study aims to assess the impact of damage caused by *Sapajus nigritus* Kerr (1792) on dendrometric variables and wood production in a *Pinus taeda* L. stand located in Bocaina do Sul, Santa Catarina, Brazil. To do so, 46 circular plots with a radius varying from 5 to 10 m were installed, in which the circumference at breast height, the total height of all trees, and the lowest height and length of damage caused by monkeys were measured. Of the 675 measured trees, 223 showed evidences of some type of damage, including "girdling" and "windowing". The girdling damage caused by capuchin monkeys was more acute and compromised 8.64 $m^3.ha^{-1}$, while windowing affected 3.23 $m^3.ha^{-1}$. The loss was equivalent to R$ 1,460,875 for the assessed 236 ha pine plantation. The gross value of the average production for undamaged trees was R$ 22,928 ha^{-1} while for damaged trees it was R$ 10,693 ha^{-1}. These results demonstrate the impact of this type of predation on *P. taeda* and the importance of quantifying and characterizing the damage as a basis for defining actions related to the management of plantations.

Produção de madeira em um povoamento de *Pinus taeda* L. atacado por *Sapajus nigritus*

RESUMO: Essa pesquisa teve por objetivo avaliar o impacto do ataque de *Sapajus nigritu* (Kerr) 1792 nas variáveis dendrométricas e na produção de madeira de um povoamento de *Pinus taeda* L., localizado em Bocaina do Sul, estado de Santa Catarina. Para isso, foram instaladas 46 parcelas circulares de raio variável (5 a 10 m), sendo medidas a circunferência à altura do peito e altura total de todas as árvores, e altura inferior e comprimento dos danos encontrados. Das 675 árvores mensuradas, 223 apresentaram algum tipo de ataque. Dos danos causados pelo macaco-prego por "anelamento" e "janelamento", o primeiro ocorreu de forma mais acentuada, comprometendo 8,64 $m^3.ha^{-1}$, enquanto o janelamento danificou 3,23 $m^3.ha^{-1}$. O prejuízo foi de R$ 1.460.875 para os 236 hectares de pinus avaliados. O valor bruto da produção média das árvores sem danos foi de R$ 22.928 ha^{-1} enquanto para as árvores atacadas foi de R$ 10.693 ha^{-1}. Tais resultados evidenciam o impacto do ataque desse primata em *P. taeda* e a importância da quantificação e caracterização dos danos como base para definir ações relacionadas ao manejo de povoamento desta espécie.

Introduction

Sapajus nigritus Kerr (1792) commonly known as the capuchin monkey, is an endemic species that occurs in the South and Southeast regions of Brazil and Northeastern Argentina (Lynch Alfaro et al., 2012). The diet of the omnivorous primate is influenced by learning, which enables the inclusion of new foods, such as *Pinus* spp. (Rock, 2000). Made up of carbohydrates, amino acids, organic acids, proteins, and mineral salts (Dinant, 2008), pine can be considered a fallback food source, with low consumption preference and high seasonal importance (Marshall and Wrangham, 2007).

The search for alternative foods by capuchin monkeys has been affected by the degradation and exploitation of the Atlantic Forest, which leads to food shortages during certain periods (Liebsch et al. 2008). The consumption of forest resources, such as the sap of *Pinus* spp., causes damage and interferes with growth and production in pine plantations. To obtain this food source, capuchin monkeys remove the bark from the tree, causing two types of damage: windowing (partial removal of the bark in one or more internodes) and girdling (bark removal around the entire circumference of the tree). In addition to compromising tree growth, these damage patterns can expose trees to other pests such as fungi (Koehler and Firkowski, 1996; Rocha, 2000; Mikich and Liebsch, 2014; Liebsch et al., 2015).

In this context, we can see the impact of primate predation on pine producers and the forestry sector, as the loss of wood volume and quality in affected areas has resulted in significant financial losses. Capuchin monkeys are native species protected under the Environmental Crimes Law (Law nº 9.605/1998) (Brazil 1998), making population control impossible. Thus, the proper monitoring of affected forests becomes of paramount importance to quantitatively assess the damage and inform decision-making aimed at preventing and controlling predation by this primate.

Research-based on this approach was developed by researchers from the Capuchin Monkey Project coordinated by Embrapa Forestry (Brazilian Agricultural Research Corporation), which resulted in studies such as those by Liebsch et al. (2015) and Liebsch et al. (2018). With the creation and development of the computational tool Capuchin Monkey Calc (Embrapa Florestas, 2018), we can estimate the loss of wood production in forest stands attacked by capuchin monkeys, in addition to predicting the production of these plantations according to the degree and age at which the attack occurred (Oliveira et al. 2015).

Considering the importance of studies related to the proper planning and management of affected forests, this study aimed to evaluate the impact of *S. nigritus* predation on dendrometric variables and economic production in a *Pinus taeda* L. stand located in Bocaina do Sul, Santa Catarina, Brazil.

Material and Methods

Study Area

The study was conducted at the Cerro Rico farm located in the municipality of Bocaina do Sul, Santa Catarina (SIRGAS 2000 coordinate averages of 27°41'32.41"S and 49°57'46.06"W). According to the Köppen classification, the climate of the region is classified as Cfb (humid subtropical mesothermal climate with cool summers, no dry season, and severe frosts). The average annual temperature is 16.5º C, relative humidity is 79.3%, and precipitation is well distributed throughout the year, with an annual average of 1500 mm (Alvares et al., 2013).

The farm has a total area of 1,535.57 ha. Planting of *P. taeda* L. was conducted in 2002 and 2003, with a spacing of 3 m x 2.5 m, for a total planted area of 236.10 ha. No thinning was performed, and the harvesting system used was the full tree.

Field data

The monitoring and measuring of 675 trees were conducted during the months of March and April 2018. To conduct the forest inventory, 46 circular plots were established with a radius varying from 5 to 10 m to include both damaged and undamaged trees. This criterion was adopted due to the predation pattern of *S. nigritus*. Thus, each plot included an average of 10 trees. The central coordinate of each plot was obtained with a GPS (Global Positioning System), model Garmim Etrex Legend®, with an approximate precision of 10 meters.

In each plot, all tree individuals were measured for circumference at breast height (CBH) using a measuring tape and height using a Vertex Hypsometer. From the CBH data, the diameter at breast height (DBH) in centimeters was obtained. In addition, the lowest height at which damage occurred (m) and the length of the damage (cm) were also measured. Types of damage (girdling and windowing) and the occurrence of dry or yellowish tips on trees were evaluated. Based on Liebsch et al. (2015) girdled trees were considered as those with only girdling as well as those with both types of damage. Subsequently, the total volume of trees (m^3) was obtained by applying the form factor formula of 0.45.

Calculation of production losses and economic evaluation

The data were entered into the SisPinus software (Pine Growth and Production Simulator) (Oliveira 2011), with the "Capuchin Monkey calc" spreadsheet (Embrapa Florestas, 2021). From this, it is possible to create three other worksheets: two for calculating losses due to physical damage to the trunk and one for estimating loss in growth in the affected stand.

In addition to the total volume, the damaged volume (m³), volume above site of damage (m³), and volume below site of damage (m³) were calculated. Further, a prognosis of growth and production of stands attacked by *S. nigritus* was also generated.

To quantify the loss of revenue per ha due to the attack (Table 1), we considered the prices of the assortments as described in the methodology by Liebsch et al. (2018). Thus, the loss in production (m^3 ha^{-1}) for the plots was obtained, and subsequently, the economic impact of the attack was quantified considering the area of the affected stands.

Table 1. Price relation of assortments of undamaged *Pinus taeda* L. trees and those damaged by *S. nigritus* in southern Brazil, based on market value in the second half of 2021.

Price per m³ (R$)		
Assortment (cm)	Undamaged	Damaged
8 to 18	53.00	53.00
18 to 25	126.00	89.00
25 to 35	173.00	89.00
35 to 45	250.00	67.00

Source: From Liebsch et al. (2018).

Liebsch et al. (2015) found that at 10 years of age, girdled trees had annual losses in DBH growth of approximately 4.0% per year, with a 27.7% loss for attacks that occurred at 5.5 years, and 4.2% for attacks that occurred in the final year. For trees with windowing, losses were 0.7% per year, with 3.57% for damage that occurred at 5.5 years, and 0.74% in the final year. The authors did not assess the extent to which these losses affect neighboring trees. However, in the case of girdling, evidence suggests that the loss of part of the crown would have a positive impact on neighboring trees due to decreased competition, thus mitigating some of the damage caused by predation. Herein, these effects were similarly not assessed, as we only calculated the economic impact and loss of wood after the harvest of damaged trees.

Results and discussion

The dendrometric variables of DBH, height, and volume showed similar outcomes for undamaged and damaged trees (Table 2).

The descriptive statistics showed similar values for dendrometric variables (Table 2). However, the average DBH for girdled and windowed trees was slightly higher than that of undamaged trees. Meanwhile, the average height of the windowed trees was greater than that of girdled and undamaged trees. The total volume of girdled trees was slightly higher than the others, followed by windowed and undamaged trees. These results can be explained by the fact that the damage was concentrated among the thickest and tallest trees in the stand. Similar results were obtained by Liebsch et al. (2015), in which bark stripping occurred in all diameter classes, though there was a preference for more vigorous trees.

Table 2. Dendrometric variables of *Pinus taeda* L. trees and those damaged by *S. nigritus* in southern Brazil.

DBH per plot		
Statistic	Undamaged	Damaged
Range	40.95	38.82
Mean	27.42	27,85
Median	27.39	27.59
Standard deviation	6.18	5.91
Coefficient of variation	22.55%	21,22%
Total height per plot		
Range	15.70	15,80
Mean	18.31	18,37
Median	18,50	19.20
Standard deviation	3.47	3.30
Coefficient of variation	18.96%	17,96%

Source: From Liebsch et al. (2018).

Of the 675 measured trees, 223 showed some type of damage. The tabulation of the information collected in the field enabled us to illustrate the percentage of occurrence of damage (girdling and windowing) by tree (Figure 1).

Figure 1 - Relation of damage caused by *S. nigritus* in a *Pinus taeda* L. stand located in Bocaina do Sul, SC.

Individuals older than 16 years of age had a higher incidence of girdling, representing 38.5%, while the incidence of windowing was higher for individuals of 15.5 years (31.2%). Table 3 shows the extent of damage to the evaluated trees, with the majority having only one type of damage. However, some trees had both girdling and windowing, and only one evaluated tree showed evidence of being girdled twice and windowed once.

Table 3. Maximum number of damages per tree caused by *S. nigritus* in a *Pinus taeda* L. stand located in Bocaina do Sul, SC.

	Number of damage sites per tree					
	Girdling			Windowing		
Age	1	2	3	1	2	3
15.3	44	2	1	8	1	-
15.5	29	3	1	14	-	-
15.6	27	2	-	13	-	-
16.2	65	1	-	12	-	-
Total	165	8	2	47	1	-

The most accentuated damage was due to girdling, with these trees exhibiting similar patterns to those described by Liebsch et al. (2015): drying and breaking off the tip, attack by microorganisms, and areas of decay. Windowing appeared to be a more recent attack, due to the presence of bark chips found near the damaged trees. However, the resin in the damaged tree is expected to isolate the damage site and enable the recovery of exposed tissue, as described by Liebsch et al. (2015).

The greatest incidence of attacks was found among the oldest trees in the population, at 16.2 years of age. Furthermore, the percentage of damage per tree showed that trees with a single incidence made up 95.3% of the girdled trees and 97.9% of the windowed trees. In other studies, the amount of damage per tree was greater than the results found herein. For example, Liebsch et al. (2015) showed that 63.8% of the studied *P. taeda* L. population was damaged by *S. nigritus*, of which 27% presented a single damage site, with trees showing up to eight sites of damage (girdling and windowing).

The height at which the damage occurred is consistent with that described in the literature, as the height of the damage site increased with the age of the trees (Figure 2). Furthermore, 13.6% of the damage sites were concentrated below 10 m of trunk height, while 59.5% occurred at up to 20 m.

The lowest height of the damage site increased with the age of the trees. This can be explained by the predation pattern typical of this primate, as they tend to damage the upper portion of trees, as has been noted by Koehler and Firkowski (1996), Rocha (2000) and Mikich and Liebsch (2009). Liebsch et al. (2015) found that 23% of the damage sites were below 7 m of trunk height. The authors point out that this section of the trunk has the greatest economic value and if such damage occurs when trees are older, the economic loss is less significant.

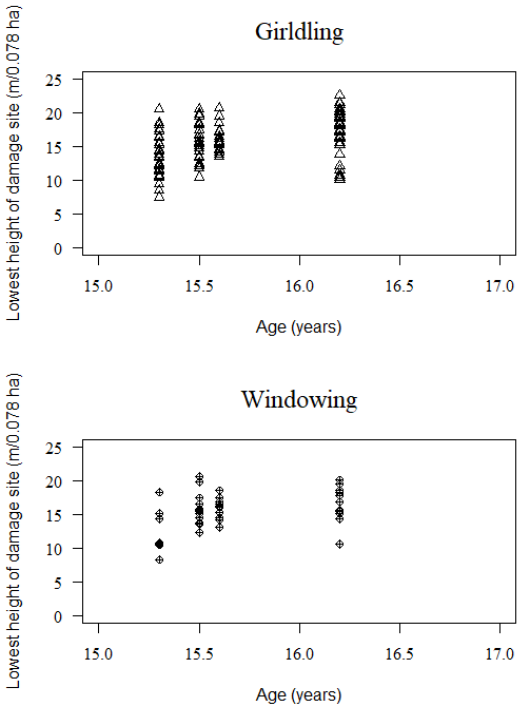

Figure 2 - Lowest height of the damage site and age of trees girdled and windowed by *S. nigritus* in a *Pinus taeda* L. stand located in Bocaina do Sul, SC.

The attack caused an impact of R$ 6,190 ha^{-1} in the production of the evaluated stand, with the total revenue being R$ 33,620 ha^{-1}. The most significant losses were in the assortments from 25 to 35 cm and 35 to 45 cm, respectively (Figure 3).

If the attack had not occurred and the wood was sold undamaged, the total revenue per ha would have been R$39,810 ha^{-1}. Thus, the loss was R$ 1,460,875 for the 236 ha pine plantation evaluated herein. Considering that, for the first 8-18 cm assortment, trees with damage showed higher productivity, a fact related to the strong commitment of the upper part to damage in ringed trees or with strong windowing.

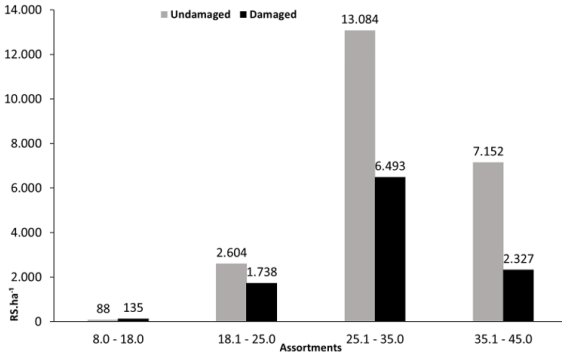

Figure 3 - Loss of production value per hectare of a *Pinus taeda* L. stand attacked by *S. nigritus* in Bocaina do Sul, SC.

In terms of volume, 8.64 $m^3.ha^{-1}$ were affected by girdling and 3.23 $m^3.ha^{-1}$ by windowing. This result confirms the work by Liebsch et al. (2018), in which losses in volume also occurred in *P. taeda* trees attacked by capuchin monkeys. Girdling was the most acute type of damage and in the first thinning, the girdled trees did not produce damaged wood. In the second thinning and clear cutting, there were losses caused by a ringed tree that had areas damaged by windowing.

The impact of the damage caused by *S. nigritus* on income obtained from thinning and clear-cutting *P. taeda* L. plantations was studied by Liebsch et al. (2018). Their results showed that the damage caused by monkeys had the greatest impact in the second thinning and that girdling resulted in both a loss of quality and a reduction in the price of the logs.

The gross value of the average production of undamaged trees was R$ 22,928 ha^{-1} while the average production of damaged trees was R$ 10,693 ha^{-1}. If no damage had occurred, these trees would have provided an income of R$16,883.$ha^{-1}$. The greatest loss occurred in the assortment from 25 to 35 cm, because of the high commercial value of these logs. In Liebsch et al. (2018), girdling caused the greatest losses in production volume, quality, and revenue, while windowing caused 45% losses in revenue when compared to healthy trees. The assortments that showed the greatest losses were 18 to 25 cm and 25 to 35 cm.

Liebsch et al. (2015) highlighted that windowing is the least harmful in terms of growth increment, however, such damage does affect the quality of the wood. Girdling, on the other hand, results in the partial drying of individuals as it interrupts the transport of sap above the lesion. In addition, the tip may also break, thus halting growth. The results presented herein reinforce the predatory behavior of *S. nigritus*, indicating that the primate attacked the tallest trees in this population, that is, the dominant and co-dominant trees. Finally, the damage resulted in significant losses to this plantation, demonstrating that it is extremely important to adopt forest management strategies to avoid greater economic losses.

Conclusions

The damage caused by *S. nigritus* to the *P. taeda* population resulted in an economic loss of 15.5% of the total revenue obtained from the sale of timber. If a production cost equivalent to 50% of total revenue is considered, the percentage of loss would be 31.1%. This study highlights the impact of this primate's behavior on a forest stand and underscores the importance of quantifying and characterizing the damage to define forest management strategies for this plantation.

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References

Alvares C. A.; Stape J. L., Sentelhas P. C.; Gonçalves J. L. M.; Sparovek G. (2013) Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, Stuttgart, 22(6):711-728. doi: 10.1127/0941-2948/2013/0507.

Brasil (1998). Lei nº 9.605, de 12 de fevereiro de 1998. Dispõe sobre as sanções penais e administrativas derivadas de condutas e atividades lesivas ao meio ambiente, e dá outras providências. *Diário Oficial da República Federativa do Brasil*, 13 fev. 1998.

Dinant S. (2008) Phloem, transport between organs and long-distance signalling. *Comptes Rendus Biologies*, 331(5): 334-346. doi: 10.1016/j.crvi.2008.03.001

Embrapa Florestas. 2021. Aplicativo para cálculo de perdas por macaco-prego: Macaco-prego Calc. Disponível em: https://www.embrapa.br/florestas/programa-macaco-prego. Acesso em: 21 nov. 2021.

Koehler A.; Firkowski C. (1996) Descascamento de pinus por macaco-prego (*Cebus apella*). *Floresta*, Curitiba, 24(1/2): 61-75.

Liebsch D.; Moreira J. M. M. A.P.; Oliveira E. B.; Mikich S. B. (2018) Impacto do descascamento de árvores de *Pinus taeda* L. por macacos-prego na produção e receita em plantios com desbastes. *BIOFIX Scientific Journal*, Curitiba, 3(1): 48-55. doi: dx.doi.org/10.5380/biofix.v3i1.56574.

Liebsch D.; Oliveira E. B.; Moreira J. M. M. Á. P.; Mikich S. B. (2016) Inventário e aplicativo computacional para avaliação de danos causados por macaco-prego em plantios de pinus. *Comunicado Técnico*, n 384. Embrapa Florestas. Colombo, PR, p.1-8.

Liebsch D.; Mikich S. B.; Oliveira E. B.; Moreira J. M. M. Á. P. (2015) Descascamento de *Pinus taeda* por macacos-prego (*Sapajus nigritus*): tipos e intensidades de danos e seus impactos sobre o crescimento das árvores. *Scientia Forestalis*, Piracicaba, 43(105):37-49.

Liebsch D.; Marques M. C. M.; Goldenbeg R. (2008) How long does the Atlantic Rain Forest take to recover after a disturbance? Changes in species composition and ecological features during secondary succession. *Biological Conservation*, 141(6):1717-1725.

Lynch Alfaro J. W.; Silva J. J. R.; Rylands A. B. (2012) How Different Are Robust and Gracile Capuchin Monkeys? An Argument for the Use of Sapajus and Cebus. *American Journal of Primatology*, 74(4): 273-286. doi: 10.1002/ajp.22007.

Marshall A. J.; Wrangham R. W. (2007) Evolutionary consequences of fallback foods. *International Journal of Primatology*, 28(6):1219-1235. doi: http://dx.doi.org/10.1007/s10764-007-9218-5.

Mikich S. B.; Liebsch D. (2014) Damage to forest plantations by tufted capuchins (*Sapajus nigritus*): too many monkeys or not enough fruits? *Forest Ecology and Management*, 314: 9-16. doi: http://dx.doi.org/10.1016/j.foreco.2013.11.026.

Mikich S. B.; Liebsch D. (2009) O Macaco-prego e os Plantios de *Pinus* spp. Comunicado Técnico, n 234. Embrapa Florestas. Colombo, PR, p.1-5.

Oliveira E. B.; Moreira J. M. M. A. P.; Liebsch D.; Mikich S. B. (2015) Ferramenta computacional para estimar perdas na produção de madeira de *Pinus taeda*, atacadas por macaco-prego (*Sapajus nigritus*). In: CONGRESSO FLORESTAL PARANAENSE, 5. 2015, Curitiba. Novas tecnologias florestais: Anais... [Curitiba]: Associação Paranaense de Empresas de Base Florestal, 2015. 10 p.

Oliveira E. B. (2011) Softwares para manejo e análise econômica de plantações florestais. *Documentos*, 216. 70p. Disponível em http://www.infoteca.cnptia.emprapa.br/infoteca/handle/doc/898050. Acesso em: 05 jan. 2022.

Rocha V. J. (2000) Macaco-Prego, como controlar essa nova praga florestal? *Floresta*, Curitiba, 30(½): 95-99.