TreeDimensional Journal, Vol. 14, e025042, 2025
Original Article | **DOI:** doi.org/10.55746/treed.2025.02.042

Minimum Diameter and Cutting Cycle of *Copaifera Langsdorffii* in Brazilian Neotropical Forest

Vanessa da Paixão Lisboa[1], Dirceu Lúcio Carneiro de Miranda[1], Luciano Cavalcante de Jesus França[2], Thiago Floriani Stepka[3], Tiago Monteiro Condé[4], Fábio Venturoli[5], Vagner Alex Pesck[6], Luciano Farinha Watzlawick[6], Gerson dos Santos Lisboa[5,*]

Abstract
The legislation applied to management plans in the Amazon region establishes a minimum cutting diameter, cutting rate, and cutting cycle for the forest as a whole, without considering the individual growth rate of each species. Given this, this study aims to estimate the minimum cutting diameter (MCD) and cutting cycle (CC) of *Copaifera langsdorffii*, a native Brazilian tree of high value in traditional medicine. For our investigation, we conducted dendrochronological analyses and growth modeling. Tree disk samples from individual trees were used, with their cross-sections sanded with different grit sizes. Growth ring width measurement was performed using Image Pro Plus software, while ring synchronization was carried out with the Cofecha software. To estimate the minimum cutting diameter and cutting cycle, we applied growth modeling through nonlinear regression, using the Gompertz, Chapman-Richards, and Weibull models. The correlation of growth rings was positive and satisfactory (0.403), exceeding Pearson's critical level (0.328, $p < 0.01$), demonstrating the species' potential for dendrochronological studies. An MCD of 56 cm and a CC of 22 years were estimated. Therefore, the studied species exhibits moderate growth, resulting in an MCD and CC different from those established by Brazilian legislation. This information is essential to support forest management practices aimed at the sustainability of the species.

Keywords
Forest Management — Amazon — Dendrochronology — Growth Modeling

[1] *Federal University of Mato Grosso*
[2] *Federal University of Uberlândia*
[3] *State University of Santa Catarina*
[4] *State University of Roraima*
[5] *Federal University of Goiás*
[6] *State University of Central-West*
***Corresponding author**: gersonlisboa@ufg.br

1. Introduction

Forest management in the Amazon is based on a polycyclic system, in which a minimum cutting diameter (MCD), cutting rate, and cutting cycle (CC) are established for the forest as a whole. Logging is carried out selectively, targeting species of commercial value (Souza, 2012). According to the law, the cutting cycle is determined based on the extraction rate from the forest, without considering the growth rate of individual species (Miranda et al., 2018).

In the state of Mato Grosso, an important region in the Midwest of Brazil, management plans follow the normative instruction nº 05 of 12/11/2006 from the Ministry of the Environment. This regulation establishes a minimum cutting diameter of 50 cm and a cutting cycle of 25 to 35 years for all species, with a maximum cutting rate of 30 $m^3.ha^{-1}$ (BRASIL, 2006). The legislation simplifies these requirements to facilitate the approval and operation of forest management plans, ultimately turning them into a bureaucratic instrument (Braz et al., 2012). However, to ensure the sustainability of Forest Management Plans, it is essential to understand the individual growth patterns of species (Silva et al., 2003; Vatraz et al., 2012).

One of the ways to assess forest growth and productivity is through continuous forest inventories with the

Received: 2024/01/01 | **Accepted:** 2025/02/24 | **Online published:** 2025/02/25

establishment of permanent plots. However, this procedure requires a medium to long-term period for data generation. When a species exhibits annual growth rings, dendrochronology allows for the reconstruction of a tree's growth in a relatively fast and reliable manner (Figueiredo Filho et al., 2017).

The growth of forest species can be influenced by both genetic characteristics and the environment in which they are found (Husch et al., 1982). Among the environmental factors that affect growth are climatic factors (temperature, wind, precipitation, and sunlight), pedological factors (physical and chemical properties, moisture, and microorganisms), topographic characteristics (slope and elevation), and competition (influence of other trees, understory, and animals). These are the main factors influencing growth (Prodan et al., 1997; Schaaf et al., 2005). All these characteristics contribute to variations in species growth.

Knowledge about growth, especially of commercially important species, is crucial to ensuring the sustainability of forest management (Borges et al., 2018; Costa et al., 2007). In Brazil, information on the age of trees in natural conditions is scarce, making dendrochronological studies a key source of such data (Aguiar & Moutinho, 2015). In the Amazon, research based on tree growth rings has contributed to understanding species growth, and this information can be applied to forest management. These studies can be used to determine the growth potential of species and establish a cutting cycle compatible with their growth, ensuring the continuity of timber production in both quantity and quality (Souza et al., 2009).

For a long time, it was believed that tropical climate species did not form annual rings, due to the less pronounced seasonal changes in environmental conditions compared to temperate forest species (Latorraca et al., 2015). However, a vast number of botanical families of tropical tree species have been identified as forming annual growth rings, demonstrating the potential for applying dendrochronological analysis to tropical forest species (Alvarado et al., 2010; Andreacci et al., 2014).

In this context, dendrochronology emerges as a valuable tool, providing data in a relatively fast and reliable manner (Loiola et al., 2019). It contributes to the generation of information that can be used in growth and yield modeling to estimate the minimum cutting diameter (MCD) and cutting cycle (CC) (Schöngart et al., 2007). Several studies have shown that species may have MCD and CC values different from those established by legislation, as demonstrated by Leoni et al. (2011), Rosa et al. (2017), Schöngart et al. (2007), and Schöngart (2008). In the southern Amazon, different MCD and CC values were also found for *Qualea paraensis* and *Parkia pendula* (Miranda et al., 2018). However, for *Copaifera langsdorffii*, there is still a lack of information to determine appropriate MCD and CC values for this species.

Thus, the objective of this study was to estimate the minimum cutting diameter and cutting cycle of *Copaifera langsdorffii* Desf. using the Gompertz, Chapman-Richards, and Weibull models.

2. Material and Methods

2.1 Study Area

The study was conducted using sample units in tropical forests under Sustainable Forest Management Plans (PMFS) in three municipalities in the state of Mato Grosso, Brazil (Brasnorte, Itaúba, and Sinop) (Figure 1.a), all of which belong to the northern mesoregion of the state.

According to Köppen's classification (Figure 1.b), the state of Mato Grosso has climates of the Am type (humid or subhumid tropical) and tropical savanna (Aw) hot-humid (Álvares et al., 2013), with 4 to 5 dry months and an average annual temperature above 18℃ in all months. The dry season occurs in autumn/winter, while the rainy season takes place in spring/summer, with annual rainfall ranging from 1,200 to 2,000 mm (Souza et al., 2013).

2.2 Species Characteristics

The species *Copaifera langsdorffii* belongs to the Fabaceae family and is commonly known as copaíba, óleo-de-copaíba, pau-de-óleo, among other names. Its height ranges from 5 to 15 meters, with diameters between 50 and 80 cm, but it can reach up to 35 meters in height and 100 cm in diameter. It is a semi-deciduous species, occurring in both primary forests and secondary formations. Flowering occurs from December to March, and its fruits mature between August and September, during which the plant is almost entirely leafless (Lorenzi, 1992). *C. langsdorffii* belongs to the ecological group of late secondary to climax species, being light-demanding yet shade-tolerant, and is considered a long-lived species (Carvalho, 2003).

Copaifera spp. have a cosmopolitan distribution, extending beyond the tropical regions of the Americas, also occurring in West Africa, from northern Argentina to Mexico (Santos et al., 2022). In Brazil, sixteen species can be found, among which *Copaifera langsdorffii* Desf. is one of the most abundant, naturally distributed across the Northeast, North, Central-West, Southeast, and South regions. It can be found in different phytophysiognomies, such as Campo Rupestre, Cerrado, Riparian or Gallery Forest, Terra Firme Forest, Seasonal Semideciduous Forest, and Ombrophilous Forest, in addition to being widely distributed in anthropized areas (Zappi et al., 2015; Santos et al., 2022). *C. langsdorffii* stands out for its extensive

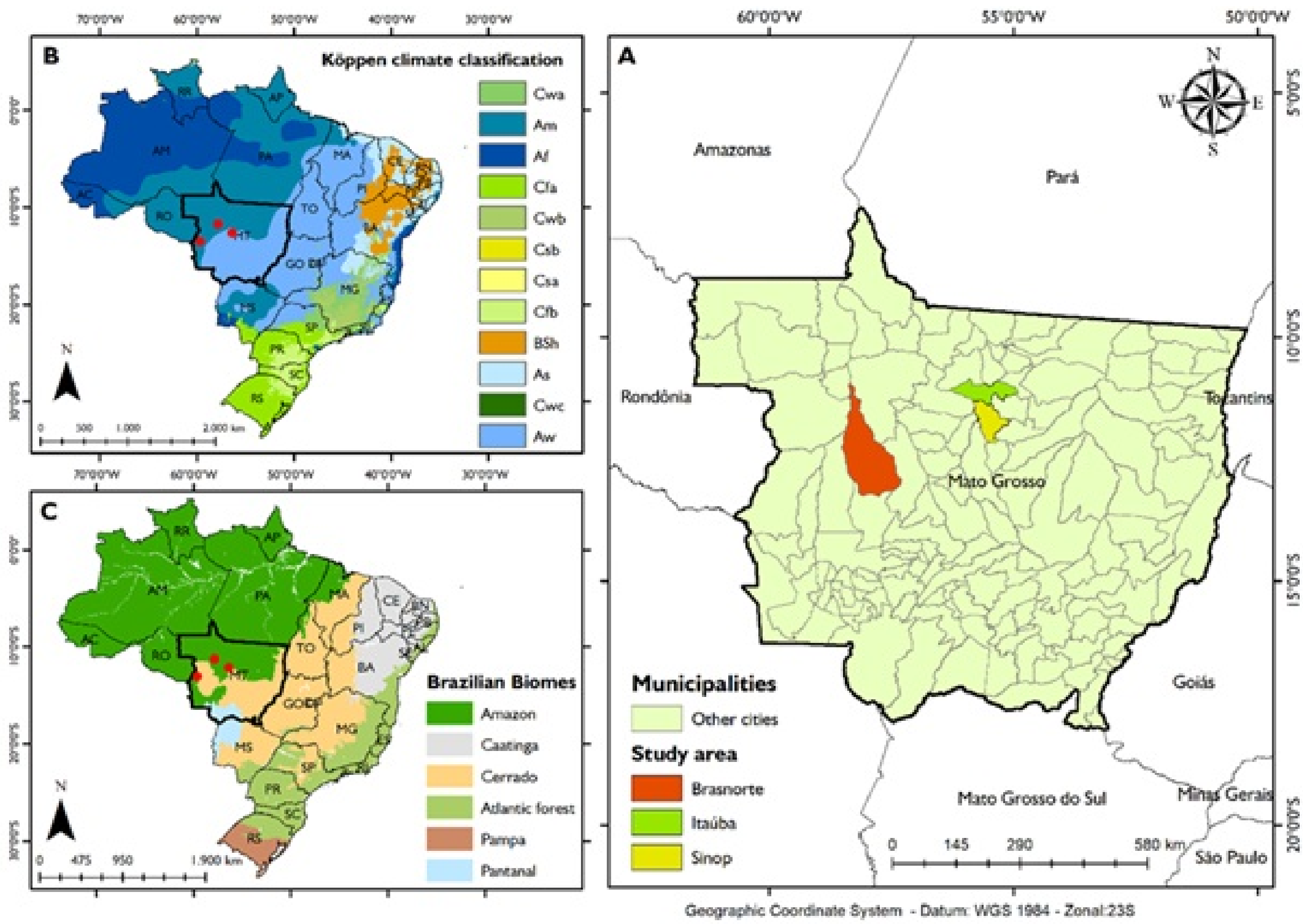

Figure 1. Location of the municipalities where samples were collected (A); Köppen climate classification (B); and Biomes of Brazil (C).

use in communities and as a target for chemical and pharmacological research (Santos et al., 2022).

It is common to find young *Copaifera* specimens regenerating in full sunlight, colonizing open areas and secondary vegetation, such as fallow lands and clearings smaller than 60 m². It is a long-lived tree (Costa and Mantovani, 1992). Its wood is moderately heavy (density of 0.77 g/cm³) and is recommended for use in civil construction, furniture making, turned pieces, panels, boards, and flooring. Additionally, it produces an oleoresin widely used in therapeutic treatments (Lorenzi, 1992).

2.3 Measurement of growth rings

Thirty-three *Copaifera langsdorffii* trees were selected, felled, and wood discs (at 1.30 m above ground level - DBH) with an approximate thickness of 10 cm were collected. These discs were then air-dried at room temperature in the Forest Management Laboratory at the Federal University of Mato Grosso, Sinop Campus, Brazil.

Subsequently, one of its cross-sections underwent a sanding and polishing process using sandpaper of different grits (50 to 1000 grains/mm²) to improve the visibility of the growth rings (Figure 2). The demarcation of the growth ring boundaries was performed with the naked eye and/or with the aid of a magnifying glass, marking two radii per sample while avoiding areas with wood abnormalities. The growth rings were marked in the pith-to-bark direction using a table magnifier with a maximum magnification of five times (Silva, 2018).

Two radii were delimited when the samples did not present displaced pith or cracks, and four radii were used for samples with displaced pith and cracks. The discs were scanned using a 1200 dpi resolution scanner, providing better detail of the growth rings. Subsequently, the growth ring width was determined using the Image Pro Plus (IPWin) software, calibrated with a digitized scale

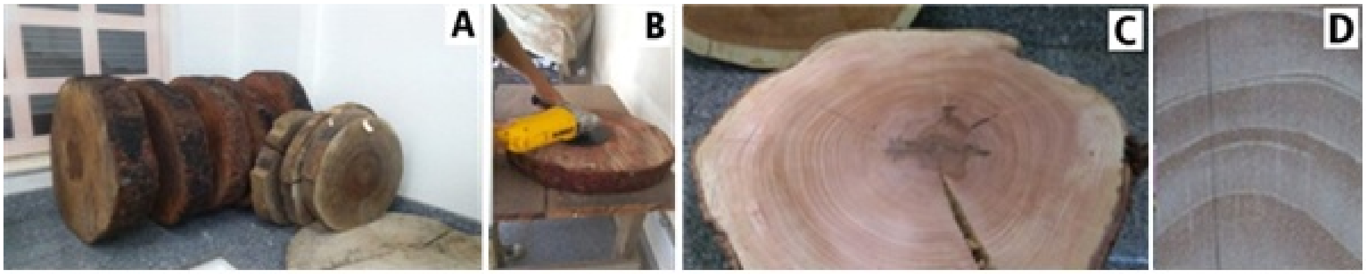

Figure 2. Preparation of samples for growth ring delimitation. Drying of the discs (A); Polishing of the discs (B); and Visible growth rings (C and D).

to a precision of 0.01 mm on the transverse section of the discs (Latorraca et al., 2015). The methodological steps of this procedure follow the order: (i) preparation of samples for dendrochronological analysis; (ii) delimitation of growth rings; (iii) digitization of the discs; and (iv) measurement of growth ring width.

2.4 Dendrochronological analysis

The quality control and verification of the synchronization of growth rings were performed using the COFECHA application (Holmes, 1984). This procedure statistically checks the dating performed, assisting in the identification of samples and/or wood sample segments that present issues with marking or measuring growth rings (Grissino-Mayer, 2001), ensuring the synchronization of the growth rings, which aims to identify errors related to the measurement of ring width in a set of trees. This synchronization was done between the radii of the same tree and between trees, generating a master series that represented all trees (Holmes, 1983). Pearson's correlation was used between each growth ring width series at a critical confidence level of 99% probability (Grissino-Mayer, 2001).

2.5 Growth curves

For the determination of growth rates, diameter growth data were used, which were obtained by averaging the width of the growth rings of the radii of each tree, multiplied by two. The increments and the growth pattern of the species were graphically described by the current annual increment (CAI) over time, and the sum of these increments resulted in the accumulated growth.

$CAI_d = dbh_{(t+1)} - dbh$ (Equation 1)

$AAI_d = \frac{dbh_{(t)}}{(t)}$ (Equation 2)

Where: CAI_d = Current annual increment in volume (m^3); AAI_d = Average annual increment in diameter (d); dbh(t+1) = diameter at breast height (1.30 m from the ground level) at the end of the considered period; dbh(t) = diameter at breast height (1.30 m from the ground level) at the beginning of the considered period; t = age in years.

2.6 Cutting cycle and minimum cutting diameter.

To estimate the minimum cutting diameter and the cutting cycle, growth modeling was used through nonlinear regression adjustment of the Gompertz, Chapman-Richards, and Weibull sigmoidal functions. In these models, the easily measurable variable or independent variable (x) is the tree's age, and the dependent variable (y) is the difficult-to-obtain increment in diameter or volume. For nonlinear regression adjustment, we used the CurveExpert Professional software. To select the best-fitted model, we observed the graphical analysis of residuals, which shows the dispersion between the real values and the estimated values, the standard error of the estimate (S_{yx}), and the adjusted coefficient of determination ($R^2(_{adj})$).

2.7 Growth models in diameter and volume as a function of age

To estimate the minimum cutting diameter and cutting cycle, we used growth modeling through nonlinear regression, using the Gompertz, Chapman-Richards, and Weibull models.

Gompertz $y = a(e^{-e^{b-cx}})$ (Equation 3)

Chapman-Richards $y = \frac{a}{(1+e^{b-cx})^{1/d}}$ (Equation 4)

Weibull $y = a - (be^{-cx^d})$ (Equation 5)

Where: y = increment in DBH (cm) or volume (m^3); a, b, c, d = model coefficients; x = age (years).

The accumulated volumes at each age were obtained according to equation 6, adjusted for the Amazon region of the state of Mato Grosso, as described by Colpini et al. (2009).

$$\ln(v) = -7{,}9906+2{,}2416\ \ln(dbh)\ \text{(Equation 6)}$$

Where: ln(v)= Natural logarithm of the volume (m^3); ln(dbh)= Natural logarithm of DBH (cm).

After obtaining the volume for each age and the accumulated volume from the best-fitted model, the current annual increment (CAIv) and the average annual increment (AAIv) in volume were calculated for each age. This resulted in the highest CAIv, which corresponds to the correct cutting period for the species, as well as the minimum cutting diameter.

$$CAI_v = AV_{(t+1)} - AV_{(t)}\ \text{(Equation 7)}$$

$$AAI_V = \frac{AV_{(t)}}{(t)}\ \text{(Equation 8)}$$

Where: CAI_V = Current annual increment in volume (m^3); AAI_V = Average annual increment in volume (m^3); AV = Accumulated volume at different ages (m^3); t = age in years.

After defining the Minimum Cutting Diameter (MCD), the Cutting Cycle (CC) was estimated using equation 8, which was obtained by the average time the species takes to pass through 10 cm diameter classes until reaching the specific MCD (Schöngart, 2008).

$$CC = \frac{Id_{(MCD)}}{(MCD \times 0{,}1)}\ \text{(Equation 9)}$$

Where: CC= Cutting Cycle (years); Id= Idade (years); MCD= Minimum Cutting Diameter (cm).

3. Result and Discussion

3.1 Dendrochronological analysis

The individuals and rays of *C. langsdorffii* that showed a negative correlation were removed from the data processing, resulting in 30 trees with positive correlation values. The correlation found was 0.403, which is a positive and satisfactory correlation, with a value higher than the critical Pearson level (0.3281, $p<0.01$). This demonstrates that there is a common growth pattern among the individuals, and that the species has potential for use in dendrochronological analyses.

We generated a master series with 164 years (1855-2018), in which 6,439 rings were analyzed, with ages ranging from 41 to 158 years, and diameters ranging from 29 to 72 cm. In Minas Gerais and Paraná, correlation values for the same species were found to be 0.60 ($p<0.01$) and 0.406 ($p<0.01$), respectively (Carvalho et al., 2018; Miranda et al., 2019). For *Cedrela fissilis* Vell., the correlation was positive, with a value of 0.566 for a critical level of 0.541 (Andreacci et al., 2014). For *Schizolobium parahyba* (Vell.) S. F. Blake, the correlation was 0.71, which is a highly significant value (Latorraca et al., 2015). Therefore, many species have potential for use in dendrochronological analyses, and the use of this technique can assist in forest management practices.

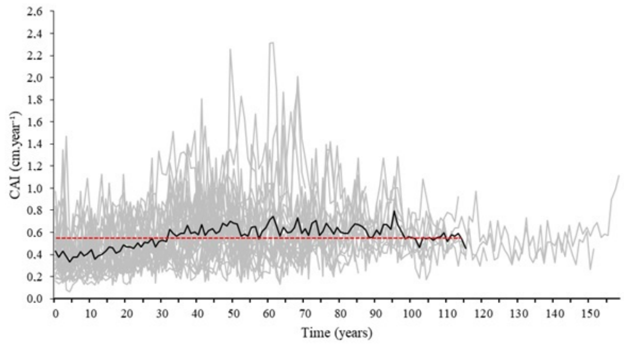

Figure 3. Growth variations as a function of age. Each gray line represents the diameter increment of each tree; the black line represents the variation of the average increment when $n>3$ samples are available; the red dashed line represents the average annual increment.

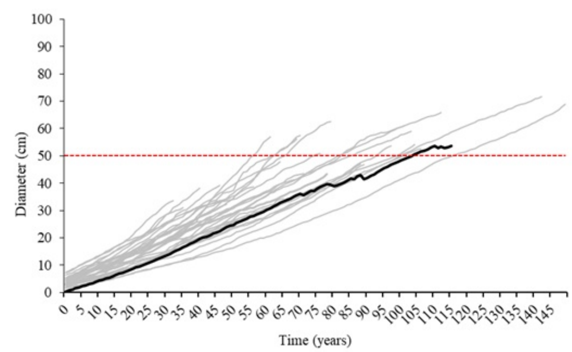

Figure 4. Diameter growth of *C. langsdorffii*. The gray line indicates the growth trajectory of each tree. The black line represents the average growth pattern of the species when $n>3$ samples are available. The red dashed line is the cutting diameter established by law.

3.2 Growth curves

All individuals exhibited a similar growth pattern, with an average annual increment of 0.560 $cm.year^{-1}$ (± 0.114) (Figure 3) during the early years of life, where they had

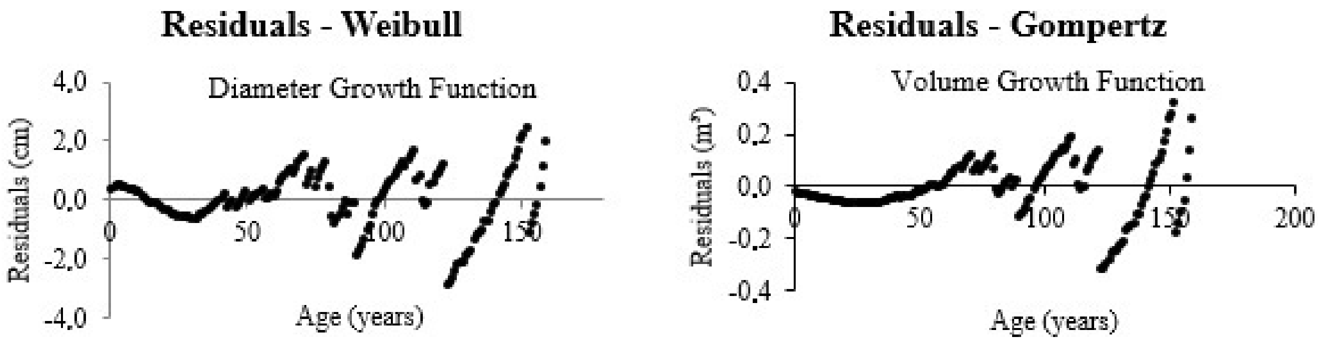

Figure 5. (a) Residuals of the Diameter Growth Function “Weibull”. (b) Residuals of the Volume Growth Function “Gompertz”.

Table 1. tatistics and equations adjusted for diameter and volume as a function of age.

Growth	Author	Model	$R^2_{(aj)}$	Syx
Diameter	Weibull	$d = 92.811761\text{-}(92.897266e^{-0.002364Id^{1,241676}})$	99.77	0.9852
Volume	Gompertz	$V = 7.637022(e^{-e^{1.752252\text{-}0,014297Id}})$	99.34	1.1092

R²aj= Adjusted coefficient of determination; Syx= Standard error of the estimate; d= diameter; V= volume; x= Age in years; a, b, c= Model coefficients.

slower growth, with the period of greatest growth occurring between 31 and 101 years, followed by a decrease after this period (Figure 3). According to Alves and Angyalossy-Alfonso (2000), smaller growth rings near the pith indicate the initial development phase of the species, with slower growth due to competition with other plants, and wider rings are formed in the intermediate growth phase, when the species has a higher growth rate compared to the other phases. This highlights that the species may exhibit growth variations throughout its life cycle, emphasizing the importance of growth studies.

In the South of the Amazon, the increments for *Qualea paraensis* and *Parkia pendula* were 0.93 $cm.year^{-1}$ ± 0.20 and 0.63 $cm.year^{-1}$ ± 0.22, respectively (Miranda et al., 2018). For *Bertholletia excelsa* Bonpl., the values were 0.71 $cm.year^{-1}$ ± 0.019 (Schöngart et al., 2015). In the Andes region of Colombia, the increment for *Albizia niopoides* (Spruce ex Benth.) Burkart was 0.94 $cm.year^{-1}$ (Giraldo and Valle, 2012). For *Calophyllum brasiliense* Cambess., the average increment was 0.43 $cm.year^{-1}$ ± 0.16 (Rosa et al., 2017).

In the Northern mesoregion of Mato Grosso, the increment was 0.4 $cm.year^{-1}$ for *Erisma uncinatum* Warm. (Borges et al., 2018). Dünisch and Latorraca (2016) found values for *Swietenia macrophylla* King of 0.33 $cm.year^{-1}$ ± 0.019. These growth differences between species can be influenced by both the characteristics of the location they inhabit and the characteristics of the species itself. Therefore, the current forest management practices do not ensure the sustainability of forests, as there is a significant variation in growth among tree species.

The species *C. langsdorffii* took about 105 years (Figure 4) to reach the minimum cutting diameter (50 cm) established by the current legislation for Sustainable Forest Management plans. This demonstrates that it is a slower-growing species compared to others, such as *Ficus insipida* Willd. and *Sloanea terniflora* (DC.) Standl., which in the Amazon rainforest required 15 and 67 years to reach 50 cm in diameter, respectively (Schöngart, 2008). On the other hand, *C. langsdorffii* has superior growth when compared to *Eschweilera albiflora* (DC.) Miers., which took 151 years to reach the same diameter (Schöngart, 2008). In upland forests in the state of Amazonas, the species *Hymenaea courbaril* L. and *Handroanthus serratifolius* (Vahl) S.O. Grose took 114 and 117 years, respectively, to reach 50 cm in diameter (Andrade, 2015). These variations highlight the importance of understanding species growth for applications in forest management plans in the Amazon.

3.3 Growth models

We fitted growth models for diameter and volume for the species. Therefore, we selected the best model based on the best results obtained from the graphical analysis of residuals (Figure 5 a, b), the standard error of the estimate (S_{yx}), and the adjusted coefficient of determination ($R^2_{(aj)}$). Thus, the best-fitted model for diameter was the Weibull model, while for volume, it was the Gompertz model (Table 1).

3.4 Cutting cycle and minimum cutting diameter

The species *C. langsdorffii* exhibited the highest current annual increment in volume (maximum CAIv) at 123 years, reaching a value of 0.04017 $m^3.year^{-1}$, with a minimum cutting diameter (MCD) of 56 cm (Figure 6). Based on this, the cutting cycle can be estimated as the time required for individuals to transition through 10 cm diameter classes, resulting in a cutting cycle of 22 years (Schöngart et al., 2007). The species' MCD was greater than the legally prescribed value (50 cm), indicating that after reaching the legally established MCD, the species was still in a growth phase (Sousa, 2019). The species required a shorter cutting cycle than what is mandated by law (25 to 35 years) to reach the optimal cutting diameter. Therefore, forest management plans with fixed CC and MCD cannot be considered sustainable, as they fail to account for the actual growth dynamics of the species (Braz et al., 2012).

In the Tapajós National Forest, MCDs were found for *Cedrela odorata L.* and *Hymenaea courbaril L.* of 36.09 cm at 64 years and 56.84 cm at 110 years, respectively, with cutting cycles of 18 years for *C. odorata* and 19 years for *H. courbaril* (Sousa, 2019). The species *Sterculia elata* Ducke and *Hura crepitans* L. exhibited MCD and CC of 56 cm and 9.7 years, and 128.8 cm and 9.7 years, respectively (Rosa, 2008). MCD of 53 cm and a cutting cycle of 11 years were found for the species *Qualea paraenses* Ducke, and MCD of 42 cm and a cutting cycle of 17 years for *Parkia pendula* (Willd.) Benth. ex Walp. (Miranda et al., 2018). In a floodplain area in the state of Amazonas, values of MCD and CC were found for low and high-density species, with MCD ranging from 47 to 70 cm among species, and CC ranging from 3.3 to 13.9 years for species with low-density wood, and CC from 21.5 to 32.1 years for species with high-density wood (Schöngart, 2008). For *Calophyllum brasiliense* Cambess., MCDs ranged from 35 to 81 cm, and cutting cycles from 14 to 63 years in different Brazilian ecoregions (Rosa et al., 2017). There are several other studies that estimate MCD and CC, including those by López and Villalba (2013) and Leoni et al. (2011).

The values of MCD and CC found for *C. langsdorffii* are different from those determined by the current legislation for FMPS; these differences were also found by the aforementioned authors. As a species with moderate growth, *C. langsdorffii* took a longer time to reach its optimal cutting point. The author Schöngart (2008)

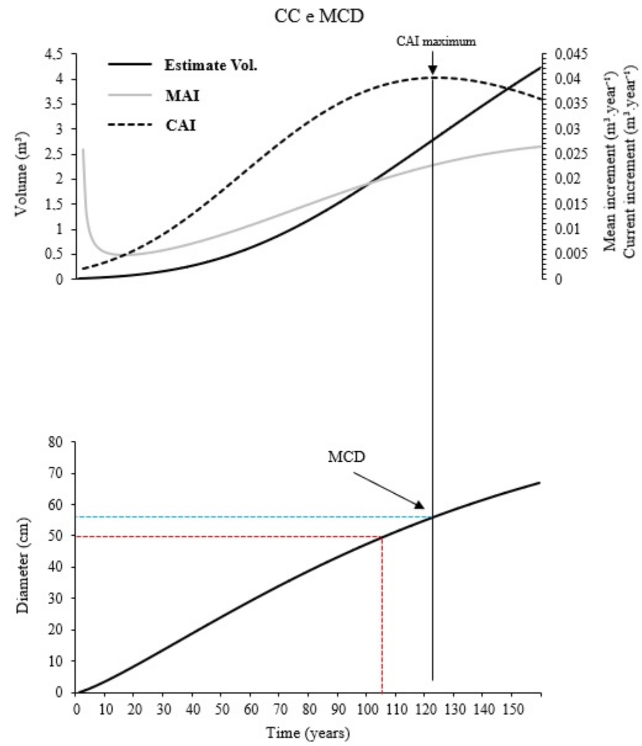

Figure 6. Growth curves based on the equations adjusted for *C. langsdorffii*. The blue dashed line represents the estimated MCD for the species. The red dashed line represents the MCD determined by law. The black line indicates the maximum CAIv.

suggests that forest management should have a management regime based on species-specific cutting cycles to avoid over-exploitation of the species.

López and Villalba (2013) recommend that the criteria used in forest management be based on species-specific estimates for each region or biome. Braz et al. (2012) share the same idea, suggesting that the cutting rate for species should be based on the potential increment and cutting cycle of each species, and that these species be grouped according to their growth rate. This highlights the great importance of growth studies, which, combined with other practices such as forest dynamics assessment through permanent plots, contribute to sustainable forest management, thus ensuring the stock for future cycles.

4. Conclusion

Dendrochronological procedures, including ring measurement and cross-dating, enhance age estimates. The species *Copaifera langsdorffii* exhibits moderate growth, which should be considered in forest management strategies. It reaches its peak volume increment at an age of 123 years, with an estimated MCD of approximately 56 cm, and a cutting cycle of 22 years. The cutting cycle currently used in management plans is not suitable for *Copaifera langsdorffii* in the humid tropical forests of upland areas in northern Mato Grosso.

Information on growth is essential to support forest management practices aimed at the sustainability of the species. Finally, for timber resources to be used properly, the management practices for the studied species must be reviewed and aligned with forest dynamics research to minimize ecological impacts and ensure future exploitations.

Acknowledgments

No acknowlegments were declared for this work.

Author Statements

✓ No conflicts of interest were declared.

✓ All existing funding sources were acknowledged.

✓ There is no evidence of plagiarism in this article.

References

Aguiar, D. L.; Moutinho, V. H. P. (2015). Análise de potencial dendrocronológico em árvores de jatobá (*Hymenaea courbaril* L.) da Amazônia brasileira. In: Congresso Brasileiro e Tecnologia da Madeira, 2, Belo Horizonte. **Anais** Belo Horizonte Instituto de Biodiversidade e Florestas, UFOPA.

Alvarado, J. R.; Tomazello Filho, M.; Pollito, P. A. Z.; Lobão, M. S. (2010). Variação da densidade do lenho e relação com a largura dos anéis de crescimento de árvores de mogno, *Swietenia macrophylla*, da floresta tropical amazônica do Peru. **Scientia Forestalis**, Piracicaba, v. 38, n. 86, p. 171-179.

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*, v. 22, n.6, 711-728, https://doi.org/10.1127/0941-2948/2013/0507

Alves, E. S.; Angyalossy-Alfonso, V. (2000). Ecological trends in the wood anatomy of some Brazilian species. I: growth rings and vessels. **IAWA Journal**, Leiden, v. 21, n. 1, p. 3-30. DOI: https://doi.org/10.1163/22941932-90000233

Andrade, V. H. F. (2015). **Modelos de crescimento para** *Hymenaea courbaril* **L. e** *Handroanthus serratifolius* **(Vahl) S.O Grose em floresta de terra firme utilizando análise de anéis de crescimento**. 73f. Dissertação (Mestrado em Ciências Agrárias), Universidade Federal do Paraná, Curitiba.

Andreacci, F.; Botosso, P. C.; Galvão, F. (2014). Sinais climáticos em anéis de crescimento de *Cedrela fissilis* em diferentes tipologias de florestas Ombrófilas do Sul do Brasil. **Floresta**, Curitiba, v. 44, n. 2, p. 323-332.

Borges, A. D.; Mattos, P. P.; Braz, E. M.; Canetti, A.; Basso, R. O. (2018). **Padrão de crescimento de cedrinho em condições de floresta natural no município de Santa Carmem, microregião de Sinop, MT**. Colombo: Embrapa Florestas. 11 p. (Embrapa Florestas. Comunicado técnico, 415).

Brasil. (2006). Instrução normativa n. 5, de 11 de dezembro de 2006. Dispõe sobre procedimentos técnicos para elaboração, apresentação, execução e avaliação técnica de Planos de Manejo Florestal Sustentável-PMFSs nas florestas primitivas e suas formas de sucessão na Amazônia Legal, e dá outras providências. **Diário Oficial da União**, Brasília, DF, n. 238, 13 dez. Seção 1 p. 155-159.

Braz, E. M.; Schneider, P. R.; Mattos, P. P.; Selle, G. L.; Thaines, F.; Ribas, L. A.; Vuaden, E. (2012). Taxa de corte sustentável para manejo das florestas tropicais. **Ciência Florestal**, Santa Maria, v. 22, n. 1, p. 137-145.

Carvalho, D. C.; Pereira, M. G.; Latorraca, J. V. F.; Pace, J. H. C.; Silva, L. D. S. A. B.; Carmo, J. F. (2018). Dendrochronology and growth of *Copaifera langsdorffii* wood in the vegetation dynamics of the Pirapitinga Ecological Station, state of Minas Gerais, Brazil. **Floresta**, Curitiba, v. 48, n. 1, p. 49-58. DOI: http://doi.org/10.5380/rf.v48 i1.49905

Carvalho, P. E. R. (2003). **Espécies arbóreas brasileiras**. Colombo: EMBRAPA. 1039 p.

Colpini, C.; Travagin, D. P.; Soares, T. S.; Silva, V. S. M. (2009). Determinação do volume, do fator de forma e da porcentagem de casca de árvores individuais em uma Floresta Ombrófila Aberta na região noroeste de Mato Grosso. **Acta Amazonica**, Manaus, v. 39, n. 1, p. 97-104.

Costa, D. H. M.; Carvalho, J. O. P.; Van Den Berg, E. (2007). Crescimento diamétrico de maçaranduba (*Manilkara huberi* chevalier) após a colheita da madeira. **Amazônia: Ci. & Desenv.**, Belém, v. 3, n. 5, p. 65-76.

Costa, M. P. & Mantovani, W. (1992). Composição e estrutura de clareiras em mata mesófila na bacia de São Paulo, SP. Pp. 178-183. In: Anais do II Congresso Nacional Sobre Essências Nativas. São Paulo, Instituto Florestal.

Dünisch, O.; Latorraca, J. V. F. (2016). Impact of Site Conditions Changes on the Tree Ring Records Suitability as Climate Proxies in the Brazilian Amazon. **Floresta e Ambiente**, v. 23, n. 2, p. 258-269. DOI: http://dx.doi.org/10.1590/2179-8087.014215

Figueiredo Filho, A.; Retslaff, F. S.; Retslaff, F. S.; Santos, T. L.; Stepka, T. F. (2017). Crescimento e Idade de Espécies Nativas Regenerantes Sob Plantio de *Araucaria angustifolia* no Paraná. **Floresta Ambiente**, Seropédica, v. 24.

Giraldo, V. D.; Del Valle, J. I. (2012). Modelación del crecimiento de *Albizia niopoides* (Mimosaceae) por métodos dendrocronológicos. **Revista Biologia Tropical**, Medellín, v. 60, n. 3, p. 1117-1036. DOI: https://doi.org/10.15517/rbt.v60i3.1762

Grissino-Mayer, H. D. (2001). Evaluating crossdating accuracy: a manual and tutorial for the computer program Cofecha. **Tree-ring Research**, Vol. 57 (2), 205-221 p.

Group, B. F.; Zappi, D. C. (2015). Growing knowledge: an overview of Seed Plant diversity in Brazil. Rodriguésia (Online), v. 66, p. 1085-1113.

Holmes, R. L. (1983). Computer-assisted quality control in tree-ring dating and measurement. **Tree-Ring Bull**, Tucson, v. 43 p. 69-78.

Holmes, R. L. (1984). Dendrochronology program library. User's manual. Tucson: University of Arizona. 51p.

Husch, B.; Miller, C. I.; Beers, T. W. (1982). **Forest mensuration**. 3ed. New York: John Wiley & Sons. 402p.

Latorraca, J. V. F.; Souza, M. T.; Silva, L. D. S. B.; Ramos, L. M. A. (2015). Dendrocronologia de árvores de *Schizolobium parahyba* (Vell.) S. F. Blake de ocorrência na rebio de Tinguá-RJ. **Revista Árvore**, Viçosa, v. 39, n. 2, p. 385-394.

Leoni, J. M.; Fonseca Júnior, S. F.; Schöngart, J. (2011). Growth and population structure of the tree species *Malouetia tamaquarina* (Aubl.) (Apocynaceae) in the central Amazonian floodplain forests and their implication for management. **Forest Ecology and Management**, v. 261, n. 1, p. 62-67. DOI: https://doi.org/10.1016/j.foreco.2010.09.025

Loiola, T. M.; Hess, A. F.; Krefta, S. M.; Dallabrida, J. P.; Denega, A.; Nascimento, B. (2019). Análise dendrocronológica do crescimento de *Araucaria angustifolia* (bertol.) kuntze no planalto serrano de Santa Catarina. **Holos**, v. 2, p. 1-9. DOI: https://doi.org/10.15628/holos.2019.4927

López, L.; Villalba, R.; Bravo, F. (2013). Cumulative diameter growth and biological rotation age for seven tree species in the Cerrado biogeographical province of Bolivia. **Forest Ecolology Managment**, v. 292, n. 1, p. 49-55.

Lorenzi, H. (1992). **Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil**. Nova Odessa: Plantarum. 352p.

Miranda, B. P.; Andrade, V. H. F.; Botosso, P. C.; Santos, T. L.; Milani, J. E. F.; Roderjan, C. V. (2019). Potencial de *Copaifera langsdorffii* Desf. (Fabaceae) como indicadora de mudanças climáticas por meio da análise dos anéis de crescimento, Paraná, Brasil. **Revista de Ciências Agroveterinárias**, Lages, v. 18, n. 3, p. 301-312.

Miranda, D. L. C.; Higuchi, N.; Trumbore, S. E.; Latorraca, J. V. F.; Carmo, J. F.; Lima, A. J. N. (2018). Using radiocarbon-calibrated dendrochronology to improve treecutting cycle estimates for timber management in southern Amazon forests. **Trees**, v. 32, n. 2, p. 587–602. DOI: https://doi.org/10.1007 / s00468-018-1658-3

Prodan, M.; Peters, R.; Cox, F.; Real, P. (1997). **Mensura Forestal**. San José, C.R.: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. 561p.

Rosa, S. A. (2008). **Modelos de crescimento de quatro espécies madeireiras de floresta de várzea da amazônia central por meio de métodos dendrocronológicos**. 77f. Dissertação (Mestrado em Ciências Biológicas), Universidade federal do Amazonas, Manaus, 2008.

Rosa, S. A.; Barbosa, A. C. M. C.; Junk, W. J.; Cunha, C. N.; Piedade, M. T. F.; Scabin, A. B.; Ceccantini, G. C. T.; Schongart, J. (2017). Growth models based on tree-ring data for the Neotropical tree species *Calophyllum brasiliense* across different Brazilian wetlands: implications for conservation and management. **Trees**, v. 31, n. 2, p. 729-742. DOI: https://doi.org/10.1007/s00468-016-1503-5

Schaaf, L. B.; Filho, A. F.; Sanquetta, C. R.; Galvão, F. (2005). Incremento diamétrico e em área basal no período 1979-2000 de espécies arbóreas de uma floresta ombrófila mista localizada no sul do Paraná. **Floresta**, Curitiba, v. 35, n. 2, p. 271-290. DOI: http://dx.doi.org/10.5380/rf.v35i2.4615.

Schöngart, J. (2008). Growth-Oriented Logging (GOL): A new concept towards sustainable forest management in Central Amazonian várzea floodplains. **Forest Ecology and Management**, v. 256, n. 1, p. 46-58.

Schöngart, J.; Gribel, R.; Fonseca-Junior, S. F.; Haugaasen, T. (2015). Age and growth patterns of Brazil nut trees (*Bertholletia excelsa* Bonpl.) in Amazonia, Brazil. **Biotropica**, v. 47, n. 5, p. 550-558. DOI: https://doi.org/10.1111/btp.12243

Schöngart, J.; Wittmann, F.; Worbes, M.; Piedade, M. T. F.; Krambeck, H. J.; Junk, W. J. (2007). Management criteria for *Ficus insipida* Willd.(Moraceae) in Amazonian white-water floodplain forests defined by tree-ring analysis. **Annals of Forest Science**, v. 64, n. 6, p. 657-664.

Silva, F. J. R. (2018). **Critérios para o manejo florestal de** *Scleronema micranthum* **ducke (malvaceae) em uma floresta de terra firme da amazônia central**. 40f. Monografia (Curso de Engenharia florestal) – Universidade do estado do amazonas, Itacoatiara.

Silva, R. P.; Nakamura, S.; Azevedo, C. P.; Chambers, J.; Rocha, R. M.; Pinto, A. C. M.; Santos, J.; Higuchi, N. (2003). Uso de banda dendrométrica na definição de padrões de crescimento individual em diâmetro de árvores da bacia do rio cuieiras. **Acta Amazonica**, Manaus, v. 33, n. 1, p. 67-84. DOI: https://doi.org/10.1590/1809-4392200331084

Sousa, L. K. V. S. (2019). **Dendrocronologia aplicada no manejo de árvores de cedro (***Cedrela odorata***) L. e jatobá (***Hymenaea coubaril***) L. ocorrentes na FLONA Tapajós, PA**. 2019. 133f. Tese (Doutorado em Ciências), Universidade de São Paulo, Piracicaba.

Souza, A. P.; Mota, L. L.; Zamadei, T.; Martim, C. C.; Almeida, F. T.; Paulino, J. (2013). Classificação climática e balanço hídrico climatológico no estado de Mato Grosso. **Nativa**, v. 1, n. 1, p. 34-43.

Souza, C. R. (2012). **Dinâmica de carbono em floresta explorada e em floresta nativa não explorada na Amazônia-Manaus.** 2012. 159f. Tese (Doutorado em ciências de florestas tropicais) - Instituto Nacional de Pesquisas da Amazônia (INPA/UFAM), Manaus, Amazonas.

Souza, L. H. S.; Finger, C. A. G.; Schneider, P. R. (2009). Incremento volumétrico de *Nectandra megapotamica* (Spreng.) Mez em floresta Ombrófila Mista. **Ciência Florestal,** Santa Maria, v. 19, n. 3, p. 305-314. DOI: https://doi.org/10.5902/19805098886

Santos, M. O.; Camilo, C. J.; Macedo, J. G. F.; Lacerda, M.N.S.; Lopes, C. M. U.; Rodrigues, A. Y. F.; Costa, J. G. M.; Souza, M. M. A. (2022). Copaifera langsdorffii Desf.: A chemical and pharmacological review. Biocatalysis and Agricultural Biotechnology, v.39. DOI: https://doi.org/10.1016/j.bcab.2021.102262

Vatraz, S.; Carvalho, J. O. P.; Gomes, J. M.; Taffarel, M.; Ferreira, J. E. R. (2012). Efeitos de tratamentos silviculturais sobre o crescimento de *Laetia procera* (Poepp.) Eichler em Paragominas, PA, Brasil. **Scientia Forestalis**, Piracicaba, v. 40, n. 93, p. 095-102. DOI: dx.doi.org/10.18671/scifor.v44n109.25