



Floristic and Phytosociological Analysis in Annual Production Units under Forest Concession Areas in the Amazon Forest

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Abstract

The objective of this study was to analyze the forest composition and phytosociological structure of two Annual Production Units (UPAs) under forest concession in the Amazon. Data from 100% forest inventories of the UPAs located in the State Forest of Paru, Pará, Brazil, were used. The analyses included: representativeness of the effective harvesting area (AEE) in relation to the gross UPA area; Jaccard similarity index; horizontal structure, filtering the 10 species with the highest Importance Value Index (IVI); volume of commercial species common to both UPAs; and stem quality. AEE of UPA 3 was 92.25% (3,449.26 ha), and 84.10% (2,192.77 ha) in UPA 4; there was 64% floristic similarity between the two UPAs; among the 10 species with the highest IVI were *Handroanthus serratifolius* and *Manilkara huberi*, both highly relevant commercially; the species with the greatest volume in UPA 3 was *Handroanthus impetiginosus*, and in UPA 4 it was *Bagassa guianensis*; and commercial species with stem quality suitable for full or partial log utilization were found in greater abundance. It was concluded that the UPAs shows high floristic similarity (64%) and that there are species with potential for both timber and non-timber products not yet being exploited.

Keywords

Sustainable Forest Management — Forest Inventory — Dense Ombrofilus Forest — Amazon Rainforest

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1. Introduction

Timber and non-timber forest products from the Amazon forest present great socioeconomic potential for improving life quality for local communities who can trade these resources for revenue (SOUSA et al., 2021). To achieve sustainable forest management, harvesting impacts should be minimized through proper planning (LIMA et al., 2021). The development of management plans is essential to maintain forest conservation (NINAN; INOUE, 2013) and to generate ecosystem services of provisioning, supporting, regulating, and cultural value (BRASIL, 2021).

This planning demands technical and scientific foundations, such as defining harvesting intensity, rotations, and adopting a monitoring system to assess the forest before, during, and after harvesting. To enable forest management operations in the Amazon, the Forest Manage-

ment Unit (FMU) is subdivided into Annual Production Units (UPAs), which are further subdivided into Production Units (PUs) (BRASIL, 2009).

Thus, long-term planning considers the FMU as a whole in a document called the Sustainable Forest Management Plan (PMFS). Short-term planning establishes activities and rules for each UPA and its respective PUs, resulting in a document called the Annual Operational Plan (POA). For example, if the PMFS establishes that the FMU will be divided into 30 UPAs, a total of 30 POAs will be prepared, one for each UPA (BRASIL, 2009).

To prepare each POA, two activities are essential: micro-zoning and a census (100% forest inventory). Micro-zoning defines the area within the UPA considered as the Effective Harvesting Area (AEE), excluding preservation areas, areas with difficult access, infrastructure zones, among others. The census is conducted within the AEE, collecting quantitative and qualitative data from all trees



that meet the inclusion criteria ($DBH \geq 40$ cm) (BLUE TIMBER FLORESTAL, 2022).

In addition to generating important data to support the planning of harvesting operations through the POA, the census can also be used to produce information about Amazon forest areas, which are often highly conserved because they are located within protected areas. In these areas, Brazil's Forest Management Law allows forest management through concession systems (BRASIL, 2006; SFB, 2023).

Such information is generated through floristic and phytosociological studies, considering similarity between areas, species and botanical family diversity, spatial distribution of individuals of the same species, horizontal and vertical structure (SOUZA; SOARES, 2013). Furthermore, these studies can provide important parameters regarding the potential for forest resource exploitation in these areas, to support decision-making for companies to participate in concession bids (SFB, 2023).

The present study aimed to analyze the floristic composition and phytosociological structure of two UPAs under forest concession, located in FMU IV of the State Forest of Paru, Pará. The hypotheses considered were a high floristic similarity between the UPAs and a significant presence of species with potential for both timber and non-timber use.

2. Materials and Methods

2.1 Study Site

The study area is located in the Paru State Forest (Flota do Paru), characterized by Dense Ombrophilous Forest vegetation. The area covers 3,612,914.02 hectares and includes the following municipalities in the state of Pará: Almeirim, Monte Alegre, Alenquer, and Óbidos (Para, 2010). In the nearby area, there are other protected areas, such as Indigenous Lands, Strict Protection Conservation Units, Sustainable Use Conservation Units, and Quilombola Territories (Figure 1)

The climate in the region is characterized as a tropical monsoon, with temperatures ranging between 18 and 30 °C. The average monthly rainfall is 2150 millimeters; the rainiest period occurs from January to June, with an average variation of 50 to 150 millimeters (ALVARES et al., 2013). The predominant soil type is Red-Yellow Argisol (76% of the composition), followed by Red-Yellow Latosol (20%), Litholic Neosols (4%), and Yellow Latosol (<1%) (IMAZON, 2013). Approximately 94% of the territory encompassing Flota do Paru are at elevations below 500 meters, about 5% ranges between 500 and 600 meters, and only 1% exceeds 600 meters, primarily located in the southern portion of Flota do Paru (CEMAL, 2013).

Within Flota do Paru, the area used in this study is located in the municipality of Monte Alegre. This area is known as Forest Management Unit (FMU) IV and it is under a forest concession. According to its Sustainable Forest Management Plan (BLUE TIMBER FLORESTAL, 2019), FMU IV covers a total of 50,938.44 hectares, subdivided into Annual Production Units (APUs) with areas ranging from 1,255.06 hectares to 3,793.22 hectares (Figure 2), from which data from APUs 3 and 4 were used.

UPA 3 has a total area of 3,793.22 ha and is divided into 38 Production Units (PUs). UPA 4 has a total area of 2,607.39 ha and is divided into 27 PUs. The PUs in PAU 4 are numbered from 1 to 25, followed by 31 and 32 (it does not include PUs 26, 27, 28, 29, and 30). Figure 3 shows the subdivision of UPAs 3 and 4 into their respective PUs.

2.2 Database

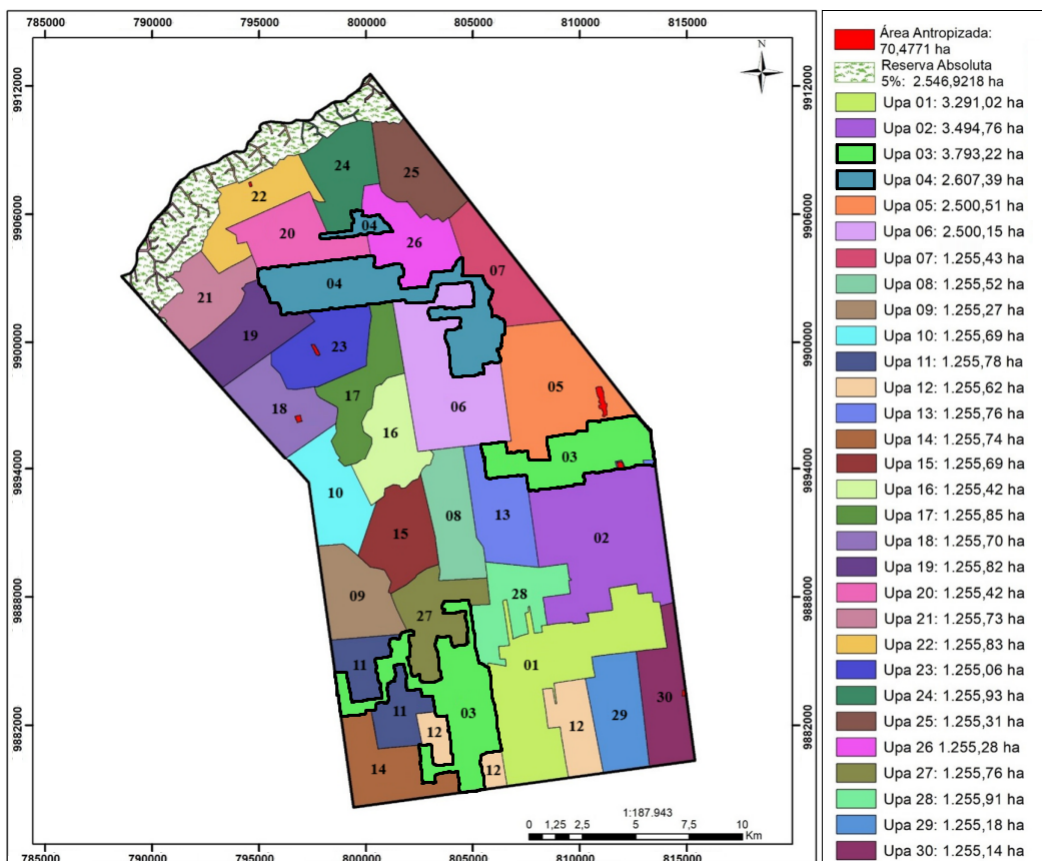
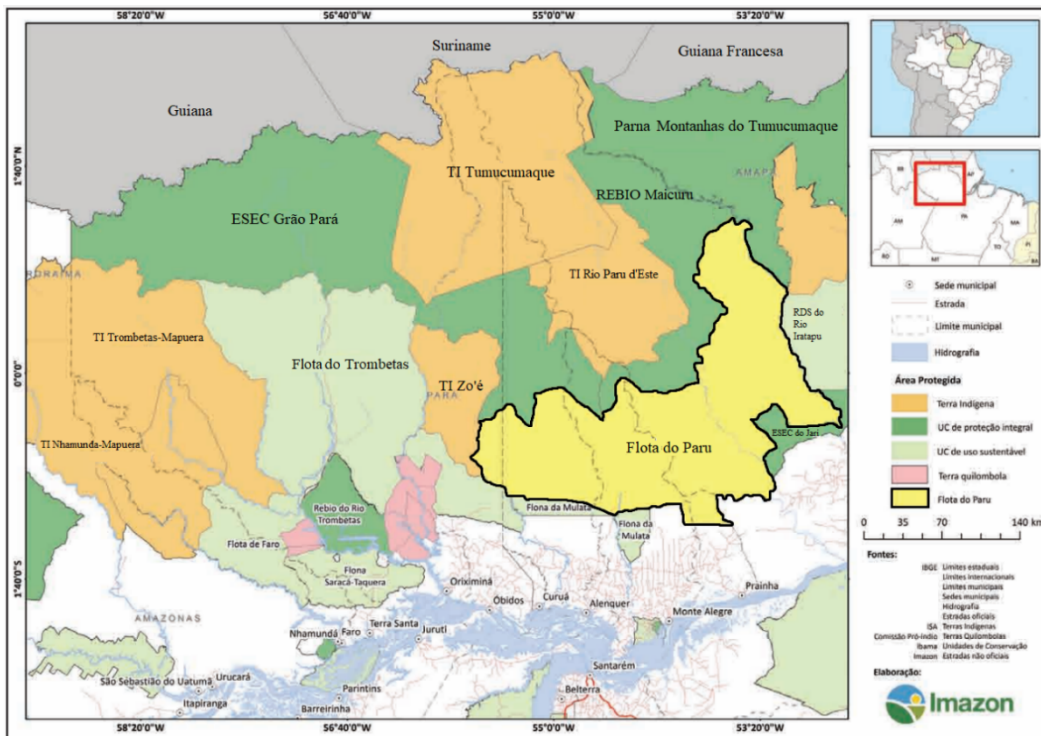
Data collected from the census in the AEEs of UPAs 3 and 4 in the years 2021 and 2022, respectively. Circumference at breast height (CBH) was collected for all trees of commercial and potentially commercial species with DBH equal or larger than 40 cm. Potentially commercial species are those not yet exploited by the company, but that may be used in the future, in the next harvesting cycle of the APU. The commercial height of the bole was estimated.

Additionally, species were identified and the stem quality of the trees was assessed and stratified into (1) straight stem no defects, allowing maximum log utilization; (2) crooked stem without defects, allowing partial log utilization; and (3) crooked stem with defects, resulting in minimal log utilization. The location of the measured individuals was also recorded using a GPS.

2.3 Data Processing and Analysis

We assessed the distribution of gross area of the UPAs in relation to the AEE as well as to permanent preservation areas, watercourses, infrastructure, gullies, areas with lianas, and steep terrain. This information indicates how much of the gross area of each UPA is being sampled through the census and used for tree harvesting in forest management. In addition, the distribution of the AEE in relation to the PUs that make up each UPA was also examined.

Next, the data collected in the census were used to: (1) analyze the floristic similarity between UPAs 3 and 4 using the Jaccard index, which ranges from 0 (no similarity between two samples) to 1 (complete similarity between two samples); and (2) analyze the horizontal structure, considering the PUs as sampling units and obtaining the phytosociological parameters of density, frequency, dominance, and importance value, selecting



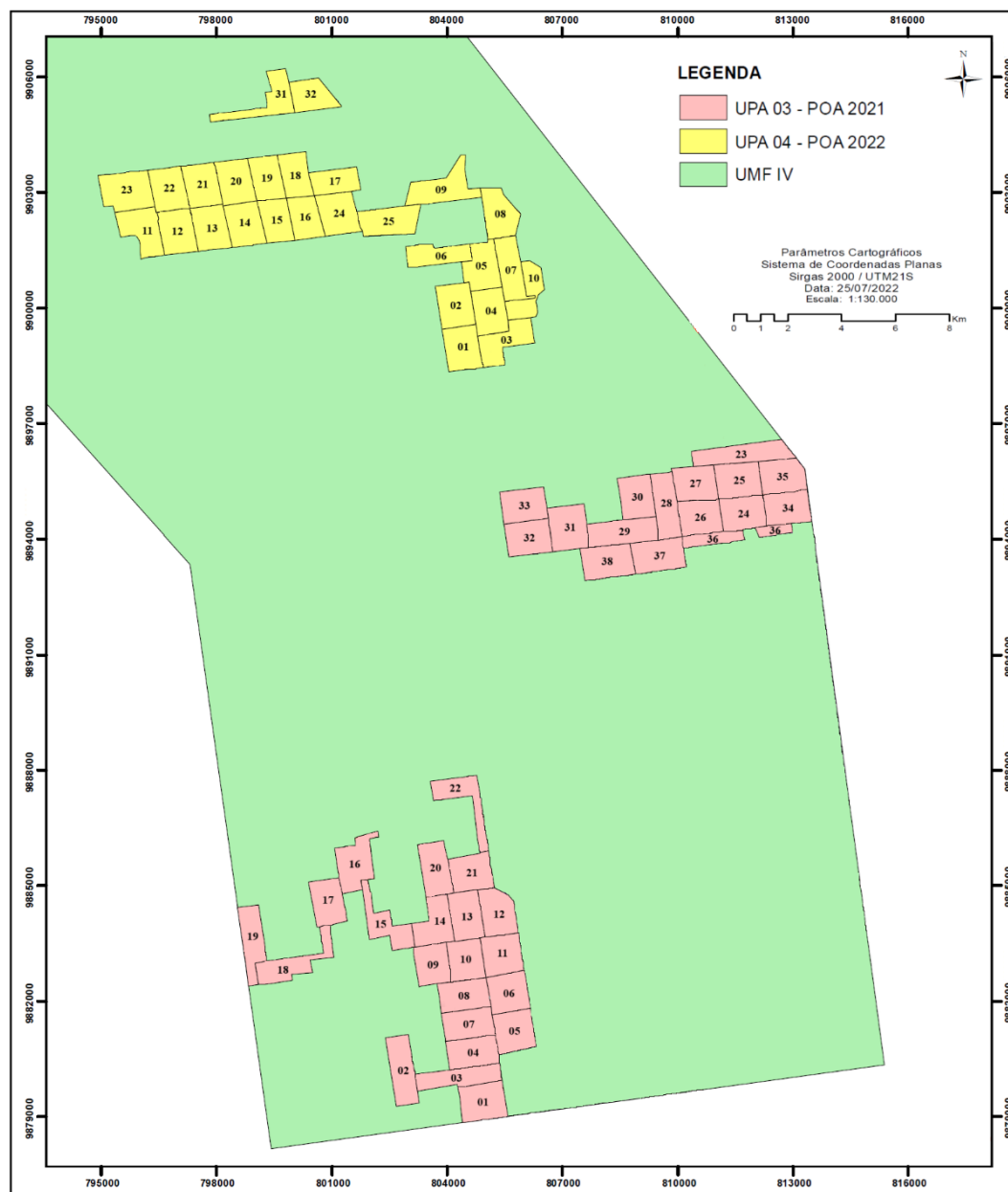


Figure 3. UPA 3 stratifies into 38 PUs and UPA 4 into 27 PUs. Source: Blue Timber Florestal (2022).

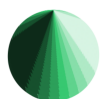
the 10 species with the highest Importance Value Index (IVI). The analyses of similarity and horizontal structure are detailed in Souza and Soares (2013).

Volume and stem quality were assessed to help harvesting planning. Commercial volume was estimated per tree using the volumetric equation of Spurr (1). Subsequently, the number of individuals per hectare and the volume (m^3/ha) of commercial species occurring in common in UPAs 3 and 4 were summed.

$$V = 0.0152 + (0.000052 \cdot DBH^2) + H \quad (1)$$

Where: V: individual volume (m^3); DBH: diameter at breast height at 1.3 m; H: stem height.

Data processing was carried out using Excel and the R software (R CORE TEAM, 2022). In R, the package “forestmangr” (BRAGA et al., 2023) was used, which includes specific functions for the management of native and planted forests.



3. Results

3.1 UPAs Gross Area

The distribution of the gross area of the UPAs, in percentages and hectares (Table 1). AEE is the predominant area in both APUs, representing more than 80% of the analyzed gross areas.

Table 1. Gross area in UPAs 3 and 4, located in the forest management unit IV, na Flota do Paru.

Area	UPA 3		UPA 4	
	(%)	(ha)	(%)	(ha)
Protection area	2.96	112.44	5.12	133.42
Water streams	0.51	19.39	0.47	12.14
Infrastructure	0.14	5.30	-	-
Valley	1.49	56.40	5.38	140.20
Vine-infested	1.31	49.80	4.94	128.85
Slope area	1.33	50.63	-	-
AEE	92.25	3,499.26	84.10	2,192.77
Total	100.00	3,793.22	100.00	2,607.39

AEE: effective harvesting areas

APU 3 has a larger gross area compared to APU 4, as well as a higher percentage of AEE, watercourses, infrastructure, and steep terrain. In contrast, UPA 4 had more valleys and liana-infested areas than UPA 3.

Figure 4 shows the distribution of AEE (in hectares) across the PUs in UPAs 3 and 4, respectively. In general, APU 3 presented PUs with larger AEEs, with emphasis on PUs 2, 23, and 38. In APU 4, the PUs with the largest AEEs were PUs 3, 24, and 25. It was possible to observe AEEs exceeding 100 ha in UPA 3, whereas in UPA 4 all PUs had AEEs smaller than 100 ha.

3.2 Floristics and Horizontal Structure

The Jaccard similarity index was 0.64 between UPAs 3 and 4, meaning that the areas are 64% similar in terms of the species recorded in the 100% forest inventory. A total of 50 different species were recorded in each UPA, and 32 species are common between the two areas.

Although, coincidentally, the number of species sampled was the same in both areas, the number of individuals in the AEE of UPA 3 (23,772) was higher than in UPA 4 (22,132 individuals). However, since the AEE of UPA 3 is larger than that of UPA 4 (Table 1), a lower density was observed in UPA 3 (6.79 individuals/ha) compared to UPA 4 (10.09 individuals/ha).

Density was also evaluated at the species level, along

with the parameters of dominance, frequency, and importance value. Table 2 presents the results of the horizontal structure of UPAs 3 and 4, respectively, considering only the 10 species with the highest Importance Value Index (IVI).

The species *Chrysophyllum lucentifolium*, *Handroanthus impetiginosus*, *Handroanthus serratifolius*, and *Bagassa guianensis* were among the 10 species with the highest IVI in both UPAs. Notably, *Chrysophyllum lucentifolium* ranked first in both areas, mainly due to its high number of individuals (density) and the presence of individuals with larger DBH (dominance).

3.3 Commercial Volume in the UPAs

Table 3 presents the commercial species that occur in both UPAs 3 and 4. In UPA 3, the species with the highest volume (m³) were *Handroanthus impetiginosus*, *Carapa guianensis*, and *Bagassa guianensis*. These species also stood out in the area when considering volume per hectare (m³/ha). In UPA 4, the species with the highest individual volume and volume per hectare were *Bagassa guianensis*, *Handroanthus impetiginosus*, and *Handroanthus serratifolius*.

3.4 Stem Quality of the Commercial Species at UPAs 3 and 4

Figure 5 shows the percentage of species classified into stem classes 1, 2, and 3 at UPAs 3 and 4. Classes 1 and 2 showed the highest representation of individuals and are therefore considered suitable for harvesting in the planning of sustainable forest management.

4. Discussion

The present study provided important results regarding the main commercial and potentially commercial species found in the area under forest concession. Forest concessions allow for sustainable forest management in protected areas designated for sustainable use, generating socioeconomic benefits (BRASIL, 2006). Their expansion in the Amazon region (SOARES; BEZERRA, 2021; PAOF, 2023) supports the collection of data on the primary vegetation of Dense Ombrophilous Forest. In addition, forest concessions also contribute to the protection of these areas against invasions, whether in isolated conservation units or mosaics of conservation units (SILVA et al., 2021a).

In this study, two areas under forest concession, UPAs 3 and 4, were analyzed in terms of: the representativeness of the area available for harvesting; floristic similarity; horizontal structure; the volume of commercial species shared between UPAs 3 and 4; and stem quality.

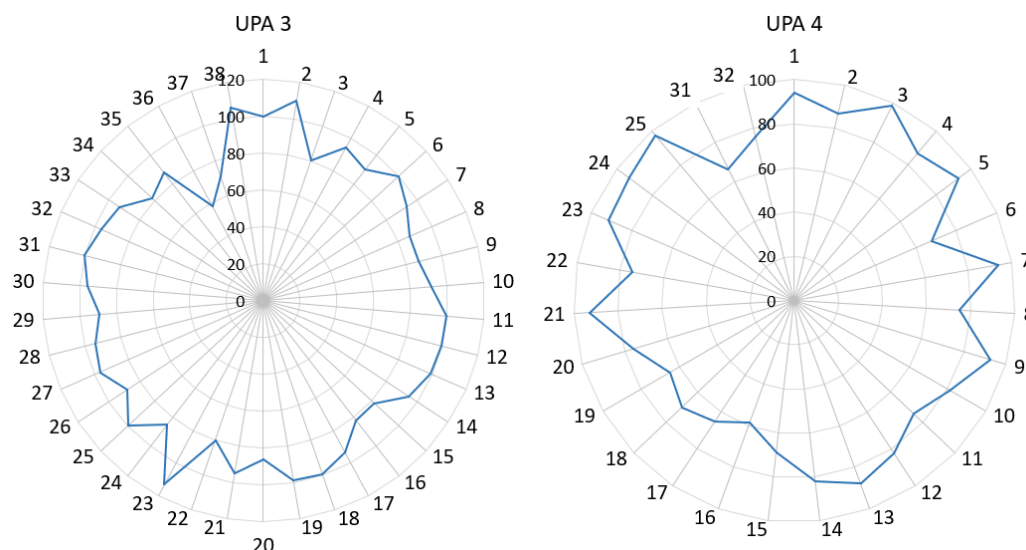
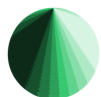


Figure 4. Distribution of the Effective Exploitation Area (AEE) of the production Units (PUs) in Annual Production Units (UPAs) 3 and 4, located in Forest Management Unit IV, in Flota do Paru.

Table 2. List of the 10 species with the highest Importance Value Index (IVI) in Annual Production Units (UPAs) 3 and 4, located in Forest Management Unit IV, in the Paru State Forest.

UPA	Scientific Name	FR	DR	DoR	IVI
3	1. Chrysophyllum lucentifolium Cronquist	3.56	17.19	13.64	11.47
	2. Manilkara huberi (Ducke) Chevalier	1.97	9.51	11.54	7.67
	3. Carapa guianensis Aubl.	3.28	12.09	6.78	7.38
	4. Micropholis venulosa (Mart. & Eichler) Pierre	3.19	5.10	9.51	5.93
	5. Handroanthus impetiginosus (Mart. ex DC.) Mattos	3.56	6.00	6.28	5.28
	6. Mahurea speciosa Choisy	2.91	6.83	5.36	5.03
	7. Bagassa guianensis Aubl.	3.56	4.28	5.38	4.41
	8. Lecythis pisonis Cambess.	3.56	3.07	4.85	3.83
	9. Handroanthus serratifolius (Vahl) S. Grose	3.56	3.80	2.86	3.41
	10. Bertholletia excelsa Humb. & Bonpl.	1.22	3.31	4.49	3.01
4	1. Chrysophyllum lucentifolium Cronquist	2.49	29.76	25.96	19.40
	2. Zollernia paraensis Huber	3.54	20.71	19.41	14.55
	3. Manilkara elata (Allemão ex Miq.) Monach.	2.62	5.72	6.19	4.84
	4. Bagassa guianensis Aubl.	3.54	4.22	6.21	4.66
	5. Handroanthus impetiginosus (Mart. ex DC.) Mattos	3.41	3.79	4.11	3.77
	6. Handroanthus serratifolius (Vahl) S. Grose	3.54	3.79	3.57	3.63
	7. Pseudopiptadenia suaveolens (Miq.) J.W. Grimes	3.54	3.77	3.52	3.61
	8. Erisma uncinatum Warm.	3.28	1.98	3.08	2.78
	9. Apuleia leiocarpa (Vogel) J.F. Macbr.	3.54	1.66	2.11	2.44
	10. Hymenaea courbaril L.	2.49	1.89	2.91	2.43

FR: relative frequency (%); DR: relative density (%); DoR: relative dominance (%); IVI: Importance Value Index (%).

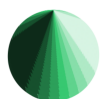


Table 3. Volume (V) and number of individuals (N) of commercial species common to UPAs 3 and 4 in Forest Management Unit IV, Flota do Paru.

Scientific name	UPA 3			UPA 4		
	N	V (m ³)	V (m ³ /ha)	N	V (m ³)	V (m ³ /ha)
<i>Astronium lecointei</i>	667	3,707.8	38.8	437	2,132.3	25.4
<i>Bagassa guianensis</i>	1,004	5,786.2	62.4	950	6,452.8	77.6
<i>Bowdichia nítida</i>	149	488.9	5.3	119	381.6	4.5
<i>Carapa guianensis</i>	2,852	6,514.2	69.7	294	627.0	7.0
<i>Cariniana micranta</i>	306	1,647.2	17.7	392	1,917.0	23.5
<i>Cedrela odorata</i>	391	1,542.0	16.7	291	1,878.8	22.3
<i>Clarisia racemosa</i>	87	265.0	2.9	87	259.0	3.2
<i>Diploptropis purpúrea</i>	57	138.4	1.5	319	870.7	10.1
<i>Dipteryx odorata</i>	181	700.4	7.7	144	706.2	7.9
<i>Enterolobium schomburgkii</i>	57	255.5	2.9	358	1,487.8	17.6
<i>Erisma uncinatum</i>	37	165.8	1.9	459	3,077.7	35.9
<i>Handroanthus impetiginosus</i>	1413	7,624.2	82.2	836	4,448.6	53.5
<i>Handroanthus serratifolius</i>	880	3,067.2	33.5	815	3,672.4	46.2
<i>Hymenaea courbaril</i>	207	1,716.1	18.2	419	3,135.5	38.5
<i>Lecythis pisonis</i>	702	4,323.8	47.2	282	1,746.0	19.7
<i>Vatairea paraenses</i>	209	1,082.5	11.6	83	413.8	4.8
<i>Vochysia guianensis</i>	125	614.1	6.7	121	870.5	9.6
Total	9,324	39,639.3	426.90	6,406	3,4077.7	407.2

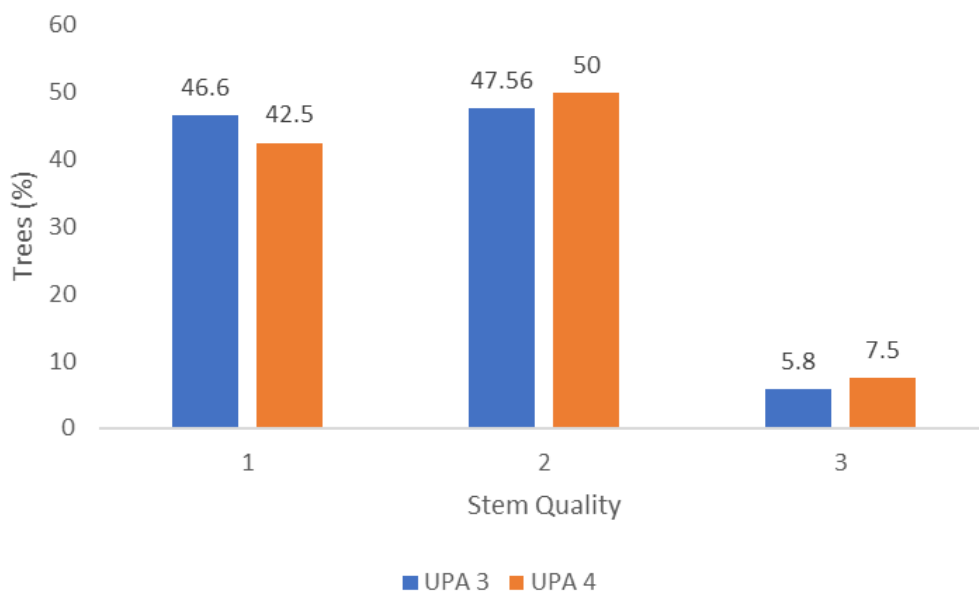


Figure 5. Stem quality classes of commercial and potentially commercial species inventoried in Annual Production Units (UPAs) 3 and 4, located in Forest Management Unit IV, in the Paru State Forest, where: (1) straight stems without defects; (2) crooked stems without defects; and (3) crooked stems with defects.



The initial stage of operational planning includes micro-zoning, which defines the Annual Exploitation Area (AEE) excluding protected areas, infrastructure zones, and remote areas. Therefore, the distribution of the gross area is essential for the preparation of the Annual Operational Plan. Based on this distribution, it is possible to quantify the size of the AEE and request the Authorization for Exploitation (AUTEX), allowing the removal of part of the individuals of commercially valuable species (BLUE TIMBER FLORESTAL, 2022; BRASIL, 2009).

In this study, the AEE was from 92.25% (UPA 3) to 84.10% (UPA 4), values close to those found in UPA 2 of the harvesting plan in the Jamari National Forest, which presented an AEE of 89.58%, equivalent to 1,743.30 ha out of a total of 1,946 ha (AMATA, 2011), and to those observed in UPA 1 of UMF II in the Saracá-Taquera National Forest, which showed an AEE of 93.80%, corresponding to 1,341.98 ha out of 1,430.00 ha (EBATA, 2020).

Since operational planning is carried out annually for each UPA, another important aspect for planning is the assessment of the available timber stock in terms of volume and species across the different UPAs. The high similarity observed between UPAs 3 and 4 (64%) was expected due to the proximity of the areas and their high degree of conservation, being located within a protected area, the Paru State Forest. Furthermore, higher similarity is expected because the data come from a full forest census with a pre-selection of commercially valuable species and those with potential for future exploitation.

Different results have been reported in studies based on sampling inventories without pre-selection of species. For example, Silva et al. (2021b) analyzed the similarity among three forest fragments in the Eastern Amazon using the Jaccard index. Although they observed some proximity between the fragments, similarity ranged from 27% to 29%, indicating a high level of historical anthropogenic disturbance. Corrêa and Freitas (2022) also analyzed Jaccard similarity in the Amazon, using data from two State Conservation Units in Amazonas: the Rio Negro Sustainable Development Reserve (RDS) and Rio Amapá RDS. Similarity values ranged from 0.18 to 0.47. These results can be explained by the level of human intervention in these RDSs, which are characterized as among the sustainable-use conservation units with the highest anthropogenic pressure for socioeconomic activities (BRASIL, 2000).

The Importance Value Index (IVI) can be used as an indicator of the ecological significance of species (ANDREADE 2017), due to the influence of the most frequent and dominant species on fundamental processes that maintain floral balance and support fauna by providing shelter and food. The use of IVI as a metric helps to assess the role of species in biodiversity conservation

and ecosystem functioning.

Vieira (2019) also conducted a study based on census data from a UPA located in the Paru State Forest. This UPA was subdivided into 42 UTs and had a total area of 4,395.71 ha. The study was based on the list of species authorized for forest exploitation, focusing on those with the highest absolute frequency, namely: *Manilkara huberi*, *Pouteria pachycarpa*, *Tetragastris panamensis*, and *Goupia glabra*. Although from a different area within the Paru State Forest, it is possible to observe that in UPAs 3 and 4, as well as in the UPA studied by Vieira (2019), there is a significant occurrence of the species popularly known as Maçaranduba (*Manilkara huberi* and *Manilkara elata*) and the species Goiabão (*Pouteria pachycarpa* and *Chrysophyllum lucentifolium* (LPF 2023)). Maçaranduba is one of the most exploited species in forest management in the Amazon (CASTRO; CARVALHO, 2014; WORBES; SCHÖNGART, 2019) due to the high number of individuals, the size of the trees, and, in addition, the physical and mechanical properties of its wood (ARAUJO et al., 2020).

The species *Chrysophyllum lucentifolium* has great importance in timber production, despite its slow growth compared to other species that are also widely harvested in the Amazon (DAVID et al., 2019). According to Song et al. (2022), it also shows potential for use as a non-timber forest product. The authors studied a methanolic extract of *C. lucentifolium* and found photoprotective, anti-inflammatory, moisturizing, and antimelanogenic effects that could be utilized by the cosmetics industry.

The presence of purple and yellow ipê species (*Handroanthus impetiginosus* and *Handroanthus serratifolius*), was recorded in UPAs 3 and 4. Among these, *Handroanthus serratifolius* is one of the species with the highest economic value, primarily for export, and is used in carpentry and joinery (PINHEIRO et al., 2021; GONÇALVES et al., 2022).

Other factors that should be analyzed to assess the feasibility of exploitation are tree volume and stem quality. Similarly to this study, Vidal et al. (2016) analyzed the volume of species in the Amazon forest; however, they used estimates for the entire set of species. The authors applied an equation adjusted from the literature and evaluated the impacts on the forest after Reduced Impact Logging.

The present study provides important information on the timber production of commercial species occurring in the two UPAs, totaling 39,639.3 m³ in UPA 3 and 34,077.7 m³ in UPA 4, respectively. From these totals, the volumes designated for harvesting, growing stock, and standing inventory must also be considered. Câmara et al. (2023) assessed native species harvested in the Amazon region over five years and recorded a total of 811 species, with



804 without forest concession (volume = 5,374,712.7 m³) and 104 with forest concession (volume = 134,511.9 m³). Morais and Oliveira (2018), when planning the harvesting at UPA located in the Altamira National Forest, reported only the remaining volume values of commercial species, ranging from 7,123.0 m³ to 4,370,592.3 m³.

As for stem quality, trees classified as class 3, according to Morais and Oliveira (2018), should be included in the inventory but are not recommended for harvesting due to their low utilization rate (<50%), and are therefore left to compose the growing stock. Stem quality, as well as tree health condition, are key criteria to be considered when planning harvesting operations in sustainable forest management in the Amazon (SIVIERO et al., 2020). Consequently, several studies incorporate stem quality classification when evaluating one or more species (SILVA et al., 2021c; LAMEIRA et al., 2022).

Overall, the study revealed a high harvesting potential for the area, with the presence of commercially important species, supporting forest management for both timber and non-timber forest products, particularly through species with high ecological importance, as indicated by the IVI.

5. Conclusion

UPAs 3 and 4, located in the Paru State Forest, present Effective Exploitable Areas (EEA) exceeding 80% of the gross area in both units. Considering the census data collected within the EEA of these two UPAs, a high floristic similarity was observed, indicating that 68% of the inventoried species are common to both areas.

The species with high potential for both timber and non-timber products are among the top ten with the highest Importance Value Index (IVI) in both UPAs. Furthermore, the volumetric stock and stem quality of the individuals enable the application of reduced-impact logging practices.

It is recommended that further studies be conducted using data collected during the planning of sustainable forest management in the Amazon, especially in areas under forest concession, in order to expand the economic, social, and environmental benefits of public forest management.

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Author Statements

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- ✓ There is no evidence of plagiarism in this article.

References

- Alvares. C. A.; Stape. J. L.; Sentelhas. P. C.; Gonçalves. J. L. M.; Sparovek. G. (2014). Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*. 22(6). 711-728. <https://doi.org/10.1127/0941-2948/2013/0507>
- Amata. (2011). Plano Operacional Anual 02 UMF III – FLONA do Jamari UPA 02. https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasil/eiro/concessao-florestal/concessoes-florestais-em-andamento-1/copy_of_amata_poa02.pdf
- Andrade. R. T. G.; Pansini. S; Sampaio. A. F.; Ribeiro. M. S.; Cabral. G. S.; Manzatto. A. G. (2017). Fitossociologia de uma floresta de terra firme na Amazônia Sul-Occidental. Rondônia. Brasil. *Biota Amazônia*. 7(2). 36-43. <http://dx.doi.org/10.1856/1/2179-5746/biotaamazonia.v7n2p36-43>
- Araujo. A. J. C.; Balboni. B. M.; Moutinho. V. (2020). Physical and Mechanical Characterization of *As tronium Lecointei* and *Manilkara Huberi* Branch Wood. *Floresta e Ambiente*. 27(2). e20170468. <https://doi.org/10.1590/2179-8087.046817>
- Blue Timber Florestal. (2022). Plano Operacional Anual da Unidade de Produção Anual 4. Floresta Estadual do Paru. https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/concessao-florestal/plano-de-manejo-florestal-sustentavel-planos-operativos-anuais-shapefile/UMF_IV_UPA_4F_POA.pdf
- Blue Timber Florestal. (2019). Plano de Manejo Florestal Sustentável de Uso Múltiplo: Floresta Estadual do Paru - UMF IV.
- Blue Timber Florestal. (2023). Resumo público do Plano de Manejo - Floresta Estadual do Paru - UMF IV - 2022-2023. <https://bluetimber.com.br/pt/documentos/RESUMO-PUBLICO-BTF-2022-2023.pdf>



- Braga. S. R. B.; Oliveira. M. L. R.; Gorgens. E. B. (2023) *Forestmanger: Forest mensuration and management*. R package 0.9.2. <http://CRAN.R-project.org/package=forestmanger>
- Brasil. *Lei 11.284 de 02 de março de 2006*. Dispõe sobre a gestão de florestas públicas para a produção sustentável; institui, na estrutura do Ministério do Meio Ambiente, o Serviço Florestal Brasileiro - SFB e cria o Fundo Nacional de Desenvolvimento Florestal - FNDF. Brasília. https://www.planalto.gov.br/ccivil_03/_Ato2004-2006/2006/Lei/L11284.htm
- Brasil. *Lei 9.985 de 18 de julho de 2000*. Sistema Nacional de Unidade de Conservação da Natureza – SNUC. Brasília. https://www.planalto.gov.br/ccivil_03/leis/l9985.htm
- Brasil. *Lei nº 14.119. de 13 de janeiro de 2021*. Institui a Política Nacional de Pagamento por Serviços Ambientais. Diário Oficial da União. Brasília. https://www.planalto.gov.br/ccivil_03/_ato2019-2022/2021/lei/l14119.htm Acesso em: 11 de jan. de 2024
- Brasil. *Resolução CONAMA nº 406. de 02 de fevereiro de 2009*. Estabelece parâmetros técnicos a serem adotados na elaboração, apresentação, avaliação técnica e execução de plano de manejo florestal sustentável com fins madeireiros para florestas nativas e suas formas de sucessão no bioma Amazônia. Brasília. <http://www.ibama.gov.br/sophia/cnia/legislacao/MMA/RE0406-020209.PDF>
- Câmara. M. H.; Vieira. G.; Araujo. J. A. R.; Salami. G.; Negreiros. A. M. P.; Sales Júnior. R. (2023). Análise da produção de madeira em área de concessão florestal na Amazônia ocidental: um estudo de caso na floresta nacional do Jamari. *Contribuciones a Las Ciencias Sociales*. 16(6). 3717-3732.
- Castro. T. C.; Carvalho. J. O. P. (2014). Dinâmica da população de *Manilkara huberi* (ducke) a. Chev. Durante 26 anos após a exploração florestal em uma área de terra firme na Amazônia brasileira. *Ciência Florestal*. 24(1). 161-169. <https://doi.org/10.5902/1980509813333>
- Comércio Ecológico De Madeiras (CEMAL). (2013). Plano de Manejo Florestal Sustentável - Concessão Flota Paru UMF I-Mariúçu. Almeirim-PA. https://ecocemal.com.br/documentos-tecnicos/PMFS_Mariucu_UMF01_PARU.pdf
- Corrêa. A. N. C.; Freitas. F. C. (2022). Fitossociologia, diversidade e similaridade em planos de manejo florestal em pequena escala no Amazonas. *BIOFIX Scientific Journal*. 7(2). 133-142. [dx.doi.org/10.5380/biofix.v7i2.84243](https://doi.org/10.5380/biofix.v7i2.84243)
- David. H. C.; Carvalho. J. O. P.; Pires. I. P.; Santos. L. S.; Barbosa. E. S.; Braga. N. S. (2019). A 20-year tree liberation experiment in the Amazon: Highlights for diameter growth rates and species-specific management. *Forest Ecology and Management*. 453. 117584. <https://doi.org/10.1016/j.foreco.2019.117584>
- Ebata Produtos Florestais. (2020) Plano Operacional Anual 2020. Floresta Nacional Saracá-Taquera (UMF II). <https://www.gov.br/florestal/pt-br/assuntos/concessoes-e-monitoramento/concessoes-florestais-em-andamento/floresta-nacional-de-saraca-taquera-pa/ebata-execucao-tecnica-da-concessao-saraca-taquera-umf2/poa-09-upa-09-2020-1.pdf>
- Gonçalves. Y. L. M.; Siqueira. E. S.; Ferreira. C. A.; Teixeira. M. S.; Correa. P. V.; Urbinati. C. V. (2022). Aplicação de algoritmos de Random Forest no suporte à identificação das espécies *Handroanthus serratifolius* (Vahl) S. O. Grose e *Handroanthus impetiginosus* (Mart. Ex DC.) Mattos (Bignoniaceae). *Brazilian Journal of Development*. 8(5). 39721-39735. <https://doi.org/10.34117/bjdv8n5-457>
- Instituto Do Homem E Meio Ambiente Da Amazônia (IMA-ZON). (2013). Cartilha do Plano de Manejo da Flota do Paru. <https://imazon.org.br/cartilha-do-plano-de-manejo-da-flota-do-paru>
- Lameira. M. K. S.; Silva. H. K. M.; Gomes. K. M. A.; Cândido. A. C. T. F.; Martorano. L. G.; Ribeiro. R. B. S.; Silva. A. R.; Gama. J. R. V. (2022). Capacidade produtiva de *Dipteryx odorata* (Aubl.) Willd. em um sistema de produção de pecuária integrada no Baixo Amazonas. Brasil. *Revista Forestal Mesoamericana Kurú*. 19(44). 56-65. <https://doi.org/10.18845/rfmk.v19i44.6102>
- Lima. B. A.; Nicoletti. M. F.; Stepka. T. F.; Carvalho. S. P. C.; Melo. L. O.; Cruz. G. S. (2021). Efeitos da exploração de impacto reduzido (EIR) na composição florística e estrutura de uma floresta ombrófila densa na Amazônia Brasileira. *Scientia Forestalis*. 49(131). e3635. 2021. <https://doi.org/10.18671/s cifor.v49n131.23>



- Laboratório De Produtos Florestais (LPF). (2023). Goiabão. https://lpf.florestal.gov.br/pt-br/?option=com_madeirasbrasileiras&view=especieestudada&especieestudadaid=206
- Morais. K. A. C.; Oliveira. L. G. (2018). Plano Operacional Anual – 2018. Unidade De Produção Anual (UPA-B / UMF III). Floresta Nacional de Altamira. https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/concessao-florestal/concessoes-florestais-em-andamento-1/pataua.altamira_umf3_poa2_2018.pdf
- Ninan. K.N; Inoue. M. (2013). Valuing forest ecosystem services: What we know and what we don't. *Ecological Economics*. 93. 137-149. <https://doi.org/10.1016/j.ecolecon.2013.05.005>
- Pará. (2010). Plano de Manejo da Floresta Estadual do Paru. Belém: Secretaria de Estado de Meio Ambiente. https://imazon.org.br/PDFimazon/Portugues/calha_norte/planos_de_manejo/PM_PAR_U_WEB.pdf
- Pará. Instrução Normativa nº 5 de 10 de setembro de 2015. Dispõe sobre procedimentos técnicos para elaboração, apresentação, execução e avaliação técnica de Plano de Manejo Florestal Sustentável nas florestas nativas exploradas ou não e suas formas de sucessão no Estado do Pará, e dá outras providências. Diário Oficial do Estado do Pará. Belém. <https://www.legisweb.com.br/legislacao/?id=303363>
- Pinheiro. K. A. O.; Ruschel. A. R.; Carneiro. F. S.; Frazão. A. S.; Souza. M. F. S.; D'Arace. L. M. C.; Amorim. M. B. (2021). Potencial de espécies comerciais analisado pelo índice de valor de importância em área de exploração de impacto reduzido. *Research. Society and Development*. 10(2). e16610212292. <http://dx.doi.org/10.33448/rsd-v10i2.12292>
- R Core Team. (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. Vienna. Austria. <https://www.R-project.org/>
- Serviço Florestal Brasileiro (SFB). (2023). Plano Anual de Outorga Florestal - PAOF 2023. https://www.gov.br/florestal/pt-br/assuntos/concessoes-e-monitoramento/plano-anual-de-outorga-florestal/plano-anual-de-outorga-florestal-publicacoes/paof_2023.pdf
- Silva. E. S.; Flores. M. S. A.; Silva. C. N.; Simões. A. V.; Marçal. C. C. L. (2021a) O desafio da gestão de unidades de conservação na zona costeira Amazônica: um mosaico como proposta no município de Maracanã. Pará. *Agroecossistemas*. 13(2). 97-119. <http://dx.doi.org/10.18542/ragros.v13i2.10061>
- Silva. S. P.; Ferreira. E. J. L.; Santos. L. R. (2021b). Fitossociologia e diversidade em fragmentos florestais com diferentes históricos de intervenção na Amazônia Ocidental. *Ciência Florestal*. 31(1). 233-251. <https://doi.org/10.5902/1980509839027>
- Silva. T. A. F.; Brandão. A. D. S.; Santos. A. V. F.; Silva. B. K. R.; Vieira. D. C.; Anhê. B. B.; Brito. S. N. S.; Monteiro. H. S. A.; Ramos. R. J. C.; Farias. P. R. S. (2021c). A influência da distribuição espacial na qualidade do fuste de *Euxylophora paraensis* (Huber) em floresta de terra firme manejada na Amazônia Oriental. *Brazilian Journal of Development*. 7(8). 84130–84146. <https://doi.org/10.34117/bjdv7n8-565>
- Siviero. M. A.; Ruschel. A. R.; Yared. J. A. G.; Vieira. S. B.; Sales. A.; Pereira. J. F.; Aguiar. O. J. R.; Brienza Junior. S.; Pereira. P. C. G.; Berberian. G. A.; Contini. K. P. S. (2020). Manejo de florestas naturais degradadas na Amazônia: estudo de caso sobre critérios de colheita. *Ciência Florestal*. 30(1). 43-59. <https://doi.org/10.5902/1980509825856>
- Soares. C.C.; Bezerra. M. G. F. (2021). A gestão da concessão florestal no estado do Pará. *Research. Society and Development*. 11(1). e18811125101. <https://doi.org/10.6008/CBPC2179-6858.2021.004.0049>
- Song. C.; Lorz. L. R.; Lee. J.; Cho. J. Y. (2022). In Vitro photoprotective, anti-inflammatory, moisturizing, and antimelanogenic effects of a methanolic extract of *Chrysophyllum lucentifolium* Cronquist. *Plants*. 11(94). 1-17. <https://doi.org/10.3390/plants11010094>
- Sousa. R. L.; Silva. S. G.; Costa. J. M.; Costa. W. A.; Maia. A. A. B.; Oliveira. M. S.; Andrade. E. H. A. (2021). Chemical profile of manually extracted andiroba oil (*Carapa guianensis* Aubl., Meliaceae) from Mamangal community, located in Igarapé-Miri, Pará, Brazil. *Scientia Plena*. 17. p. 1-8. Doi: <https://doi.org/10.14808/sci.plena.2021.127201>



- Souza. A. L.; Soares. C. P. B. (2013). *Florestas nativas: estrutura, dinâmica e manejo*. Viçosa: UFV. 322 p.
- Vidal. E.; West. T. A. P.; Putz. F. E. (2016). Recovery of biomass and merchantable timber volumes twenty years after conventional and reduced-impact logging in Amazonian Brazil. *Forest Ecology and Management*. 376. 1-8. <http://dx.doi.org/10.1016/j.foreco.2016.06.003>
- Vieira A.M.R. (2019). Padrão espacial de espécies florestais em diferentes classes de diâmetro na floresta estadual do Paru. Pará. <http://rima.im.ufrj.br:8080/jspui/handle/1235813/6964>. Acesso em: 06 de jul. de 2023
- Worbes. M.; Schöngart. J. (2019). Measures for sustainable forest management in the tropics – A tree-ring based case study on tree growth and forest dynamics in a Central Amazonian lowland moist forest. *Plos One*. 14. 8. e0219770.<https://doi.org/10.1371/journal.pone.0219770>