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Articles

Effects of bamboo dominance and mortality on population structure and phytosociology of timber species in Southwestern Amazonian forests

Efeitos da dominância e mortalidade do bambu na estrutura populacional e fitossociologia de espécies madeireiras em florestas do Sudoeste Amazônico

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ABSTRACT

Timber forest management is an important activity in Acre, but in the eastern portion of the state the forests present a high density of bamboo culms (*Guadua* spp.), which leads to lower diversity, high tree mortality, and reduced biomass and carbon accumulation. This study analyzed and compared the population structure of timber species across three forest typologies: (1) areas without bamboo dominance, (2) with dominance, and (3) post-mortality of bamboo (*Guadua* spp.) in the southwestern Amazon. In the study area, three distinct forest typologies were identified: non-dominance, dominance, and post-mortality of *Guadua* spp. In each typology, three 0.5-ha plots were installed, and commercial individuals with DBH ≥ 10 cm were recorded. Dendrometric parameters (basal area, basal area per hectare, and over-bark stand volume) and phytosociological metrics (relative density, relative dominance, relative frequency, and importance value) were assessed. In areas without bamboo dominance, basal area, volume, and density of commercial species were significantly higher than in areas where bamboo was present or had died. In the same typology, early secondary and climax species showed high importance values, whereas in the other typologies a reduction in the importance of these species was observed. The changes caused by bamboo, especially after its mortality, can negatively affect the population structure and dynamics of timber species, compromising sustainable forest management.

Keywords: Biodiversity; Commercial species; *Guadua* spp.; Sustainable forest management; Importance value

RESUMO

O manejo florestal madeireiro é uma atividade importante no Acre, mas no leste do estado as florestas apresentam alta densidade de bambu (*Guadua* spp.), o que provoca menor diversidade, alta mortalidade arbórea e redução no acúmulo de biomassa e carbono. Este estudo analisou e comparou a estrutura populacional de espécies madeireiras em três tipologias florestais: (1) áreas sem dominância, (2) com dominância e (3) pós-mortalidade de bambu (*Guadua* spp.) na região sudoeste da Amazônia. Na área estudada, identificou-se três tipologias florestais distintas: florestas sem dominância, com dominância e pós-mortalidade de *Guadua* spp. Em cada área, instalou-se 3 parcelas de 0.5 ha e identificou-se os indivíduos comerciais com DBH ≥10 cm. Observou-se parâmetros dendrométricos (área basal, área basal por hectare e volume populacional com casca) e fitossociológicos (densidade relativa, dominância relativa, frequência relativa e valor de importância). Na tipologia sem dominância de bambu, a área basal, o volume e a densidade de espécies comerciais foram significativamente maiores do que nas áreas onde o bambu estava presente ou havia morrido. Nessa mesma tipologia, espécies secundárias iniciais ou clímax apresentaram alto valor de importância, enquanto nas demais tipologias observou-se uma diminuição no valor de importância dessas espécies. As alterações causadas pelo bambu, especialmente após sua mortalidade, podem prejudicar a estrutura populacional e a dinâmica das espécies madeireiras, comprometendo o manejo florestal sustentável.

Palavras-chave: Biodiversidade; Espécies comerciais; *Guadua* spp.; Manejo florestal sustentável; Valor de importância

1 INTRODUCTION

The Amazon Rainforest is home to the highest diversity of tree species in the world, averaging 563 trees and up to 121 species per hectare (Ter Steege et al., 2023). With approximately 15,000 tree species (Esquivel-Muelbert et al., 2020), the region's biodiversity faces increasing threats from anthropogenic activities like selective logging of native species (Lapola et al., 2023).

Selective logging often occurs indiscriminately and illegally and targets high-value species attractive to the consumer market. This represents a threat to the perpetuation of these species, since extraction disproportionately removes large-diameter individuals and disrupt population structures (Bousfield et al., 2023). This practice jeopardizes species regeneration and long-term forest sustainability.

In Acre, in the southwestern Amazon, the dominance of woody bamboos (*Guadua* spp.) in the understory presents additional challenges for sustainable forest management (Hechenberger et al., 2022). It is estimated that forests containing species of the genus *Guadua*, mainly *G. weberbaueri* and *G. sarcocarpa*, cover approximately 161,500 km² (Carvalho et al., 2013) in Brazil (Acre and southern Amazonas), Bolivia (Pando), and Peru (Madre de Dios).

It is important to note that populations of these *Guadua* bamboo species, which dominate the forest understory in the southwestern Amazon, exhibit sprawling growth and form an extensive network of sympodial underground rhizomes (Londoño, 1996), and die naturally and synchronously on a massive scale after a single flowering and fruiting event (Silveira, 2005) every 27-28 years (Carvalho et al., 2013). Carvalho et al. (2013) estimated that, on average, *Guadua* bamboo populations in the southwestern Amazon occupy 330 km², with the largest estimated at 2,570 km². Thus, the synchronous mortality that occurs in these bamboo populations, in addition to its large spatial range, has the potential to alter the structural and floristic characteristics of the forests where it occurs (Griscom; Ashton, 2006; Griscom et al., 2007).

In Acre alone, about 75% of forest types have *Guadua* spp. as a primary or secondary component of the understory (Acre, 2010). These bamboo-dominated forests exhibit up to 60% lower tree diversity (Griscom et al., 2007) and elevated tree mortality, reducing basal area and carbon stocks (Griscom; Ashton, 2006).

In the forests of Acre, it is estimated that there is a volume of 800.1 million m³ of bamboo culms stems in the forest understory (Bayma et al., 2023). This high density of *Guadua* spp., combined with a low basal area, triggers significant changes in the forest ecosystem, including increased temperature and light penetration, resulting in a drier environment (Hechenberger et al., 2022).

Although these bamboo species are not yet exploited in the region and do not have characteristics suitable for the furniture sector, they hold potential for industrial applications such as the production of bioplastics, biochar, and charcoal (Bayma et al., 2025).

The international timber market primarily demands species with high commercial value, typically late secondary or climax species. In contrast, pioneer or early secondary species tend to have low market value due to their lower wood quality and are generally confined to domestic markets (Reategui-Betancourt et al., 2024). Fadrique et al. (2021), in a study in bamboo forests in the Peruvian Amazon, noted that the ecological changes induced by the bamboo species *G. sarcocarpa* and *G. weberbaueri* may favor fast-growing pioneer species, which require intense light for development (Budowski, 1965). This suggests that not all tree species, particularly those with timber potential that are less tolerant of forest disturbances, can adapt to the changes caused by bamboo presence. Notably, there is a lack of studies evaluating how late secondary or climax timber species are affected by the ecological changes caused by *Guadua* species in western Amazon forests.

Given the economic and ecological significance of logging in southwestern Amazon, where bamboo presence is prominent, this study aimed to analyze and compare the population structure of timber species in non-dominant, dominant, and post-mortality bamboo (*Guadua* spp.) forest areas in the region.

2 MATERIALS AND METHODS

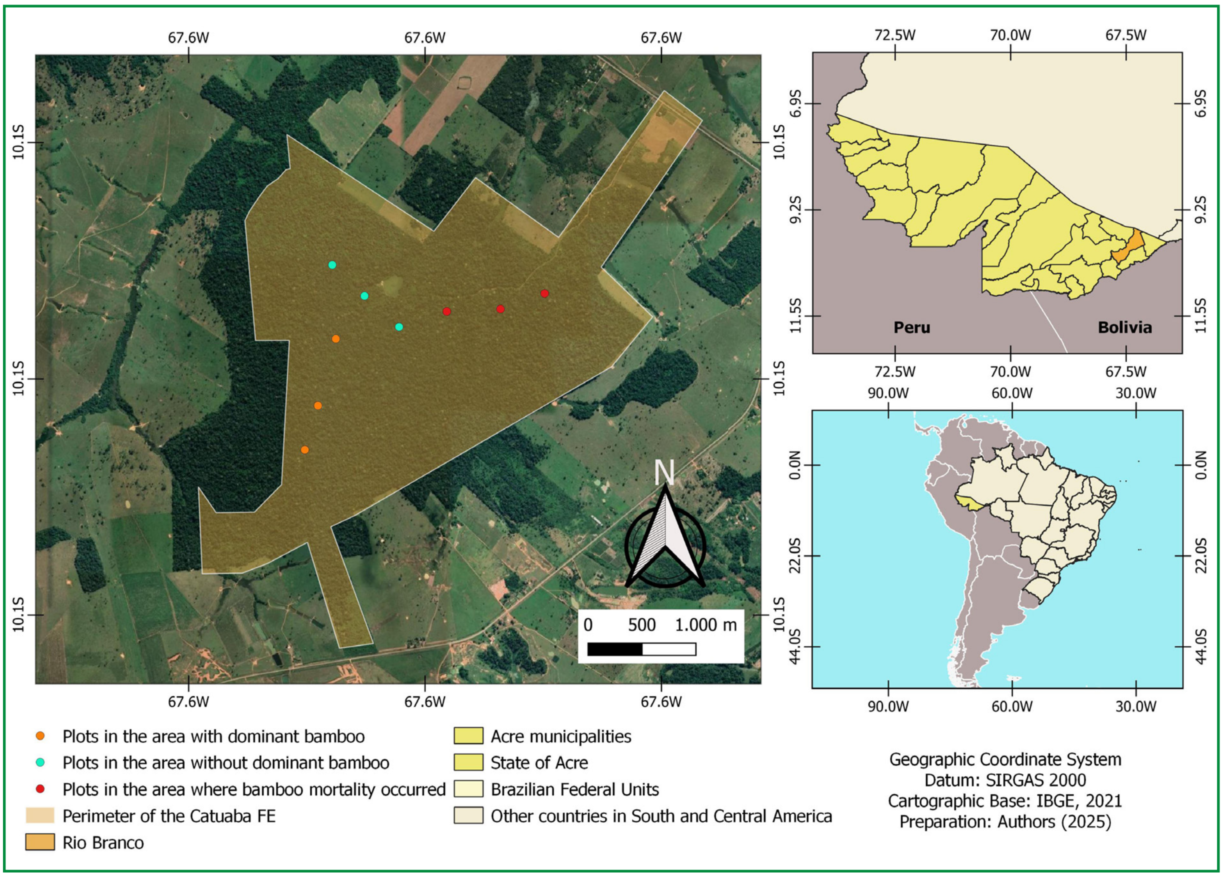
2.1 Timber Species Identification

We analyzed IBAMA's DOF (Forest Origin Document) reports (2020–2022) to identify legally logged timber species in Acre State (IBAMA, 2023). Scientific names and timber volumes (m^3) were compiled into a spreadsheet, verified against the World Flora Online database, and cross-referenced with species recorded in our phytosociological survey.

2.2 Study Area Characterization

The research was conducted in the Catuaba Experimental Farm (FEC), a 1,200-hectare forest fragment in Senador Guiomard, Acre, Brazil (10°04'S; 67°37'W, 241 m elevation) (Figure 1). The site comprises mixed primary and secondary vegetation, predominantly Open Ombrophilous Forest with Bamboo and Palms (Januário et al., 2022).

Figure 1 – Location of the Catuaba Experimental Farm in Senador Guiomard, Acre, Brazil



Source: Authors (2025)

The local terrain is gently undulating, with soils including Typical Dystrophic Red Latosol, Typical Aluminum Red-Yellow Latosol, Typical Dystrophic Red Argisol, Typical Dystrophic Haplic Plinthosol, and Typical Dystrophic Haplic Gleysol, all of low natural fertility (Januário et al., 2022). Climate data show an annual rainfall of 2,022 mm and a mean temperature of 24.8°C (range: 23.2–25.7°C) (Sousa, 2020).

2.3 Plot Establishment and Data Collection

Plots were established in three forest types: bamboo-dominant areas, non-bamboo-dominant areas, and post-bamboo mortality areas, visually identified during field visits. In the typology where bamboo die-off occurred, this phenomenon took place naturally, approximately five years before the experiment was conducted.

For each typology, three 0.5-ha plots (100 × 50 m) were randomly established and subdivided into eight 625 m² subplots to facilitate data collection, with ≥500 m spacing between plots. All commercial trees with DBH ≥10 cm were inventoried (Fadrique et al., 2021). Bamboo culm density was quantified in five 10 × 20 m subplots in each bamboo-dominated area, which were randomly distributed. Botanical identification was performed in the field by an experienced parataxonomist and confirmed at the Herbarium of the Zoobotanical Park (UFAC/PZ), Federal University of Acre, Brazil.

2.4 Dendrometric and Phytosociological Parameters

Field measurements included the circumference at 1.3 m from the ground (converted to diemeter), as well as total and commercial tree height. Based on these data, the following dendrometric parameters were calculated: basal area, basal area per hectare, and population volume with bark. For volume estimation, a form factor of 0.7 was adopted, as recommended in the literature due to its widespread use in volumetric studies of native forests, and which can also be applied to planted forests (Miranda, Bernardino Junior, and Gouveia, 2015).

Additionally, the following phytosociological parameters were evaluated: relative density, relative dominance, relative frequency, and importance value (Ferreira et al., 2025). These indicators allowed for the characterization of the composition and structure of tree species present in the sampled areas.

2.5 Statistical Analysis

Data normality (Shapiro–Wilk) and variance homogeneity (Levene) were tested. Analysis of variance and Tukey's test, at a 5% significance level, were used to compare the density, basal area, and volume of commercial species across typologies. Statistical analyses were performed using RStudio software, version 2025.09.2+418.

2.6 Population Structure Analysis

Commercial species were grouped into diameter classes (10 - 20 cm; 20.1 - 30 cm; 30.1 - 40 cm; 40.1 - 50 cm; 50.1 - 60 cm; 60.1 - 70 cm; 70.1 - 80 cm; 80.1 - 90 cm; 90.1 - 100 cm; 100.1 - 110 cm; 110.1 - 120 cm and >120 cm) to analyze diametric distribution, and into four height classes (1 - Individuals with total height ≤ 5 m; 2 - Total height between 5.1 and 10 m; class 3 - Total height between 10.1 and 15 m; 4 - Total height > 15 m) to analyze the vertical structure.

2.7 Ecological Group Classification

The identified commercial species were classified into ecological groups based on Budowski's (1965) categories: pioneers (pi), early secondary (es), late secondary (ls), and climax (c). Due to the large number of species and limited literature, they were grouped into two main categories: pi/es and ls/c. Existing literature classifications determined each species' group. For unclassified species, traits like trunk height and diameter, life cycle, wood density, and light tolerance were used following Budowski's framework (Budowski, 1965; Almeida et al., 2025). Species lacking enough data were labeled "Unclassified."

3 RESULTS AND DISCUSSIONS

3.1 Phytosociology and Timber Species Diversity

Across the three forest typologies, 481 commercial trees representing 42 species and 18 families were cataloged. The non-bamboo-dominant area contained the highest richness (56.5% of individuals, 80.9% of species, 94.4% of families) (Table 1). Bamboo-dominant areas showed 3,475 culms ha^{-1} density.

Table 1 – Number of individuals, species and botanical families of commercial timber plants found in different forest types at the Catuaba Experimental Farm, Senador Guiomard, Acre, Brazil

Typology	Number of trees	Number of species	Number of families
Non-bamboo-dominant	272	34	17
Dominant-bamboo	132	26	13
Post-mortality of bamboo	77	27	13

Source: Authors (2025)

Tree density in the non-bamboo-dominant area (181.3 ind.ha^{-1}) was significantly higher (Tables 2 and 3), with reductions of 71.7% and 51.4% in post-mortality and bamboo-dominant areas, respectively.

Table 2 – Density (ind.ha^{-1}), basal area (m²), and volume (m³) of commercial timber species per hectare in different forest typologies at the Catuaba Experimental Farm, Senador Guiomard, Acre, Brazil

Plot	Non-bamboo-Dominant			Dominant-bamboo			Post-mortality of bamboo		
	D	BA	V	D	BA	V	D	BA	V
1	184	18.71	113.87	124	8.97	57.78	76	8.80	61.24
2	150	16.16	83.54	86	6.27	38.89	62	4.80	32.15
3	210	16.84	98.34	54	6.64	43.88	16	1.12	6.05
Average	181.3a	17.2a	98.5a	88.0b	7.2b	46.8b	51.3b	4.9b	33.1b
CV (%)	16.6	7.6	15.4	39.8	20.1	20.9	61,1	78.3	83.3

Source: Authors (2025)

Where: CV = coefficient of variation; D = Density; BA = Basal area; V = volume. Different letters indicate significant differences between the averages.

Table 3 – Comparative analysis of commercial tree density, basal area, and wood volume among forest types at the Catuaba Experimental Farm, Senador Guiomard, Acre, Brazil

Density of commercial individuals							
	gl	**Sum Sq**	**Mean Sq**	**F-Value**	**P-Value**	**Shapiro wilk**	
							p
Typologies	2	26956	13478	12.960	0.006**	0.892	0.212
Residuals	6	6237	1040	-	-	-	-
Basal area of commercial individuals							
	gl	**Sum Sq**	**Mean Sq**	**F-Value**	**P-Value**	**Shapiro wilk**	
						W	**p**
Typologies	2	256.59	128.30	20.650	0.002**	0.952	0.722
Residuals	6	37.28	6.21	-	-	-	-
Wood volume from commercial individuals							
	gl	**Sum Sq**	**Mean Sq**	**F-Value**	**P-Value**	**Shapiro wilk**	
						W	**p**
Typologies	2	7146	3573	9.851	0.0127*	0.986	0.988
Residuals	6	2176	363	-	-	-	-

Source: Authors (2025)

Where: Sum Sq = Sum of Squares; Mean Sq = Mean Square; A p-value less than 0.05 indicates a significant difference according to the analysis of variance; * = The result is statistically significant at the 5% level; ** = The result is statistically significant at the 1% level; W = Shapiro-Wilk test statistic that measures the adherence of the data to the normal distribution; p = P-value of the Shapiro-Wilk test, with p-values greater than 0.05 indicating the normality of the data.

In the non-bamboo-dominant typology, a basal area of 51.7 m^2 (17.2 $m^2.ha^{-1}$; CV = 7.6%) was recorded. This value decreased by 71.6% and 57.7% in the post-mortality (4.9 $m^2.ha^{-1}$; CV = 78.3%) and bamboo-dominant area (7.3 $m^2.ha^{-1}$; CV = 20.1%), respectively (Table 2).

Statistical analysis revealed that the basal area in the non-*Guadua* spp. dominant typology was significantly higher compared to the other typologies (Tables 2 and 3). Additionally, no significant difference was observed in the basal area between the bamboo-dominant and post-mortality typologies.

Regarding commercial timber volume, the non-bamboo-dominant area exhibited average values 66.3% and 52.4% higher than those recorded in the bamboo-dominant and post-mortality areas, respectively. These differences were statistically significant (Tables 2 and 3).

In the non-bamboo-dominant area, the species with the highest importance values were *Protium altissimum*, *Carapa guianensis*, *Eschweilera* sp., *Clarisia racemosa*, and *Apuleia leiocarpa* (Table 4). Notably, all these species, except *A. leiocarpa*, were recorded in all plots.

Table 4 – List of the top 10 commercial timber species with the highest Importance Value (VI) in the forest typologies studied at the Catuaba Experimental Farm, Senador Guiomard, Acre, Brazil

	Typology Non-bamboo-dominant							
Species	**N**	**FA**	**FR**	**DA**	**DR**	**DoA**	**DoR**	**IV (%)**
Protium altissimum	102	100.00	4.92	68.00	37.50	5.95	34.54	25.65
Carapa guianensis	51	100.00	4.92	34.00	18.75	1.50	8.73	10.80
Eschweilera sp.	15	100.00	4.92	10.00	5.51	0.86	5.02	5.15
Clarisia racemosa.	11	100.00	4.92	7.33	4.04	0.99	5.74	4.90
Apuleia leiocarpa	3	66.67	3.28	2.00	1.10	1.39	8.09	4.16
Chrysophyllum prieurii	12	66.67	3.28	8.00	4.41	0.69	4.03	3.91
Jacaranda copaia	5	100.00	4.92	3.33	1.84	0.60	3.48	3.41
Aspidosperma desmanthum	8	66.67	3.28	5.33	2.94	0.53	3.10	3.11
Marlimorimia psilostachya	3	66.67	3.28	2.00	1.10	0.78	4.56	2.98
Dialium guianense	6	66.67	3.28	4.00	2.21	0.51	2.98	2.82
	Typology Dominant-bamboo							
Species	N	FA	FR	DA	DR	DoA	DoR	IV (%)
Castilla ulei	10	100.00	5.88	6.67	7.58	1.65	22.73	12.06
Protium altissimum	21	100.00	5.88	14.00	15.91	0.90	12.41	11.40
Jacaranda copaia	9	66.67	3.92	6.00	6.82	1.11	15.30	8.68
Eschweilera sp.	14	100.00	5.88	9.33	10.61	0.62	8.53	8.34
Aspidosperma desmanthum	8	100.00	5.88	5.33	6.06	0.32	4.44	5.46
Sterculia sp.	9	100.00	5.88	6.00	6.82	0.23	3.19	5.30
Chrysophyllum prieurii	8	100.00	5.88	5.33	6.06	0.17	2.34	4.76
Astronium lecointei	6	100.00	5.88	4.00	4.55	0.22	3.02	4.48
Parkia nitida	4	100.00	5.88	2.67	3.03	0.25	3.50	4.14
Qualea tessmannii	7	66.67	3.92	4.67	5.30	0.18	2.51	3.91
	Typology Post-mortality of bamboo							
Species	**N**	**FA**	**FR**	**DA**	**DR**	**DoA**	**DoR**	**IV (%)**
Castilla ulei	8	66,67	4,65	5,33	10,39	0,82	16,74	10,60
Parkia nitida	4	100,00	6,98	2,67	5,19	0,58	11,87	8,01
Vochysia sp.	1	33,33	2,33	0,67	1,30	0,84	17,29	6,97
Ceiba sp.	2	66,67	4,65	1,33	2,60	0,60	12,26	6,50
Jacaranda copaia	5	66,67	4,65	3,33	6,49	0,40	8,34	6,50
Chrysophyllum prieurii	7	66,67	4,65	4,67	9,09	0,10	2,19	5,31
Apuleia leiocarpa	5	66,67	4,65	3,33	6,49	0,16	3,38	4,84
Eschweilera sp.	4	100,00	6,98	2,67	5,19	0,10	2,17	4,78
Aspidosperma desmanthum	4	66,67	4,65	2,67	5,19	0,09	1,90	3,92
Cedrela odorata	4	66,67	4,65	2,67	5,19	0,07	1,45	3,77

Source: Authors (2025)

Where: N = Number of individuals; FA = Absolute frequency (%); FR = Relative frequency (%); DA = Absolute density (ind.ha^{-1}); DR = Relative density (%); DoA = Absolute dominance (m^2.ha^{-1}); DoR = Relative dominance (%); IV = Importance value.

In the bamboo-dominant area, the species with the highest importance values were *Castilla ulei*, *Protium altissimum*, *Jacaranda copaia*, *Eschweilera* sp., and *Aspidosperma desmanthum* (Table 4).

In the post-mortality typology, *Castilla ulei*, *Parkia nitida*, *Vochysia* sp., *Ceiba* sp., and *Jacaranda copaia* had the highest importance values (Table 4). It is worth noting that only one individual of *Vochysia* sp. was cataloged in this typology, but its significant importance value was due to its large cross-sectional area (1.2732 m²).

The observed reductions in diversity, tree density, and basal area in bamboo-dominant and post-mortality areas align with previous studies. Bamboo dominance can reduce tree species richness by up to 60% (Griscom et al., 2007) and basal area by 87.4% (Griscom & Ashton, 2006). However, no prior studies have specifically addressed the impact of bamboo on commercial timber species.

Decrease in timber species density in bamboo-affected areas raises concerns for sustainable logging. CONAMA Resolution 406/2009 (Brazil, 2009) mandates the preservation of commercial trees with D ≤ 50 cm if their density is ≤ 3 ind.100 ha^{-1}. For commercial species classified as vulnerable on the Official National List of Endangered Flora, no individual suppression is allowed if density is ≤ 4 ind. per 100 ha (Brazil, 2015).

In the non-bamboo-dominant area, 19 species with 38 individuals with D > 50 cm were suitable for sustainable logging. These numbers declined significantly in bamboo-affected areas: the bamboo-dominant area had only 10 species and 16 individuals (representing reductions of 47.4% and 57.9%, respectively), while the post-mortality area contained just 6 species and 9 individuals (reductions of 68.4% and 76.3%). This substantial decrease in harvestable trees threatens the long-term sustainability of timber extraction in bamboo-affected forests, as reduced diversity heightens the risk of overexploitation. Rockwell et al. (2014) propose a unique approach for sustainable logging in bamboo-dominated areas: (1) enriching the area with seedlings of commercial tree species and (2) reducing timber extraction volumes following the die-off of *Guadua* spp. populations. These authors also stress the importance of promoting the exploitation of non-timber forest products, such as latex (*Hevea brasiliensis*) and açaí (*Euterpe precatoria*), to offset potential financial losses resulting from the reduced availability of commercial timber in bamboo forests.

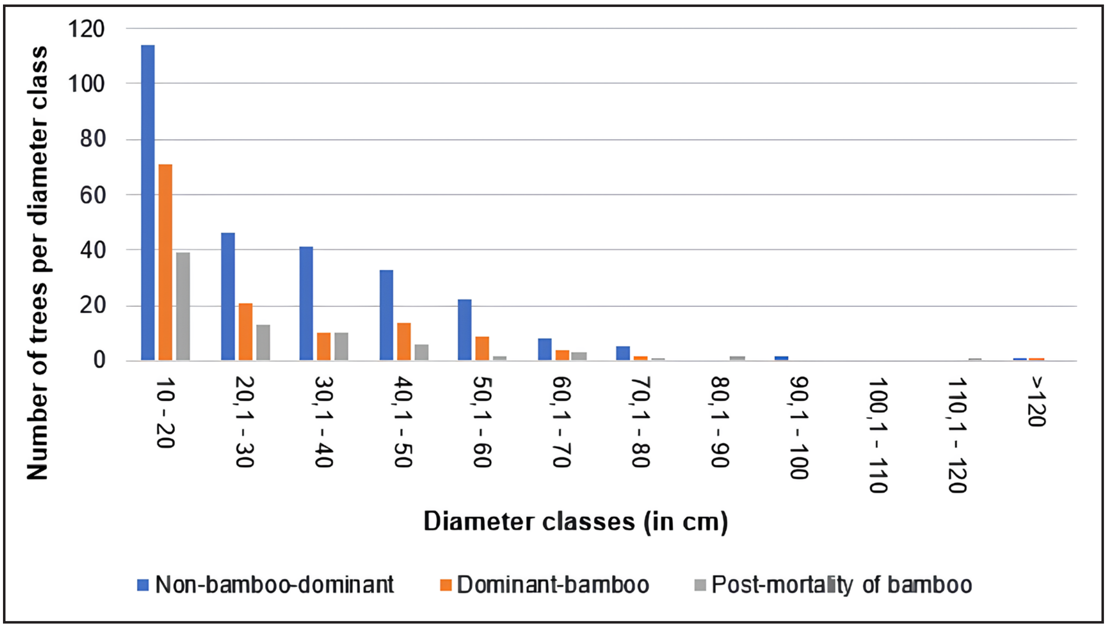
Assessing the importance value of species in post-mortality environments or in areas dominated by bamboo is crucial. The Importance Value (IV), calculated using phytosociological parameters such as specific density, dominance, and frequency, helps determine species dominance in a given area and serves as an indicator of the forest's successional stage (Jannat et al., 2020). The predominance of late secondary and climax species (50.2% IV) in non-bamboo forests confirms their advanced successional status. However, research gaps remain regarding the specific impacts of bamboo on the population structures of commercial timber species. In this context, it is essential to conduct studies that specifically assess how competition for light, space, and resources influences different successional groups, as well as to monitor the population dynamics of commercial species throughout the bamboo life cycle.

Previous studies demonstrate bamboo's influence on species composition. Griscom et al. (2007) reported high IVs for commercial species *A. parvifolium* and *J. copaia* in Peruvian *Guadua*-dominated forests, while Silveira (2005), in a study conducted in the same region as this research, documented similar patterns for *C. pentandra* and *Z. rhoifolium* in comparable ecosystems. In contrast, in forests without bamboo, four timber species (*P. rohrii*, *P. altissimum*, *D. guianense*, and *Eschweilera* sp.) were found among the top ten species with the highest importance values.

3.2 Diametric Distribution and Vertical Structure of Timber Species

The post-mortality and bamboo-dominant areas showed reductions of 65.8% and 37.8%, respectively, in the number of trees with diameters between 10 and 20 cm. These areas also exhibited more pronounced reductions of 71.8% and 54.5%, respectively, in the number of trees with diameters between 20.1 and 30 cm (Figure 2).

Figure 2 – Diametric distribution of individuals of commercial species by forest typology evaluated at the Catuaba Experimental Farm, Senador Guiomard, Acre, Brazil



Source: Authors (2025)

Average tree height was similar across all typologies (9.9 m in non-bamboo-dominant, 9.5 m in bamboo-dominant, and 9.8 m in post-mortality areas). However, the non-bamboo-dominant area had a higher proportion of trees (58.4%) in the 5.1–10 m height class.

A fundamental principle of sustainable forest management involves ensuring natural regeneration of harvested species by protecting smaller-diameter trees to grow and progress to higher diameter classes (Rockwell et al., 2014). Post-mortality areas present dual challenges: they contain fewer harvestable trees (DBH > 50 cm) and limited numbers of smaller trees (39 trees of 10-20 cm DBH versus 71 in unaffected areas), potentially impairing regeneration capacity. The reduced number of individuals with D ≤ 30 cm aligns with findings by Griscom and Ashton (2006) in *Guadua* spp.-dominated areas in southeastern Peru, where bamboo caused physical damage to trees with diameters between 5 and 29 cm, leading to a significant reduction in their density and height. Hechenberger et al. (2022), in a study conducted in the same area as this research, also reported that bamboo dominance in forests causes physical damage, such as stem breakage or leaning, to tree populations, confirming that these structural impacts threaten sustainable logging practices.

Given this situation, and considering that the life cycle of the local bamboo population lasts up to 28 years, it can be inferred that the floristic and phytosociological characteristics of the post-mortality areas of bamboo studied here represent the peak of the deleterious effects that bamboo can cause to the structure and floristics of the forests they occupy. Thus, from an ecological point of view, and considering that the study in these areas was conducted only five years after the mortality of the bamboo, the lower tree density, basal area, and volume can be attributed to the dominant presence of bamboo throughout its full life cycle.

3.3 Ecological Grouping of Timber Species

Among the 42 species cataloged, 19% remained unclassified due to insufficient data. The non-bamboo-dominant areas showed a 55% greater abundance of late secondary and climax species compared to pioneer and early secondary species. While bamboo-dominant and post-mortality areas maintained a slight predominance of late secondary/climax species, their importance values revealed distinct patterns: these species demonstrated higher IVs in non-bamboo and post-mortality areas, though the latter also showed elevated values for unclassified species (Table 5).

Table 5 – Number of species classified by ecological group cataloged in the forest typologies evaluated at the Catuaba Experimental Farm, Senador Guiomard, Acre, Brazil

Typologies	Ecological groups					
	ls/c		pi/es		un	
	N	IV	N	IV	N	IV
Non-bamboo-dominant	20	50.2	9	39.0	5	10.8
Dominant-bamboo	11	29.4	9	36.8	6	33.8
Post-mortality of bamboo	13	39.0	8	29.6	6	31.4

Source: Authors (2025)

Where: N = Number of species; IV = Importance value (%); ls/c = Late secondary or climax species; pi/es = Pioneer or early secondary species; and un = Unclassified species.

The reduction in the number of late secondary or climax species, as well as their importance values in bamboo-dominated and post-mortality areas, supports findings from other studies: *Guadua* spp.-dominated areas tend to have a higher prevalence of species characteristic of early successional stages (Silveira, 2005; Griscom et al., 2007; Fadrique et al., 2021). The predominance of pioneer or early secondary species in these environments is attributed to the changes induced by bamboo dominance, which create gaps in the forest canopy, increasing light penetration and temperature within the forest (Griscom et al., 2007).

To understand how bamboo-induced changes in forests affect different species, it is essential to consider factors related to each ecological group, such as seed characteristics and shade tolerance. Pioneer or early secondary species typically have dormant seeds that remain viable in the soil for extended periods. These species also require high light levels for growth (Budowski, 1965). Consequently, in environments with increased solar radiation, such as bamboo-dominated forests, species from these ecological groups are favored.

However, according to Rockwell et al. (2014), pioneer or early secondary species in areas with high bamboo densities often have limited commercial value due to their smaller height and diameter, as well as low-density and whitish wood, which restricts their use by the timber industry (Budowski, 1965; Silveira, 2005). In contrast, seeds of late secondary and climax species generally lack dormancy and remain viable in the soil for shorter periods. These species are better adapted to shaded environments (Griscom et al., 2007; Fadrique et al., 2021).

Timber species classified as late secondary or climax are more commercially valuable and in higher demand due to their denser, more resistant wood and desirable organoleptic properties such as color, hardness, and texture (Budowski, 1965; SIMA, 2020). Pina et al. (2021), in a study conducted in the Cerrado region, also noted that wood from secondary and climax species tends to have higher commercial value than that of pioneer species, largely due to its greater density. Nevertheless, some pioneer species, such as *Dalbergia miscolobium*, may also possess high commercial value. In agreement with these findings, Ferraz et al. (2004), in a study conducted in Central Amazonia, observed that most timber species in the region exhibit traits typical of late-successional ecological groups, including larger seeds and high wood density. However, some species may display a combination of attributes characteristic of both early- and late-successional groups, reflecting greater ecological plasticity.

The commercial value of a species' wood is determined by several factors, including organoleptic characteristics — such as color, odor, texture, weight, and hardness — which directly influence its potential uses. In general, pioneer and early secondary species have low-density and less durable wood, which significantly limits their applications (SIMA, 2020).

Understanding how commercial timber species respond to bamboo is essential, given the economic relevance of timber management in Acre. Yet, bamboo dominance is often neglected in planning. To address this, Rockwell et al. (2014) suggest adapting management practices, and Viana et al. (2024) highlight the importance of knowing the physical and chemical properties of regional bamboo species to enable their commercial use and reduce timber stock losses in *Guadua* spp.-dominated areas.

4 CONCLUSIONS

The study is innovative because, in addition to being the first assessment of the population structure of commercial timber species in forests dominated by *Guadua* spp. in the southwestern Amazon, it also reveals evidence that areas with bamboo dominance, whether containing live or dead individuals, show notable declines in the density, basal area, and volume of commercial timber species, as well as fewer trees in early diameter classes, which may limit natural regeneration.

These impacts, including the reduction in diversity and in the importance of late secondary and climax species, highlight the need for adapted sustainable forest management practices. Considering the importance of sustainable forest management for the Amazon region, further research is necessary to determine whether current regulations are adequate or require adjustments to ensure regeneration in bamboo-dominated forests.

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REFERENCES

ACRE. Governo do Estado do Acre. **Zoneamento ecológico-econômico do Acre: Fase II: Escala 1:250.000: Documento-síntese**. 2 ed. Rio Branco: SEMA, 2010.

ALMEIDA, M. V. V.; FERNANDES, M. M.; ALMEIDA, A. Q.; PEREIRA, M. G.; JOSÉ, M. B.; et al. Floristics and phytosociology of models ecological restoration intercropped with Eucalyptus in theBrazilian Atlantic Forest. **Ciência Florestal**, v. 35, e85350, p. 1-21, 2025. DOI: 10.5902/1980509885350. Accessed in: 10 Jul 2025.

BAYMA, M. M. A.; AMARAL, E. F.; AFONSO, D. G.; AMARAL, E. F.; OLIVEIRA, L. C.; DONATO, V. G. N. Uso sustentável do bambu nativo do Acre, Amazônia, Brasil: Potencial para a produção de bioplásticos, biochar e carvão vegetal. **Revista Aracê**, v. 7, n. 4, p. 20281-20296, 2025. DOI: 10.56238/arev7n4-266. Accessed in: 08 Dec 2025.

BAYMA, M. M. A.; PEREIRA, J. E. S.; OLIVEIRA, L. C; AMARAL, E. F.; SIVIERO, A.; MORET, A. S. Estimativa de volume de Bambu *Guadua* spp. do Acre, Amazônia, Brasil. **DELOS: Desarrollo Local Sostenible**, v. 16, n. 42, p. 471-488, 2023. DOI: 10.55905/rdelosv16.n42-030. Accessed in: 10 Jul 2025.

BRASIL. Ministério do Meio Ambiente. **Instrução Normativa MMA nº 1, de 12 de fevereiro de 2015**. Brasília: MMA, 2015. Available from: https://www.marcca.com.br/ZpNbw3dk20XgIKXVGacL5NS8haIoH5PqbJKZaawfaDwCm/legislacaofederal/instrucao.normativa/2015/mma1.htm. Accessed in: 10 Jul 2025.

BRASIL. Ministério do Meio Ambiente. **Resolução CONAMA 406/2009**. 2009. Available from: http://www2.mma.gov.br/port/conama/legiabre.cfm?codlegi=597. Accessed in: 29 Jun 2024.

BUDOWSKI, G. Distribution of tropical American rain forest species in the light of successional processes. **Turrialba**, v. 15, p. 40-42, 1965. Available from: https://repositorio.catie.ac.cr/bitstream/handle/11554/13616/BCO25089937i.pdf?sequence=1&isAllowed=y. Accessed in: 17 Jan 2025.

BOUSFIELD, C. G.; MASSAM, M. R.; PERES, C. A.; EDWARDS, D. P. Large-scale impacts of selective logging on canopy tree beta-diversity in the Brazilian Amazon. **Journal of Applied Ecology**, v. 60, n. 6, p. 1181-1193, 2023. DOI: 10.1111/1365-2664.14403. Accessed in: 10 Jul 2025.

CARVALHO, A. L.; NELSON, B. W.; BIANCHINI, M. C.; PLAGNOL, D.; KUPLICH, T. M.; DALY, D. C. Bamboo-Dominated Forests of the Southwest Amazon: Detection, Spatial Extent, Life Cycle Length and Flowering Waves. **PLoS ONE**, v. 8, n. 1, e54852, 2013. DOI: 10.1371/journal.pone.0054852. Accessed in: 10 Jul 2025.

ESQUIVEL-MUELBERT, A.; PHILLIPS, O. L.; BRIENEN, R. J. W.; FAUSET, S.; SULLIVAN, M. J. P.; et al. Tree mode of death and mortality risk factors across Amazon forests. **Nature Communications**, v. 11, 5515, 2020. DOI: 10.1038/s41467-020-18996-3. Accessed in: 10 Jul 2025.

FADRIQUE, B; SANTOS-ANDRADE, P; FARFAN-RIOS, W; SALINAS, N.; SILMAN, M.; FEELEY, K. J. Reduced tree density and basal area in Andean forests are associated with bamboo dominance. **Forest Ecology and Management**, v. 480, 118648, 2021. DOI: 10.1016/j.foreco.2020.118648. Accessed in: 10 Jul 2025.

FERRAZ, I. D. K.; LEAL FILHO, N.; IMAKAWA, A. M.; VARELA, V. P.; PIÑA-RODRIGUES, F. C. M. Características básicas para um agrupamento ecológico preliminar de espécies madeireiras da floresta de terra firme da Amazônia Central. **Acta Amazonica**, v. 34, n. 4, p. 621-633, 2004. DOI: 10.1590/S0044-59672004000400014. Accessed in: 08 Dec 2025.

FERREIRA, T. S.; TETTO, A. F.; KOVALSYKI, B.; SANTOS, J. F. L.; MARCON, A. K.; BATISTA, A. C. Diversity, structure and ecology of a tree-shrub community established in a fire-excluded forest-grassland ecotone in southern Brazil. **Ciência Florestal**, v. 35, e68951, 2025. DOI: 10.5902/1980509868951. Accessed in: 10 Jul 2025.

GRISCOM, B. W.; ASHTON, P. M. S. A self-perpetuating bamboo disturbance cycle in a neotropical forest. **Journal of Tropical Ecology**, v. 22, n. 5, p. 587-597, 2006. DOI: 10.1017/S0266467406003361. Accessed in: 10 Jul 2025.

GRISCOM, B. W.; DALY, D. C.; ASHTON, M. S. Floristics of bamboo-dominated stands in lowland terra-firma forests of southwestern Amazonia. **The Journal of the Torrey Botanical Society**, v. 134, n. 1, p. 108-125, 2007. DOI: 10.3159/1095-5674(2007)134[108:FOBSIL]2.0.CO;2. Accessed in: 10 Jul 2025.

HECHENBERGER, S.; FERREIRA, E. J. L.; CARVALHO, A. L.; BRAZIL, M. V. S. Danos físicos causados pelo bambu (*Guadua weberbaueri* Pilg.) em espécies arbóreas e implicações para a exploração madeireira em Floresta Ombrófila Aberta com Bambu no leste do Acre. **Research, Society and Development**, v. 11, n. 6, e39911629279, 2022. DOI: 10.33448/rsd-v11i6.29279. Accessed in: 10 Jul 2025.

IBAMA. Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis. **Transporte de produtos florestais**. Available from: https://dadosabertos.ibama.gov.br/dados/DOF/AC/transporte/2023.html. Accessed in: 15 Jun 2024.

JANNAT, M.; KAMRUZZAMAN, M.; HOSSAIN, M. K. Assessment of Natural Regeneration Potential of Native Tree Species in a Community Managed Forest of Bangladesh. **International Journal of Environment**, v. 9, n. 1, p. 100-114, 2020. DOI: 10.3126/ije.v9i1.27598. Accessed in: 10 Jul 2025.

JANUÁRIO, J. L.; CARVALHO, A. L.; FERREIRA, E. J. L.; SILVA, S. M. M. Utilização dos índices de vegetação para determinação da extensão do ciclo de vida do bambu em um fragmento localizado na região Leste do Acre. **Research, Society and Development**, v.11, n.6, e12711628734, 2022. DOI: 10.33448/rsd-v11i6.28734. Accessed in: 10 Jul 2025.

LAPOLA, D. M.; PINHO, P.; BARLOW, J.; ARAGÃO, L. E. O. C.; BERENGUER, E.; et al. The drivers and impacts of Amazon forest degradation. **Science**, v. 379, eabp8622, 2023. DOI: 10.1126/science.abp8622. Accessed in: 10 Jul 2025.

LONDOÑO, X. **Diversity and distribution of new world bamboos, with special emphasis on the Bambuseae**. INBAR Working Paper No. 8, International Network for Bamboo and Rattan. New Delhi: INBAR, 1996. 31 p. Available from: https://idl-bnc-idrc.dspacedirect.org/bitstreams/2b54999a-cc1b-4c25-a386-77030389b74a/download. Accessed in: 09 Dec 2025.

MIRANDA, D. L. C.; BERNARDINO JUNIOR, V.; GOUVEIA, D. M. Fator de forma e equações de volume para estimativa volumétrica de árvores em plantio de *Eucalyptus urograndis*. **Scientia Plena**, v. 11, n. 3, 030202-1, 2015. Available from: https://scientiaplena.org.br/sp/article/view/2427. Accessed in: 10 Jul 2025.

PINA, J. C.; OLIVEIRA, A. K. M.; BOCCHESE, R. A. Composição florística e potencial de uso das espécies em uma área do bioma Cerrado em Bandeirantes – MS. **Research, Society and Development**, v. 10, n. 1, e19910111425, 2021. DOI: 10.33448/rsd-v10i1.11425. Accessed in: 10 Jul 2025.

REATEGUI-BETANCOURT, J. L.; FREITAS, L. J. M.; SANTOS, K. R. B.; BRICEÑO, G.; MATRICARDI, E. A. T.; RUSCHEL, A. R.; FERREIRA, N. C. F. Timber yield of commercial tree species in the eastern Brazilian Amazon based on 33 years of inventory data. **Forestry: An International Journal of Forest Research**, v. 97, n. 1, p. 1-10, 2024. DOI: 10.1093/forestry/cpad043. Accessed in: 10 Jul 2025.

ROCKWELL, C. A.; KAINER, K. A.; D'OLIVEIRA, M. V. N.; STAUDHAMMER, C. L.; BARALOTO, C. Logging in bamboo-dominated forests in southwestern Amazonia: Caveats and opportunities for smallholder forest management. **Forest Ecology and Management**, v. 315, p. 202-210, 2014. DOI: 10.1016/j.foreco.2013.12.022. Accessed in: 10 Jul 2025.

SILVEIRA, M. **A floresta aberta com bambu no sudoeste da Amazônia: padrões e processos em múltiplas escalas**. Rio Branco: EDUFAC, 2005.

SIMA. Secretaria de Infraestrutura e Meio Ambiente. **Identificação macroscópica de madeiras Comerciais do Estado de São Paulo**. São Paulo: Instituto Florestal, 2020.

SOUSA, J. W. Características climáticas do município de Rio Branco, Acre, período de 1990-2019. **Scientia Naturalis**, v. 2, n. 2, p. 723-740, 2020. Available from: https://periodicos.ufac.br/index.php/SciNat/article/view/4231. Accessed in: 10 Jul 2025.

TER STEEGE, H.; PITMAN, N. C. A.; AMARAL, I. L.; COELHO, L. S.; MATOS, F. D. A.; et al. Mapping density, diversity and species-richness of the Amazon tree flora. **Communications Biology**, v. 6, 1130, 2023. DOI: 10.1038/s42003-023-05514-6. Accessed in: 10 Jul 2025.

VIANA, T. H. C.; SILVA, M. S.; SENA, MURAD, J. R. L.; RODRIGUEZ, A. F. R. Applications of Guadua weberbaeuri fiber: a systematic review from the perspective of civil construction, between the years 2017 to 2022. **Ciência Florestal**, v. 34, n. 2, e72310, 2024. DOI: 10.5902/1980509872310. Accessed in: 10 Jul 2025.

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