



STRUCTURE AND COMPOSITION OF THE VEGETATION OF A TROPICAL FOREST IN THE PERUVIAN AMAZON

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ABSTRACT

The tropical forests in the Peruvian High Amazon are strategic ecosystems for biodiversity conservation; however, their structural complexity and successional patterns remain understudied, limiting the development of effective management plans. This study characterizes the floristic composition, Importance Value Index (IVI), diametric structure, and sociological position of the National Agrarian University of the Amazon Reserved Forest (BRUNAS). The study provides a quantitative diagnostic of the forest's structural integrity to facilitate conservation strategies in high-altitude Amazonian remnants. Two permanent sampling plots (1.0 ha each) were established, recording all individuals with a diameter at breast height (DBH) ≥ 10 cm. Horizontal structure was determined through IVI, while vertical organization was assessed using sociological position analysis. The results revealed high taxonomic diversity, with a total richness of 113 and 114 species per plot. *Senefeldera inclinata* (IVI = 16.4%) and *Parkia panurensis* (IVI = 10.2%) emerged as the most dominant species. The diameter distribution followed an inverted "J" curve, with 85.5% of individuals concentrated in the lower DBH classes (10-20 cm), indicating vigorous natural regeneration. Vertical stratification showed a well-defined hierarchy where *S. inclinata* dominates the lower strata, whereas *P. panurensis* occupies the middle and upper layers. In conclusion, the BRUNAS forest exhibits a balanced structure and high resilience, typical of primary forest remnants. These findings demonstrate that stem diameter distribution and vertical organization analysis is essential to ensure the long-term conservation of these high-Amazonian ecosystems.

Keywords: Forest Management, Forest Structure, Importance Value Index, Sociological Position, Tropical Biodiversity

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ESTRUTURA E COMPOSIÇÃO FLORÍSTICA DA VEGETAÇÃO DE UMA FLORESTA TROPICAL NA AMAZÔNIA PERUANA

RESUMO As florestas tropicais da Alta Amazônia peruana são ecossistemas estratégicos para a conservação da biodiversidade; no entanto, sua complexidade estrutural e padrões sucessionais permanecem pouco estudados, limitando o desenvolvimento de planos de manejo eficazes. Este estudo caracteriza a composição florística, o Índice de Valor de Importância (IVI), a estrutura diamétrica e a posição sociológica da Reserva Florestal da Universidad Nacional Agraria de la Selva (BRUNAS). O estudo fornece um diagnóstico quantitativo da integridade estrutural da floresta para facilitar estratégias de conservação em remanescentes amazônicos de altitude. Foram estabelecidas duas parcelas permanentes de amostragem (1,0 ha cada), registrando todos os indivíduos com diâmetro à altura do peito (DAP) ≥ 10 cm. A estrutura horizontal foi determinada através do IVI, enquanto a organização vertical foi avaliada por meio da análise da posição sociológica. Os resultados revelaram alta diversidade taxonômica, com uma riqueza total de 113 e 114 espécies por parcela. *Senefeldera inclinata* (IVI = 16,4%) e *Parkia panurensis* (IVI = 10,2%) surgiram como as espécies mais dominantes. A distribuição diamétrica seguiu uma curva de "J invertido", com 85,5% dos indivíduos concentrados nas classes de DAP inferiores (10-20 cm), indicando uma regeneração natural vigorosa. A estratificação vertical mostrou uma hierarquia bem definida, onde *S. inclinata* domina os estratos inferiores, enquanto *P. panurensis* ocupa as camadas média e superior. Em conclusão, a floresta BRUNAS exibe uma estrutura equilibrada e alta resiliência, típica de remanescentes de floresta primária. Estes achados demonstram que a análise da distribuição diamétrica e da organização vertical é essencial para garantir a conservação a longo prazo destes ecossistemas da Alta Amazônia.

Palavras-Chave: Manejo florestal, Estrutura florestal, Índice de Valor de Importância, Posição sociológica, Biodiversidade tropical

1. INTRODUCTION

Tropical forests are vital for stabilizing biogeochemical cycles and harboring over two-thirds of terrestrial biota (Hofhansl et al., 2019). The Peruvian Amazon, with its rich floristic diversity, supports endemic species of high ecological value (Zárate et al., 2015; Oré et al., 2021). However, anthropogenic pressures such as deforestation and land-use change threaten the resilience of these ecosystems. In Peru, despite the existence of protected areas, many biodiversity hotspots and nature's contributions to people (NCPs) remain inadequately protected, especially in transition zones where structural data are limited (Móstiga et al., 2023).

The floristic composition and structure of these forests are pivotal to understanding their successional status and conservation condition. Species diversity is influenced by abiotic factors and disturbance history (Bienu et al., 2023; Sanjeewani et al., 2024). As human pressures increase, affecting the biodiversity and functionality (Marsh et al., 2025), studying structural attributes becomes essential to assess forest health and its capacity to withstand climatic stress (Forzieri et al., 2022).

Forest structure is traditionally analyzed through the Importance Value Index (IVI), diametric distribution, and sociological position. The IVI identifies species critical to ecological balance by combining abundance, dominance, and frequency (Acosta et al., 2006). Furthermore, the diametric distribution often displaying an inverted "J" curve reflects the forest's successional stage and demonstrates whether natural regeneration is sufficient to sustain the ecosystem over time (Mijares-S. & Pérez-Buitrago, 2018). Similarly, the sociological position reveals the vertical organization and hierarchy across strata, which is fundamental for understanding niche differentiation and competition for resources (Astigarraga et al., 2025).

The Reserved Forest of the National Agrarian University of the Amazon (BRUNAS) represents a strategic study site in the Peruvian High Amazon. Situated in a transitional area between lowland and high-



altitude forests, it serves as a primary model for studying how structural integrity is maintained in fragmented landscapes (Bañares-de-Dios et al., 2022). Despite its importance, detailed diagnostics of its vertical and horizontal organization are needed to optimize conservation strategies that ensure its long-term sustainability.

The aim of this research was to characterize the floristic composition, Importance Value Index, structure, and sociological position of the BRUNAS forest. We hypothesize that the forest maintains a balanced structural organization characterized by an inverted "J" diametric distribution and a well-defined vertical stratification. This structure indicates a high capacity for natural regeneration and ecosystem resilience, providing a reliable baseline for the design of sustainable management strategies in the High Amazonian remnants.

2. MATERIAL AND METHODS

2.1 Study area

The study was conducted in the Reserved Forest of the National Agraria University of the Amazon (BRUNAS), located in Tingo María, Peru (Figure 1). This region represents a strategic ecotone between the Lowland and High Amazon, characterized by high taxonomic diversity and its role as a biodiversity hotspot within the Peruvian protected area system (Móstiga et al., 2023). The climate is classified as tropical rainforest (Af) according to Köppen (1948), with an average annual temperature of 25.5°C and relative humidity of 85%. Annual precipitation is approximately 3,000 mm, with a well defined rainy season occurring from November to March that significantly influences forest regrowth and phenological patterns (Zepner et al., 2021).

The topography is mountainous, dominated by the Ibiapaba Formation with fertile soils that support subtropical premontane moist forests (bmh-PST) according to Holdridge (1982) classification. We established two Permanent Sampling Plots (PSP) of 1 hectare (100 x 100 m) each to evaluate structural variations across the local relief: PSP-1, situated on a lowland hill (735 m a.s.l.; -9.308566°, -75.994678°), and PSP-2, situated on a highland hill (875 m a.s.l.; -9.313650°, -75.987408°). Despite the

relatively small elevational difference (140 m), the distinction between these topographic positions is justified by variations in slope and drainage patterns, which are known to drive niche differentiation and structural complexity in Andean-Amazonian transition zones (Bañares-de-Dios et al., 2022; Marcelo-Peña et al., 2007). Such structural diversity is a pivotal modulator of ecosystem resilience and tree growth synchrony in response to climatic stress (Astigarraga et al., 2025; Forzieri et al., 2022), making the BRUNAS forest an ideal model for assessing the health of High Amazonian remnants.

2.2 Sampling protocol

Tree inventory was conducted between 2015-2016 across two 1-hectare (100 m x 100 m) permanent sampling plots (PSP). Following a stratified random design based on topographic variations (lowland vs. highland hills), each plot was divided into 25 subplots of 20 m x 20 m (400 m²). We recorded and measured all tree individuals with a diameter at breast height (DBH) ≥ 10 cm.

DBH was measured at 1.30 m from the ground using a metric tape, and total height was estimated using a Suunto PM-5/360PC clinometer. To ensure plot orientation and alignment, a Suunto compass was utilized. Taxonomic identification followed a rigorous protocol: specimens were first characterized in situ and, for those requiring further verification, botanical samples were collected using pole pruners. Samples were preserved in newspapers and dried in a wooden airtight dryer at the Forest Seed Certification Laboratory. Final taxonomic determination was performed at the Herbarium of the Missouri Botanical Garden (Oxapampa, Peru) with the collaboration of specialized botanists. The use of Permanent Sampling Plots (PSP) facilitates a precise quantitative characterization of forest architecture and composition. In addition to DBH and height, we calculated primary ecological variables, including abundance, frequency, and dominance. These parameters were integrated into the Importance Value Index (IVI) to evaluate the ecological significance of species within each topographic condition. This methodological framework provides a robust baseline for analyzing how species are

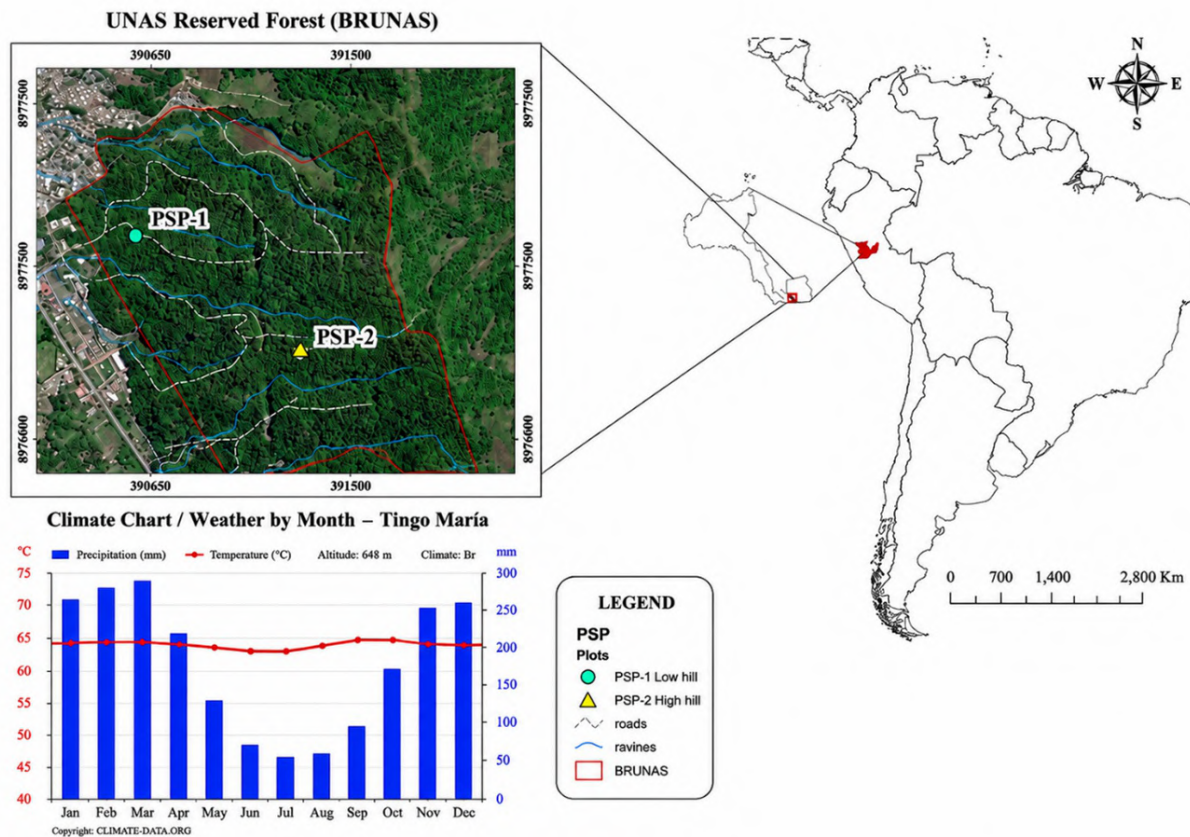


Figure 1. Location of the study site within the Huánuco Department. The reserved forest of the National Agrarian University of the Amazon - BRUNAS, and location of the permanent sampling plots. Climate diagram of the study area for the period 1993-2022 (Zepner et al., 2021). The red line indicates the average monthly temperature, the blue line indicates average precipitation; the light blue indicates the rainy season and dark blue indicates when the average precipitation is greater than 100 mm

Figura 1. Localização do local de estudo no Departamento de Huánuco. A Reserva Florestal da Universidade Nacional Agrária da Amazônia - BRUNAS, e localização das parcelas de amostragem permanente. Diagrama climático da área de estudo para o período de 1993-2022 (Zepner et al., 2021). A linha vermelha indica a temperatura média mensal, a linha azul indica a precipitação média; o azul claro indica a estação chuvosa e o azul escuro indica quando a precipitação média é superior a 100 mm

spatially and vertically distributed in High Amazonian remnants, ensuring the reproducibility of the structural diagnostic.

2.3 Structural and phytosociological analysis

To characterize the forest architecture and the ecological significance of the species, we integrated horizontal, diametric, and vertical structural parameters as follows:

Horizontal Structure and Importance Value Index (IVI)

The horizontal structure was evaluated through the Importance Value Index (IVI), which determines the phytosociological

significance of each species by integrating three relative variables: abundance, frequency, and dominance (Mostacedo & Fredericksen, 2000; Suárez-R. & Vargas-R., 2019). Dominance was determined based on the Basal Area (BA), calculated from the Diameter at Breast Height (DBH) measured at 1.30 m from the soil line (Mijares-S. & Pérez-Buitrago, 2018). The mathematical expressions for these indicators are detailed in Table 1.

Diametric Structure

For the analysis of diametric structure, individuals in each plot were grouped into diameter classes with 10 cm intervals (e.g.,

Table 1. Mathematical expression and description of elements to determine the IVI indicators
Tabela 1. Expressão matemática e descrição dos elementos para determinar os indicadores IVI

Indicator	Mathematical Expression	Description of Elements
IVI	$IVI = [Ar + Dr + Fr] / 3$	Ar = Relative abundance; Dr = Relative dominance; Fr = Relative frequency of species i.
Abundance	$Ar = [Ai / \sum A] \times 100$	Ar = Relative abundance of species i; Ai = Number of individuals of species i; $\sum A$ = Total number of individuals in the plot.
Frequency	$Fr = [Fi / \sum F] \times 100$	Fr = Relative frequency of species i; Fi = Number of subplots where species i per hectare; $\sum F$ = Sum of occurrences of all species across subplots.
Dominance	$Dr = [\sum Bi / \sum AB] \times 100$	Dr = Relative dominance of species i; Bi = Basal area of species i; $\sum AB$ = Total basal areas of the plot.
Basal area	$AB = [\pi/4] \times [DBH]^2$	AB = Absolute basal area; DBH = Diameter at Breast Height.

10–20 cm, 20–30 cm). This distribution was used to identify successional patterns and the regenerative capacity of the forest community (Prodan et al., 1997).

Vertical Structure (Sociological Position)

The vertical organization was characterized by subdividing the vegetation into three uniform strata—Lower, Middle, and Upper—based on the maximum total height recorded in each sampling plot (Lamprecht, 1990). The predefined height categories for these strata are detailed in Table 2.

To determine the Absolute (PSa) and Relative Sociological Position (PSr), we followed the method proposed by Finol (1976). This approach assigns a phytosociological value to each substratum (VFe) based on individual density, as described in Table 3. This analysis enables a quantitative assessment of species distribution across the different canopy layers (Acosta et al., 2006).

2.4 Statistical analysis

Data processing and statistical analysis were performed using R software version

4.4.2 (R Core Team, 2025), via the RStudio interface. We employed the tidyverse collection of packages, specifically dplyr and tidyr, for data cleaning, consistency checks, and structural manipulation (Wickham et al., 2019).

The Importance Value Index (IVI), diametric distribution, and sociological position data were organized into comparative matrices for PSP-1 and PSP-2. For data visualization, we utilized the ggplot2 package to generate: (i) rank-abundance bar graphs for IVI values, (ii) frequency histograms for 10 cm diameter classes, and (iii) stacked bar charts to illustrate species distribution across vertical strata. These quantitative procedures ensured a robust diagnostic of forest architecture.

3. RESULTS

Floristic Composition and Diversity

A total of 1,235 individuals were identified in the BRUNAS Reserved Forest. In PSP-1 (lowland), we recorded a richness of 113 species distributed across 41 families. In PSP-2 (highland), the richness was 114

Table 2. Categorias predefinidas com base na altura total e PSP
Tabela 2. Predefined categories based on total height and PSP

PSP	Stratum	Category
1	Lower (height < 1/3 of the upper height)	Less than 12.98 m
	Middle (between 2/3 and 1/3 of the upper height)	Between 12.98 m and 25.96 m
	Upper (height > 2/3 of the upper height)	Greater than 25.96 m
2	Lower (height < 1/3 of the upper height)	Less than 19.55 m
	Middle (between 2/3 and 1/3 of the upper height)	Between 19.55 m and 39.09 m
	Upper (height > 2/3 of the upper height)	Greater than 39.09 m

Table 3. Mathematical expression and description of elements for sociological position
Tabela 3. Expressão matemática e descrição dos elementos para a posição sociológica

Indicator	Mathematical Expression	Description of Elements
Phytosociological value of the substratum (VFe)	$VFe = ne/N$	n = individuals in the substratum; N = Total number of individuals of all species; e = Species.
Absolute sociological position (PSa)	$PSa = VFe(i) * n(i) + VFe(m) * n(m) + VFe(s) * n(s)$	n = individuals of each species; i = lower; m = middle; s = upper.
Relative sociological position (PSr)	$PSr = PSa/\Sigma PSa$	PSr = Relative sociological position; PSa = Absolute sociological position.

species belonging to 39 families. The family with the highest species richness was Fabaceae, followed by Euphorbiaceae and Moraceae. The Shannon-Wiener diversity index (H') was 4.12 for PSP-1 and 3.98 for PSP-2, reflecting high floristic complexity. The Pielou evenness index (J') reached 0.87 and 0.84, respectively. These values demonstrate that the forest remnants maintain high diversity and a balanced distribution of individuals, despite the significant ecological dominance of certain species in the highland plot.

Horizontal Structure: Importance Value Index (IVI)

The analysis of the Importance Value Index (IVI) (Figure 2) showed that the ten most ecologically important species account for 55.04% of the total IVI in both plots.

In PSP-1, the forest was dominated by *Parkia panurensis* H.C Hopkins (Fabaceae) with an IVI of 10.24%, followed by *Senefeldera inclinata* Müll. Arg. (Euphorbiaceae) (5.5%) and *Casearia ulmifolia* Vahl (Salicaceae) (5.3%).

In PSP-2, the dominance of *S. inclinata* was more pronounced, reaching an IVI of 16.36%. It was followed by *Pourouma minor* Benoist (Urticaceae) (5.39%) and *Cedrelinga cateniformis* (Ducke) Ducke (Fabaceae) (3.71%). Other relevant species in this plot included *Hevea guianensis* Aubl. (Euphorbiaceae) (3.64%) and *Otoba parvifolia* (A.DC.) A.H. Gentry (Myristicaceae) (3.62%) (Figure 2).

Diametric Structure

The diametric distribution in both plots followed the "inverted J" pattern (Figure 3), indicating active natural regeneration. In PSP-1, 85.55% of the individuals (581 trees) were concentrated in the smaller diameter

classes (10–30 cm). In PSP-2, a similar trend was observed with 76.4% of the individuals (424 trees) within the same range.

The highest concentration of individuals occurred in the first diameter class [10–20 cm], representing 59.7% of the total in PSP-1 and 50.1% in PSP-2 (Figure 3). The number of individuals decreased progressively as diameter increased, with very few trees reaching classes greater than 60 cm, which is typical of these Amazonian transition forests.

Vertical Structure and Sociological Position

The vertical organization revealed a high density of individuals in the lower and middle strata (Table 4). In PSP-1, *P. panurensis* achieved the highest Relative Sociological Position (PSr = 20.59%), with 48 individuals in the middle stratum and 12 reaching the upper canopy.

In PSP-2, *S. inclinata* showed an absolute dominance in the vertical profile (PSr = 88.46%), being present with 99 individuals in the lower stratum and 65 in the middle stratum (Table 4). Species like *P. minor* and *H. guianensis* showed a more homogeneous vertical occupation, appearing in all three strata, which suggests a high capacity to occupy different light conditions in the forest profile (Figure 4).

4. DISCUSSION

The high species richness recorded in the BRUNAS forest remnants is consistent with the high biological diversity reported for the Peruvian Amazon. Our results align with Alvarez-Montalván et al. (2021), who emphasize that these transition forests maintain significant complexity despite historical fragmentation. The Shannon-Wiener index values ($H' > 3.9$) and Pielou

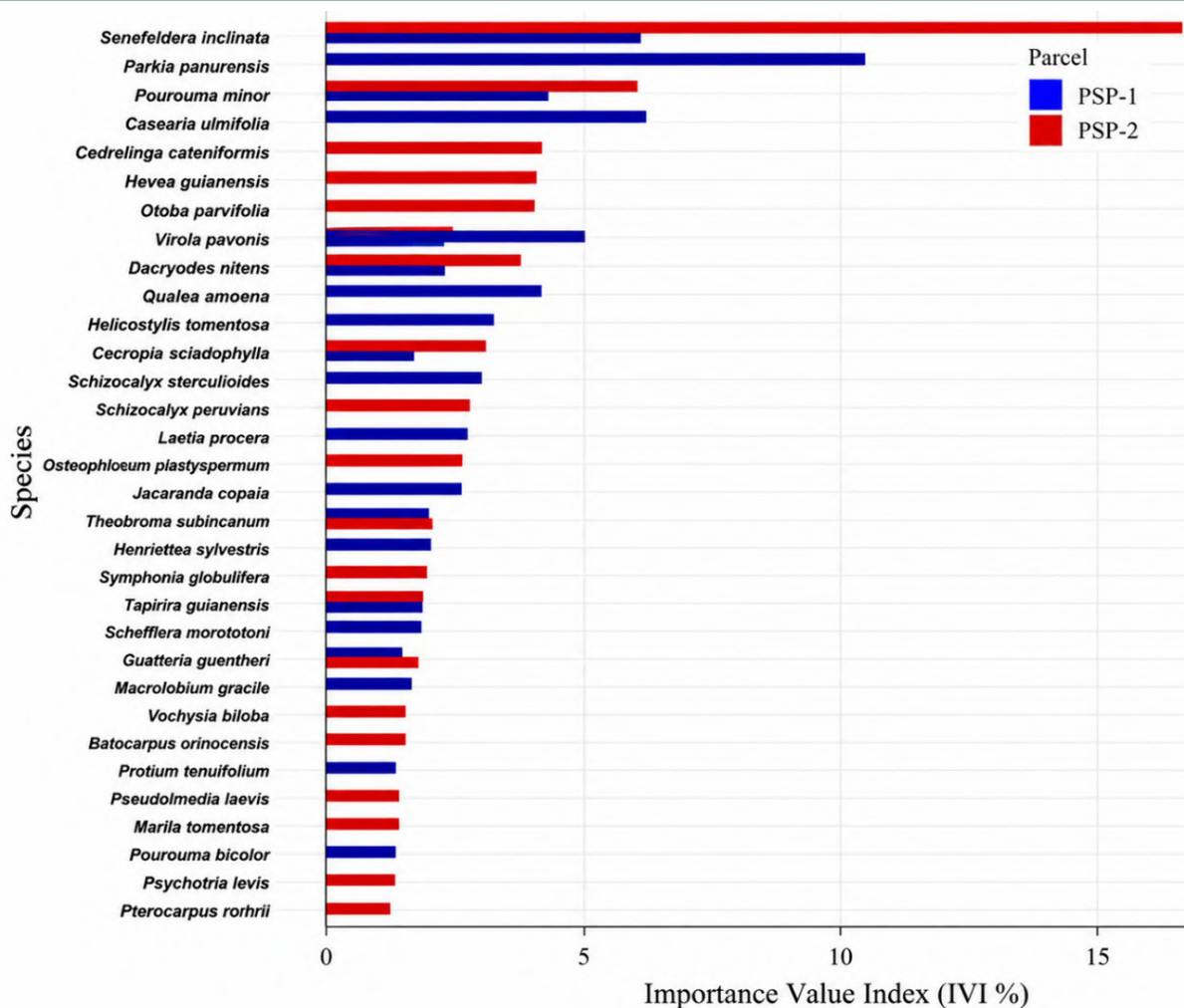


Figure 2. IVI of woody species in PSP-1 and PSP-2 (inclusion criteria: DBH $\geq$ 10 cm)
Figura 2. IVI das espécies lenhosas no PSP-1 e PSP-2 (critério de inclusão: DAP $\geq$ 10 cm)

evenness ($J' > 0.8$) suggest a balanced community structure, typical of well-preserved remnants where a few species do not absolutely overwhelm the system, a phenomenon described as "oligarchic dominance" by Hofhansl et al. (2019).

A notable ecological pattern was the contrasting dominance between the two plots, with *Parkia panurensis* prevailing in PSP-1 and *Senefeldera inclinata* in PSP-2. This variation is likely driven by edaphic properties and topographic position, as suggested by Bañares-de-Dios et al. (2022), who state that soil gradients are primary drivers of floristic composition in tropical forests.

The dominance of *S. inclinata* in the highland plot can be explained by its functional attributes: it acts as a late-successional species with high capacity for

shade tolerance in its early stages, allowing it to dominate the lower and middle strata. In contrast, *P. panurensis* functions as a large canopy tree that requires more light, explaining its importance in the lowland plot where the canopy might be more dynamic.

The vertical organization of the BRUNAS forest is characterized by a high density of individuals in the lower and middle strata. This structure is typical of recovering tropical forests in the Peruvian Amazon, where vertical complexity increases as the forest matures after past disturbances (Gutiérrez Huamán et al., 2021).

Species such as *Pourouma minor* and *Hevea guianensis* demonstrated a plastic ecological strategy by occupying all three vertical strata. According to Hofhansl et al. (2019), such species possess functional traits including specific wood density and leaf

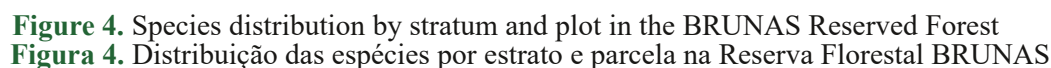
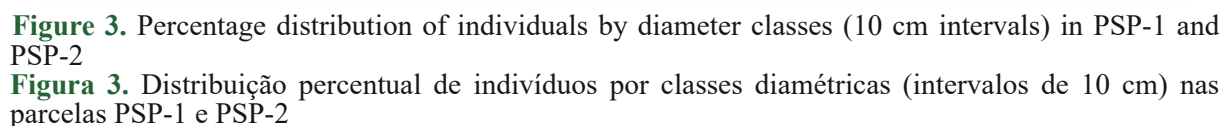


Table 4. Vegetation profile (vertical structure PSP-1 and PSP-2). PSR: Relative Sociological Position. PSP: Permanent Sampling Plot. Vfi: Lower Phytosociological Value. VFm: Middle Phytosociological Value. VFs: Upper Phytosociological Value

Tabela 4. Perfil da vegetação (estrutura vertical PSP-1 e PSP-2). Vfi: Valor Fitossociológico Inferior. VFm: Valor Fitossociológico Médio. VFs: Valor Fitossociológico Superior

Species	PSP	Lower Stratum		Middle Stratum		Upper Stratum		PSR	N°/ha
		n°/ha	Vfi	n°/ha	VFm	n°/ha	VFs		
<i>Parkia panurensis</i>	1	4	0.54	48	38.54	12	0.76	20.59	64
<i>Senefeldera inclinata</i>		15	2.01	47	37.74	0	0	19.95	62
<i>Casearia ulmifolia</i>		3	0.40	44	35.33	3	0.19	17.21	50
<i>Pourouma minor</i>		2	0.27	29	23.29	2	0.13	7.48	33
<i>Qualea amoena</i>		3	0.40	28	22.48	2	0.13	6.98	33
<i>Virola pavonis</i>		2	0.27	27	21.68	0	0	6.48	29
<i>Schizocalyx sterculioides</i>		5	0.67	19	15.26	0	0	3.24	24
<i>Helicostylis tomentosa</i>		3	0.40	17	13.65	0	0	2.58	20
<i>Laetia procera</i>		0	0.00	17	13.65	0	0	2.57	17
<i>Dacryodes nitens</i>		1	0.13	12	9.64	0	0	1.28	13
<i>Senefeldera inclinata</i>	2	99	46.53	65	32.18	0	0	88.46	164
<i>Pourouma minor</i>		6	2.82	14	6.93	3	0.10	1.51	23
<i>Schizocalyx peruvianus</i>		13	6.11	4	1.98	0	0	1.15	17
<i>Otoba parvifolia</i>		11	5.17	7	3.47	2	0.07	1.07	20
<i>Cecropia sciadophylla</i>		3	1.41	10	4.95	0	0	0.71	13
<i>Symphonia globulifera</i>		9	4.23	4	1.98	0	0	0.61	13
<i>Psychotria levis</i>		9	4.23	2	0.99	0	0	0.53	11
<i>Theobroma subincanum</i>		8	3.76	3	1.49	0	0	0.46	11
<i>Hevea guianensis</i>		2	0.94	8	3.96	2	0.07	0.45	12
<i>Dacryodes nitens</i>		4	1.88	7	3.47	1	0.03	0.42	12
Other 103 species	1	53	7.10	258	207.17	24	1.51	11.65	335
Other 104 species	2	97	45.59	151	74.75	11	0.37	4.63	259
Total	1	91	12.194	546	438.44	43	2.71	100.00	680
	2	261	122.67	275	136.13	19	0.65	100.00	555

architecture that allow them to transition efficiently from the shaded understory to the illuminated upper canopy. The presence of these taxa across the vertical profile indicates a healthy recruitment process and a stable successional state, as they are capable of maintaining populations under varying light conditions within the forest interior.

The "inverted J" pattern observed in the diametric distribution (Figure 3) confirms that the forest is undergoing active natural regeneration. This recruitment pattern is essential for long-term structural maintenance, as noted by Marcelo-Peña et al. (2007).

The observed decrease in the abundance of certain late-successional or specialist taxa is often a signature of past anthropogenic pressures. In the region of Tingo María, selective logging and agricultural expansion have historically altered forest microclimates. As pointed out by Suárez-R & Vargas-R (2019), such interventions favor pioneer

species at the expense of specialists, which are more sensitive to the edge effects and temperature fluctuations typical of fragmented landscapes. Therefore, the current dominance of species like *S. inclinata* may also reflect a process of floristic homogenization resulting from these historical disturbances.

The structural stability and high diversity found in this study reinforce the role of the BRUNAS Reserved Forest as a vital germplasm reservoir. As highlighted by Bienu et al. (2023), maintaining these structural parameters and species richness is crucial for ecosystem services, including carbon sequestration and the preservation of evolutionary lineages in the face of ongoing climate change.

5. CONCLUSION

The forest structure in the BRUNAS reserved area exhibits a balanced diametric

distribution in an inverted "J" shape, confirming our hypothesis regarding the occurrence of natural regeneration processes and the capacity for self-replacement of the community. The high density of individuals in the lower diameter classes ensures the maintenance of forest architecture despite local environmental pressures. Vertical stratification reveals a well-defined hierarchy, where *Senefeldera inclinata* and *Parkia panurensis* emerge as dominant species in the lower and middle strata, respectively. The sociological position analysis indicates that the forest is not uniform; instead, it presents a complex organization where species competition and niche specialization allow for the coexistence of high biodiversity across different canopy layers. These findings validate the prediction that structural integrity in High Amazonian forest remnants is linked to a vigorous successional state. Consequently, the results provide a quantitative baseline that justifies the conservation of the BRUNAS forest as a strategic representative of Peruvian High Amazon forests.

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AUTHOR CONTRIBUTIONS

Quispe-Janampa, D. P.: Conceptualization, Investigation, Data curation, Formal analysis, Writing – original draft; Guerrero-Vejarano, T. E.: Investigation, Formal analysis, Writing – original draft; Cruz, R. G. P. de la: Data curation, Formal analysis, Writing – original draft, Writing – review & editing; Santos-Flores, C.: Investigation, Data curation, Formal analysis, Writing – original draft; Daza-Panduro, G.: Investigation, Formal analysis, Writing – original draft; Cruz, B. A. C. de la: Investigation, Data curation, Formal analysis, Writing – original draft; Dionisio-Armas, J. A.: Data curation, Formal analysis, Writing – original draft, Writing – review & editing; Portal-Cahuana, L. A.: Investigation, Formal analysis, Writing – review & editing.

DATA AVAILABILITY

The entire dataset supporting the findings of this study has been published within the article.

7. REFERENCES

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