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Article

Estructura y composición florística de bosques asociados a especies de *Theobroma* en la Amazonía colombiana

Structure and floristic composition of forests associated to *Theobroma* species in the Colombian Amazon

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Resumen

Conocer estructuralmente el bosque permite entender la relación natural entre especies nativas y silvestres del género Theobroma; sin embargo, resulta escasa la información sobre el particular en regiones tropicales. El objetivo del presente trabajo fue evaluar la estructura, composición y diversidad de bosques asociados a los taxones silvestres de Theobroma en la Amazonía Colombiana. Se establecieron cinco parcelas circulares de 25.24 m de diámetro (500 m2) en el municipio Cartagena de Chairá departamento del Caquetá y en el municipio Puerto Leguízamo, departamento de Putumayo. Asociados a especies silvestres de Theobroma en la Amazonía Colombiana se registraron 190 individuos, distribuidos en 35 familias, 85 géneros y 123 especies. Las familias con mayor índice de valor de importancia fueron Moraceae (41.04), Fabaceae (37.31), Myristicaceae (34.33), Malvaceae (26.53), Burseraceae (24.67), Lecythidaceae (17.07), Lauraceae (13.47) y Rubiaceae (12.40); en cuanto a las especies destacaron por su IVI Iryanthera laevis, Brosimum cf. potabile, Eschweilera albiflora, Iryanthera crassifolia, Neea parviflora, Theobroma glaucum y Parinari campestri. Los valores de diversidad de Shannon mostraron que los bosques de El Guamo y La Cocha presentan un alto grado de diversidad (3.58 y 3.51, respectivamente). Los índices fitosociológicos y de valor de importancia permitieron identificar cuatro taxones arbóreos sobresalientes: Iryanthera laevis, Brosimum cf. potabile, Eschweilera albiflora e Iryanthera crassifolia; los cuales de alguna manera representan un potencial para la conservación de materiales criollos de cacao.

Palabras clave: Composición florística, distribución diamétrica, estructura, índices de diversidad, índice de valor de importancia (IVI), Theobroma.

Abstract

The objective of this work was to evaluate the structure, composition and biodiversity of forests associated with wild species of Theobroma in the Colombian Amazon. Five circular plots with a diameter of 25.24 m (500 m2) were established in the municipality of Cartagena de Chairá department of Caquetá, and in the municipality of Puerto Leguizamo, department of Putumayo. 190 individuals associated to wild Theobroma species were registered in the Colombian Amazon, distributed in 35 families, 85 genera, and 123 species. The most representative species found were Iryanthera laevis, with 8 individuals; Brosimum cf. potabile, with 7 individuals; Eschweilera albiflora, with 6 individuals; Iryanthera crassifolia, with 5 individuals, and Neea parviflora, Theobroma glaucum and Parinari campestris, with 4 individuals each. Of the 35 families found in the study area, the most representative for their IVI were Moraceae (41,04), Fabaceae (37.31), Myristicaceae (34.33), Malvaceae (26.53), Burseraceae (24.67), Lecythidaceae (17.07), Lauraceae (13.47), and Rubiaceae (12.40). The diversity index of Shannon (H) exhibited the following values for the established plots: Palmichales (3.38), El Jordán (3.16), El Guamo (3.58), Las Vegas (3.34), and La Cocha (3.51). Shannon's diversity values showed that the forests of El Guamo and La Cocha have a high degree of diversity (3.58 and 3.51 respectively). The phytosociological and importance value indices allowed the identification of four outstanding tree species Iryanthera laevis, Brosimum cf. potabile, Eschweilera albiflora and Iryanthera crassifolia, which somehow represent a potential for the conservation of native cocoa materials.

Key words: Floristic composition, diameter distribution, importance value index (IVI), diversity indexes, structure, Theobroma.

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Introduction

The Colombian Amazon is considered one of the regions with the greatest biodiversity and endemism in the world (Ter Steege *et al.,* 2013). This species diversity in tropical rainforests is fundamental to their functioning, resilience and ability to provide goods and services (Gómez *et al.*, 2018). However, cattle ranching, illicit crops and illegal logging have caused deforestation at an unprecedented rate in Colombia, which significantly affects plant diversity (Gómez *et al*., 2018, González-Orozco *et al*., 2020).

The forests of the Amazon are characterized by their great floristic and faunal richness and for harboring a wide variety of timber and non-timber forest products of immense value (González-Orozco *et al*., 2020). Information on the floristic structure and composition is an important tool for the evaluation of a forest's potential and the definition of management strategies (Mena *et al.*, 2020). This is obtained through certain parameters such as diversity, frequency, density, dominance, diametric and spatial distribution, which show the development of the forests (Dionisio *et al.*, 2016).

Within this context, it is valuable to know the forest structurally in order to understand the natural relationship of native species with wild species of the *Theobroma* genus. Currently, there are some biodiversity studies involving different taxa of *Theobroma*, including *Theobroma cacao* L. "cultivated species" (Sánchez *et al.*, 2016); *Theobroma grandiflorum* (Wild. ex Spring) Schum (Peña and Alegre, 2017), and *Theobroma subincanum* Mart (Vela, 2019). However, in tropical regions, information on the relationships between them (Gómez *et al.*, 2018) and native species of forests, in this case those of the *Caquetá* and *Putumayo* regions, is scarce.

The objective of this study was to evaluate the structure, composition and diversity of forests associated with wild *Theobroma* species in the Colombian Amazon.

Materials and Methods

Study area

The study was carried out in the municipality of *Cartagena de Chairá*, department of *Caquetá*, where three sampling plots were established in the lower *Caguán* area, particularly in the villages of *Palmichales, El Jordán* and *El Guamo*. Two more plots were established in the *Puerto Leguízamo* municipality, department of *Putumayo*, in *Las Vegas* and *La Cocha* (Figure 1). The study areas in *Caquetá* and *Putumayo* have an altitude that varies between 181 and 228 m. The vegetation corresponds to a tropical rainforest (TRF) (Holdridge, 2000), which formed a natural secondary forest without thinning, subdivided into the following categories: plateau forest (*El Jordán, El Guamo* and *La Cocha*) and plain forest (*Palmichales, Las Vegas*).

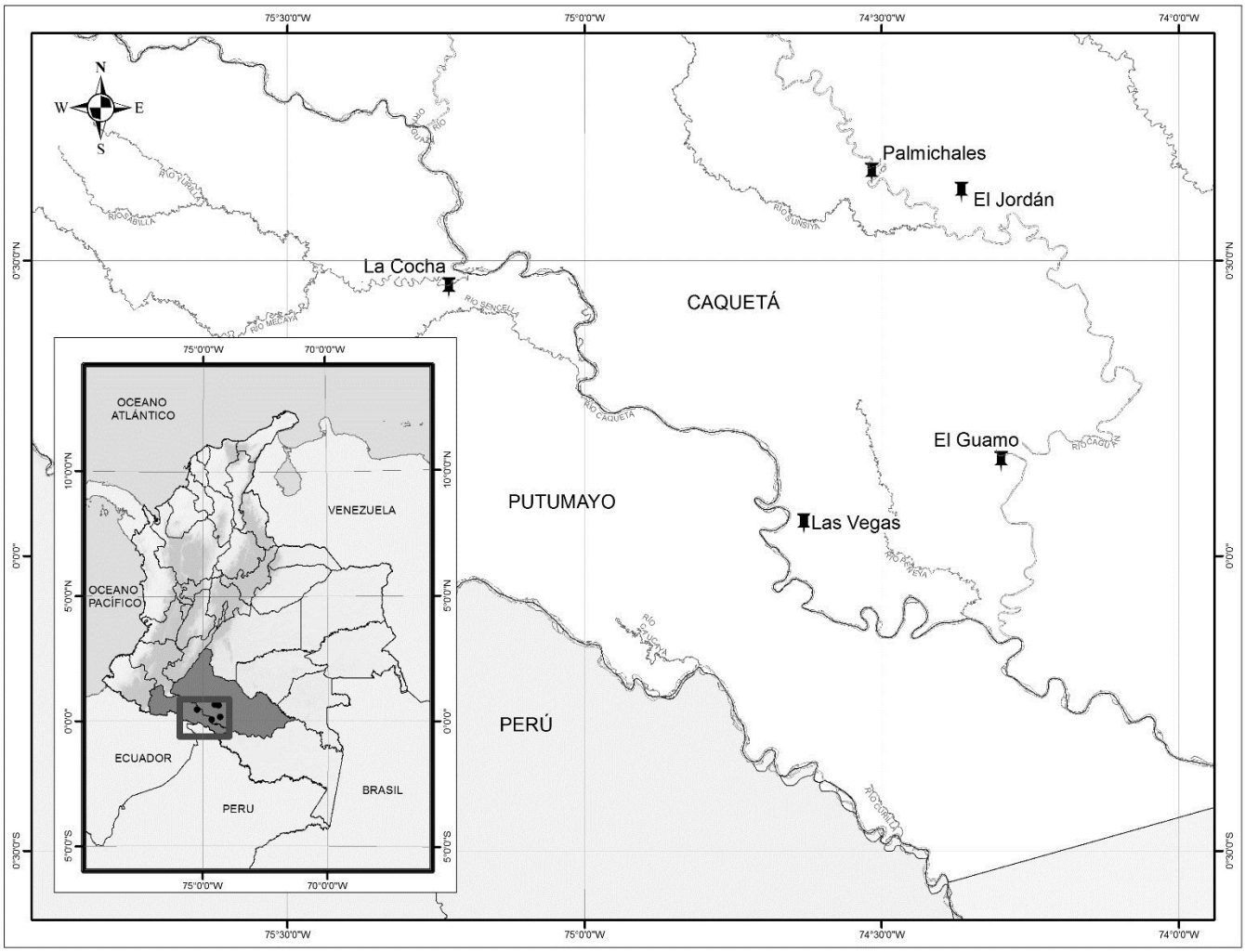

Figure 1. Geographical location of the sampling zones in the departments of *Caquetá* and *Putumayo*.

In the *Caquetá* and *Putumayo* region, the average annual temperature ranges between 24 and 26 °C. The average annual precipitation corresponds to the range of 3 300-3 600 mm; in a monomodal regime, with a period of low precipitation from the beginning of November to mid-February and an increase in rainfall from mid-March to the end of October. Relative humidity in the area varies between 78 and 87 % (González-Orozco *et al*., 2020).

Sampling methods

The sampling sites were selected by locating species of the genus *Theobroma* that grow in their natural conditions. These specimens were considered as the central axis for the establishment of five circular plots of 25.24 m in diameter (500 m^2), based on the methodology adapted from Barreto *et al*. (2018). At the sampling sites, all tree individuals with a diameter at breast height (*DBH*) larger than ≥ 10 cm were inventoried; this diameter was measured with a Forestry Suppliers diameter tape, and total height (m), with a Suunto Pm-5 hypsometer.

Samples of young branches, leaves, flowers, and fruits of the species present in the area were collected (Avendaño-Arrazate *et al*., 2021). The collected material was identified in the Herbarium of the Natural History Museum of *Unidades* with the support of the Colombian Amazon Herbarium (COAH) of the *Instituto de Investigaciones Amazónicas* (Amazonian Research Institute– SINCHI).

Floristic composition and diversity

Based on primary information, the plots were floristically characterized in order to identify composition of the species and analyze their horizontal and vertical structure. The number of individuals was quantified, and the family, genus and species to which they belonged was determined (Cano and Stevenson, 2009).

Horizontal structure

The horizontal structure was analyzed based on the abundance, frequency and dominance discriminated by their absolute and relative values (Mena *et al*., 2020). Based on these variables, the Importance Value Index (IVI) was calculated as the sum of the parameters expressed as a percentage of abundance, frequency, and relative dominance (Avendaño-Arrazate *et al*., 2021).

Floristic diversity was determined using Shannon's richness index (*H'*), the inverse Simpson index (*1/D*) —which means that the diversity trend should be interpreted with higher values of the index—, and Margalef's structural index of diversity. The Jaccard similarity index (*J*) was calculated in order to compare the floristic composition or the similarity between fragments (Magurran, 1988).

Vertical structure

An analysis of the distribution of diameter and height was carried out based on the distribution in diameter and altimetric classes (Manzanilla *et al.*, 2020). Subsequently, the vertical stratification reflecting the distribution of canopies in the vertical profile was analyzed with respect to native cocoa trees, based on the

International Union of Forest Research Organizations (IUFRO) methodology; the species present were distributed into three strata: upper stratum, with a total height range greater than or equal to 10 m; middle stratum, with a height of 6 to 10 m, and lower stratum, with less than 6 m in height. Once the stratification was consolidated, the values and phytosociological position were calculated using the formulas shown in Table 1.

Table 1. Phytosociological indicators (Jerez *et al.,* 2011).

Indicator	Formula	Description
Phytosociological value	$PV = \frac{n}{N}$ (a)	*PV* = Phytosociological value *n* = Number of individuals in the substratum *N* = Total number of individuals of all species.
Absolute sociological position of the species	$ASP = PV(l) * n(l) + PV(m) * n(m) + PV(h) * n(h)$ (b)	*ASP* = Absolute sociological position of the species *PV* = Phytosociological value of the sub-stratum *N* = No. of individuals of each species *l* = Lower *m* = Medium *h* = Higher
Percentage sociological position of the species	$\%SP = ASP/\Sigma ASP$ (c)	*%SP* = Percentage sociological position of the species *ASP* = Absolute sociological position of the species *ΣASP* = total sum of absolute values

Results and Discussion

Floristic composition

Horizontal structure. 190 individuals, distributed into 35 families, 85 genera and 123 species, were registered in the five sampling plots established in *Caquetá* and *Putumayo*. The families with the highest number of taxa were Moraceae, Fabaceae, Myristicaceae, Malvaceae, Burseraceae, Lauraceae and Rubiaceae, which together accounted for 56 % of the total number of inventoried trees (Table 2).

Table 2. Dominant families based on the Importance Value Index (IVI), number of genera, species and individuals in plots in *Caquetá* and *Putumayo*, Colombian Amazon.

Family	Genus	Species	Individuals	IVI 300 %
Moraceae	7	10	18	41.04
Fabaceae	6	13	17	37.31
Myristicaceae	5	9	25	34.23
Malvaceae	6	10	15	26.53
Burseraceae	5	9	14	24.67
Lecythidaceae	2	4	12	17.07
Lauraceae	6	9	9	13.47
Rubiaceae	7	8	10	12.40
Urticaceae	4	6	7	11.77
Sapotaceae	3	7	7	11.03
Subtotal	51	85	134	229.52
Remaining families	35	38	56	70.48
Overall total	85	123	190	300

In a similar way to the present research, studies of landscape vegetation in the Colombian Amazon cite Moraceae, Rubiaceae, Burseraceae, Fabaceae and Lauraceae among the families with the largest number of species (Cano and Stevenson, 2009; Meza and Armenteras, 2018). One of the most important families

in the tropical forests of the Brazilian Amazon is Fabaceae, which in many cases has the largest number of species; other important families are Lauraceae, Sapotaceae, and Lecythidaceae (Carim *et al.*, 2013). In the *Caquetá* and *Putumayo* plots, Fabaceae was the best represented family, with 13 species; it stood out with the highest number of genera (6) and had the second value in ecological importance after the Moraceae family (Table 2).

An analysis of the family IVI by plot showed that Fabaceae stood out among the six most important families for the five plots under study and registered the highest IVI in three of them (P1-*Palmichales*, P3-*El Guamo* and P4-*Las Vegas*). The taxon with the largest number of species belonged to the *Inga* genus. In the evaluation of the tree composition of taxa associated with *Criollo cacao* in secondary forests in Mexico and the Amazonian zone of Brazil and Ecuador, Fabaceae has been identified as one of the botanical families with most species (Roa *et al.,* 2009; Veiga *et al*., 2015; Paredes *et al.,* 2020; Avendaño-Arrazate *et al*., 2021; Imaña *et al.,* 2021).

Iryanthera laevis Markgr, with eight individuals; *Brosimum* cf*. potabile* Ducke, with seven individuals; *Eschweilera albiflora* (DC.) Miers, with six individuals; *Iryanthera crassifolia* A.C.Sm., with five individuals, and *Neea parviflora* Poepp. & Endlicher, *Theobroma glaucum* H. Karst. and *Parinari campestris* Aubl., with four individuals each, were the most representative due to their abundance. *Iryanthera laevis*, *Ficus trigona* L.F, *Brosimum* cf*. potabile*, *Theobroma subincanum* Mart, and *Eschweilera albiflora* exhibited the highest importance value (Table 3).

Table 3. Horizontal structure of the main forest stands in plots in *Caquetá* and *Putumayo*, Colombian Amazon.

Species	AA	AR	AF	RF	AD	DR	IVI
Iryanthera laevis Markgr.	8.00	4.21	4.00	2.50	0.47	5.89	12.60
Ficus trigona L. F	1.00	0.53	1.00	0.63	0.85	10.57	11.72
Brosimum cf. *potabile* Ducke	7.00	3.68	3.00	1.88	0.42	5.19	10.75
Theobroma subincanum Mart.	3.00	1.58	3.00	1.88	0.42	5.17	8.63
Eschweilera albiflora (DC.) Miers	6.00	3.16	3.00	1.88	0.28	3.47	8.51
Inga cf. *nobilis* Willd.	1.00	0.53	1.00	0.63	0.46	5.69	6.85
Iryanthera crassifolia A.C.Sm.	5.00	2.63	4.00	2.50	0.05	0.58	5.71
Inga acreana Harms	2.00	1.05	1.00	0.63	0.32	3.99	5.67
Inga sp.6	1.00	0.53	1.00	0.63	0.33	4.15	5.31
Trattinickia rhoifolia Willd. ex Spreng.	1.00	0.53	1.00	0.63	0.32	4.03	5.19
Neea parviflora Poepp. & Endlicher.	4.00	2.11	3.00	1.88	0.08	0.95	4.93
Theobroma glaucum H. Karst.	4.00	2.11	3.00	1.88	0.06	0.78	4.76
Pseudolmedia laevis (Ruiz & Pav.) J.F Macbr.	2.00	1.05	2.00	1.25	0.18	2.20	4.50
Astrocaryum standleyanum L.H.Bailey	3.00	1.58	3.00	1.88	0.08	0.94	4.39
Parinari campestris Aubl.	4.00	2.11	2.00	1.25	0.08	1.00	4.36
Protium sp.1	2.00	1.05	2.00	1.25	0.16	1.96	4.26
Eschweilera coriacea (DC.) S.A. Mori	2.00	1.05	2.00	1.25	0.15	1.87	4.17
Euterpe precatoria Mart.	3.00	1.58	2.00	1.25	0.08	0.96	3.79
Bursera inversa Daly	2.00	1.05	2.00	1.25	0.11	1.31	3.61
Virola calophylla (Spruce) Warb.	3.00	1.58	2.00	1.25	0.06	0.77	360
Subtotal	63	33.7	45	28.18	4.96	61.47	123.31
Remaining species	126	67	115	72	3	39	177
Overall total	190	100	160	100	8	100	

AA = Absolute abundance; AR = Percentage of individuals/Species; AD = Absolute dominance; DR = Basimetric area ratio/Species; AF = Absolute frequency; RF= Relative frequency; IVI= Importance Value Index of the species.

When comparing the species between plots, a difference was observed between the study sites, where the plots P1-*Palmichlaes*, P2-*El Jordán*, and P3-*El Guamo* (*Caquetá*) shared the species with a higher IVI than those of *Brosimum* cf. *potabile* and *Iryanthera laevis*, which were not representative of P4-*Las Vegas* or P5-*La Cocha*, two sites that are part of a different geographic region (*Putumayo*). In the P3-*El Guamo* and P5-*La Cocha* plots, they were recorded among the five species with an IVI above that of *Eschweilera albiflora*.

Three *Theobroma* species were identified —*Theobroma subincanum* Mart, *Theobroma glaucum* H. Karst, and *Theobroma obovatum* Klotzch ex Bernoulli—, with three, four and one individual, respectively; *Theobroma subincanum* and *Theobroma glaucum* were common to plots 1 and 5. *Theobroma subincanum* stood out as one of the top five species with the highest index of importance (8.63) in the study areas. In a research study on the diversity and distribution of wild relatives of cocoa in Colombia, González-Orozco *et al*. (2020) point out that the variation of microenvironments in the Amazon landscape promotes the presence of certain *Theobroma* taxa, such as those observed in the present study; this is partly related to the hydrological conditions in the Amazonian rivers as strong drivers of wild *Theobroma cacao* distribution.

Floristic diversity

The Shannon diversity index (*H*) for *Palmichales* was 3.38; for *El Jordán*, 3.16; for *El Guamo*, 3.58; for *Las Vegas*, 3.4, and for *La Cocha*, 3.51 (Table 4). The evenness analysis was evaluated using the inverse Simpson index (*1/D*), whose value was 0.97 for *Palmichales*, 0.95 for *El Jordán*, 0.97 for *El Guamo*, 0.96 for *Las Vegas*, and 0.97 for *La Cocha.* According to the results, there was high diversity in all the

sampled communities, due to the high number of species. As for the Margaleff index, all the plots registered values above 5, which suggests that they are highly diverse forests; those of *El Guamo* (9.72) and *La Cocha* (9.34) were outstanding.

Table 4. Comparison of alpha diversity, species richness and diversity between plots in *Caquetá* and *Putumayo*, Colombian Amazon.

	Palmichales	***El Jordán***	***El Guamo***	***Las Vegas***	***La Cocha***
Species	30	27	38	30	35
Individuals	32	36	45	39	38
Dominance_*D*	0.035	0.050	0.030	0.037	0.031
*Simpson*_1-*D*	0.964	0.949	0.969	0.962	0.968
*Shannon*_ *H'*	3.379	3.160	3.579	3.344	3.514
Menhinick	5.303	4.500	5.665	4.804	5.678
Margalef	8.368	7.255	9.720	7.916	9.347
Evenness_*J*	0.993	0.958	0.984	0.983	0.988

In the Amazonian tropical forest, Lima *et al.* (2019) document that the Shannon Diversity Index is (*H'*=3.57) and the evenness index is (*J*=0.79); therefore, the studied forest has a good diversity. According to authors like Condé and Tonini (2013) and Carim *et al.* (2013), the values for the Shannon diversity index are low compared to those registered in tropical forests in other Amazonian regions such as *Roraima* in Brazil. This is due to the dominance of certain species and to a low floristic similarity at the genus level.

According to Prieto and Arias (2007), the high floristic diversity of the Colombian Amazon is based on the dominance of a few taxonomic groups that make up most of the wealth of species, as evidenced by the analysis of the dominance of families, which showed that 28.5 % of the families represented 69. 1% of the wealth of species.

In the mature forest, high alpha diversity indices were observed; this is characteristic of the upper part of the Amazonian bio-region, where the world's greatest wealth of tree species is registered.

The Jaccard similarity index indicated that the most similar plots were those of *Palmichal* and *El Jordán*, as well as *Palmichal* and *El Guamo*. While the *La Cocha* plot showed the greatest dissimilarity compared to the other plots, the Jaccard similarity index indicated that the *Palmichal* and *El Jordán* plots were the most similar (Table 5).

Table 5. Jaccard index for the five plots established in *Caquetá* and *Putumayo*, Colombian Amazon.

Similarity	Jaccard index
Palmichal and *El Jordán*	0.140
Palmichal and El Guamo	0.133
Palmichal and *Las Vegas*	0.053
Palmichal and *La Cocha*	0.121
El Jordán and *El Guamo*	0.121
El Jordán and *Las Vegas*	0.018
El Jordán and *La Cocha*	0.107
El Guamo and *Las Vegas*	0.046
El Guamo and *La Cocha*	0.090
Las Vegas and *La Cocha*	0.016

The plots with the highest Jaccard index were those that shared the geographical area of *El Cartagena de Chairá* in *Caquetá*. On the other hand, the lowest rates were obtained in *Las Vegas* and *La Cocha;* although these are part of the same geographical area (*Putumayo*), they belong to two different forest types: Plain Forest and Plateau Forest, respectively. Another low index was recorded in *El Jordán* and *Las Vegas*, two plots that differ both in geographic location and forest type. These behaviors are associated with agro-climatological and geological conditions such as relief, climate and soil changes, among others, which have an influence on the behavior of the vegetation, since they influence the development of high levels of species and habitat richness, associated with high biodiversity estimates for the Amazonian Forest region (Cárdenas, 2014; Andrade *et al*., 2017).

Vertical structure

Diameter distribution. In the *Caquetá* and *Putumayo* plots, the histogram of diameter distribution showed that individuals predominate in the first three diameter classes, representing 86 % of the total. It was determined that the species with the highest diametric class were *Ficus trigona* L.F, *Inga* cf*. nobilis* Willd, *Trattinickia rhoifolia* Willd. ex Spreng, and *Iryanthera laevis* (Figure 2).

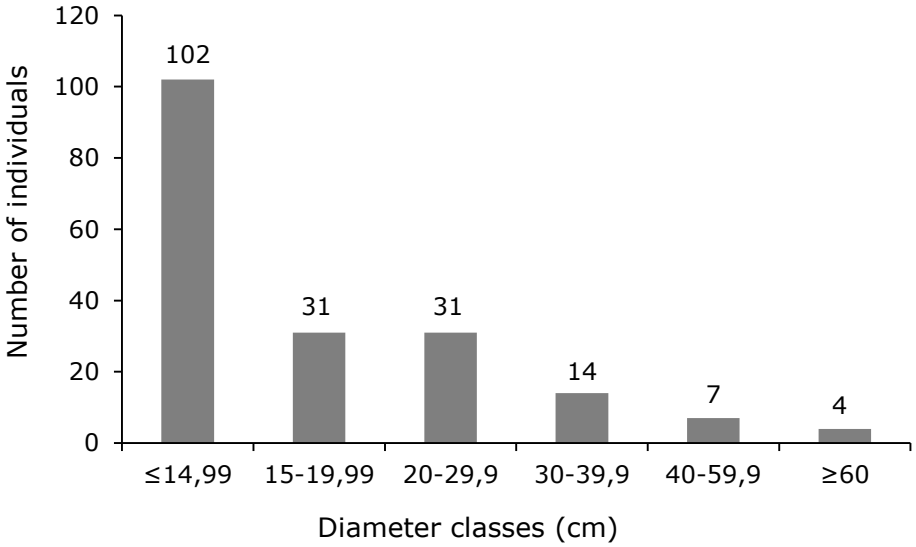

Figure 2. Diametric classification of individuals in plots in *Caquetá* and *Putumayo*, Colombian Amazon.

The behavior observed in the diameter distribution is similar to that cited by Paredes *et al.* (2020) in a tropical forest in Ecuador, where the secondary forest structure was observed to be largely represented by small-stemmed trees and tended to accumulate fast-growing woody plant species (pioneer species). The first diameter classes included the largest number of individuals, which denotes a dynamic of mortality and recruitment that is important for regeneration within the forest, since the species present in the lower diameter classes are part of a process of taxon turnover that originates other successional stages, evidencing a sustained balance between individuals that die and those that grow (Rodríguez and Brenes, 2009; Veiga *et al*., 2015).

Altimetric distribution. In *Caquetá* and *Putumayo*, the individuals were distributed into six altitudinal classes; 60 % of the individuals (115) were concentrated in the middle stratum, with heights of less than 15 m (Figure 3).

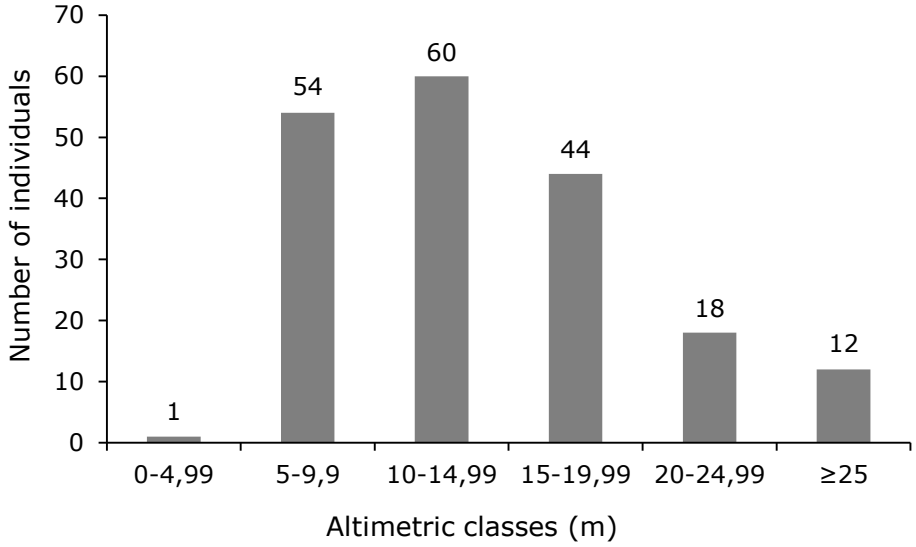

Figure 3. Altimetric classification of individuals in plots in *Caquetá* and *Putumayo*, Colombian Amazon.

The altimetric distribution coincides with the behavior for the Amazonian region reported by other authors. Lima *et al*. (2019) point out that in a dense shade forest in the eastern Amazon, 69 and 57 % of the species occurred in the middle stratum, with heights varying from 13.5 to 23.5 m. Dionisio *et al*. (2016) in a dense forest in the state of Roraima recorded 70.29 % of individuals in the middle stratum; Condé and Tonini (2013) in a forest of the same state obtained similar percentages of about 71.3 % in the middle stratum. In *Rondonia*'s forests, Andrade *et al*. (2017) cite a distribution of individuals with heights of less than 20 m that is characteristic of young forests and which guarantees the continuity of species within the forest structure.

In the assessment of the phytosociological position of the species present in the *Caquetá* and *Putumayo* plots, the following stood out as the most important: *Iryanthera laevis* (4.420), *Brosimum* cf*. potabile* (4.180), *Eschweilera albiflora*

(3.523), *Iryanthera crassifolia* (2.867), *Parinari campestris* (1.794), and *Theobroma glaucum* (1.794) (Table 6). Most of the trees of the wild *Theobroma* taxa in the *Caquetá* and *Putumayo* plots of the Colombian Amazon were located in the upper stratum, with heights between 13 and 25 m.

Table 6. Phytosociological position of the main species in plots in *Caquetá* and *Putumayo*, Colombian Amazon.

Species	Lower SP	Medium SP	Higher *SP*	*ASP*	*% SP*
Iryanthera laevis Markgr.	0.000	0.516	4.232	4.747	4.420
Brosimum cf*. potabile* Ducke	0.000	0.258	4.22	4.489	4.180
Eschweilera albiflora (DC.) Miers	0.000	0.258	3.526	3.784	3.523
Iryanthera crassifolia A.C.Sm.	0.000	0.258	2.821	3.079	2.867
Parinari campestris Aubl.	0.000	0.516	1.411	1.926	1.794
Theobroma glaucum H. Karst.	0.000	0.516	1.411	1.926	1.794
Neea parviflora Poepp. & Endlicher.	0.037	0.258	1.411	1.705	1.588
Euterpe precatoria Mart.	0.000	0.258	1.411	1.668	1.553
Lacistema nena J.F.Macbr.	0.000	0.258	1.411	1.668	1.553
Theobroma subincanum Mart.	0.000	0.258	1.411	1.668	1.553
Virola calophylla (Spruce) Warb.	0.000	0.258	1.411	1.668	1.553
Virola elongata (Benth.) Warb	0.000	0.258	1.411	1.668	1.553
Anaxagorea brevipes Benth.	0.000	0.000	1.411	1.411	1.313
Bocageopsis multiflora (Mart.) R.E.Fr.	0.000	0.000	1.411	1.411	1.313
Coussapoa orthoneura Standl.	0.000	0.000	1.411	1.411	1.313
Dialium guianense (Aubl.) Sandwith	0.000	0.000	1.411	1.411	1.313
Eschweilera coriacea (DC.) S.A. Mori	0.000	0.000	1.411	1.411	1.313
Inga acreana Harms	0.000	0.000	1.411	1.411	1.313
Inga japurensis T.D.Penn	0.000	0.000	1.411	1.411	1.313
Maquira coriacea (H.Karst.) C.C Berg	0.000	0.000	1.411	1.411	1.313
Subtotal	0.04	3.87	37.39	41.28	38.44
Remaining species	0.22	8.77	57.11	66.10	61.58
Overall total	0.26	12.64	94.49	107.39	100.01

The phytosociological and importance value indices allowed the identification of five outstanding tree species: *Iryanthera laevis, Brosimum* cf. *potabile, Eschweilera albiflora* and *Iryanthera crassifolia*, which represent a potential for the conservation of wild cocoa materials (*Theobroma* sp). According to Avendaño-Arrazate *et al*. (2018), Criollo cocoa is a genetic resource that has been preserved for many years in environments that are totally isolated from commercial populations, where it develops in coexistence with different species typical of the jungle, in this case the Amazon; studies on the tree composition and structure under natural conditions would favor the issuance of criteria on their habitat and diversity, and the identification of associated forest taxa of importance in their environment. This would contribute to the promotion of its conservation, as well as to know tree species with potential for being implemented as shade in productive systems (Avendaño-Arrazate *et al*., 2021).

Conclusions

In forests associated to *Theobroma* in the Colombian Amazon the most important canopy families are Moraceae, Fabaceae, Myristicaceae, Malvaceae, and Burseraceae; *Iryanthera laevis* stands out for its ecological importance and phytosociological position.

Shannon diversity values vary between 3.16 and 3.58; this shows a high degree of diversity and is related to the Jaccard index, which indicates low similarity between plots, possibly due to geographic differences and to differences in forest types.

Three *Theobroma* species were identified, from which *Theobroma subincanum* stands out for its ecological importance (IVI 8.63), and *Theobroma glaucum*, for its phytosociological position (%SP 1.794).

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Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Jairo Rojas Molina and Pablo Fernando Ramos: design of the study definition of methodology, data analysis, field data collection and writing of the manuscript; Mauricio Andrés Castro, Allende Pesca Moreno, Yeraldine Vargas and Laura Escobar: data analysis, writing, review and correction of the manuscript.

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