Floristic Composition, Structure, and Diversity of a Forest Remnant in the Ecuadorian Chocó: The Case of 'La Montaña'

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Abstract

Floristic composition is a key indicator of a region's biodiversity, as it helps identify the species present, their interactions, and the spatial distribution of plant communities. The objective of this study was to assess the floristic composition, structure, and diversity of vegetation units at the "La Montaña" enclave, circumscribed at the Estación Experimental Tropical Pichilingue, Instituto Nacional de Investigaciones Agropecuarias (INIAP), Los Ríos Province, Ecuador. The 210 ha area was split into 31 parcels (400 m^2 each), where the presence of plants and the diameter and height of trees were analysed. The importance value index (IVI) was calculated on the basis of abundance, dominance, and relative frequency. The plant units were grouped according to floristic and structural similarities. The floristic inventory included a total of 23 botanical families, 55 species and 366 individuals. The families with the most representatives were Moraceae, Malvaceae, Fabaceae, Mimosaceae, and Areaceae. During the study, three vegetation units were identified: forest, swamp, and flood zones. In the forest zone, *Anacardium excelsum* was the dominant species, whereas in the swamp and flood zones, *Erythrina glauca* and *Cecropia pertata*, were the dominant species. The forest zone had the highest diversity of species (H_{SD}= 0.9103, H'= 3.114 and D_{mg}= 8.087), followed by the flood zone (H_{SD}= 0.8724, H'= 2.512 and D_{mg}= 4.348) and the swamp zone (H_{SD}= 0.6923, H'= 1.335 and D_{mg}= 1.228). The floristic inventory provides information about plant biodiversity, which helps in understanding plant structure and arboreal composition.

INTRODUCTION

Biodiversity is the ecosystem's biological richness on which humanity depends (Aguirre, 2019, Suárez et al., 2018, Chimarro et al., 2023). Forests are the largest land ecosystems, occupying 31% of the land surface. Their essential ecological functions include preventing erosion, recycling CO_2 from the air, reducing global warming, regulating rains, contributing to the refilling of aquafers, and preserving biodiversity (FAO, 2020).

Climate change poses challenges for biodiversity, particularly for freshwater ecosystems at high latitudes (He et al., 2019, Reid et al., 2019). On the other hand, the effects of rising temperatures on biodiversity vary extensively among regions (O'Gorman et al., 2019). Jackson et al. (2024) reported that in the analysed regions, the total biomass of invertebrates increased with increasing temperature, suggesting possible compensatory mechanisms. These findings highlight the importance of considering both the diversity of species and biomass when assessing the impact of climate change on the biodiversity of ecosystems. Thus, biodiversity is dependent on climate change.

Primary forests, especially tropical humid forests, presented the highest rates of biodiversity. This biodiversity decreases the more these environments are altered (McDermott, 2024). These ecosystems provide crucial services for human well-being, such as food, weather regulation, and biodiversity preservation (Songliang and Sean, 2021; Barral et al., 2024).

Biodiversity plays an important role in the efficiency and resiliency of ecosystems, with a direct influence on their ability to provide these previously mentioned services (Manzanilla et al., 2020; Neto et al., 2023). Nonetheless, human activities and climate change significantly impact the availability and quality of natural resources. These phenomena threaten the stability of ecosystems and the services they provide (Leal et al., 2020). An integrated approach to ecosystem management is essential for balancing human needs with biodiversity conservation, as it enhances efficiency, resilience, and long-term sustainability (Díaz et al., 2020).

Ecosystems offer a wide range of ecological services to society, both directly and indirectly. Additionally, they serve as sources of natural resources, regulate vital processes, and support essential life-sustaining functions (Manzanilla et al., 2020). Sometimes, they have also been influenced and modelled by ancestral cultures; thus, it is crucial to avoid any alterations to the life cycles they regulate (Machín and Casas, 2006; González, 2015).

Continental Ecuador is home to 91 ecosystems, as identified by the Ecosystem Classification System. Of these, 27 ecosystems are located in coastal regions, comprising 35% of the region's land area. One of these ecosystems is the Bosque Siempreverde Estacional de Tierras Bajas del Chocó Ecuatoriano (Siempreverde Stational Forest of the lowlands of the Ecuadorian Choco), which is found in the northwestern province of Esmeraldas. Historically, however, its extension reached southern Guayas and Los Rios Provinces (MAE, 2013; Cuesta et al., 2015; Rodríguez-Echeverry and Leiton, 2020). However, there has been a decrease in extension due to anthropic activities such as agriculture, livestock, and urban growth (Aguirre et al., 2021a; Aguirre et al., 2021b). This type of forest possesses a remarkable diversity of amphibian, reptile, bird, and mammal species inhabiting various ecological niches (Morrone, 2019).

The diversity of ecosystems and species makes Ecuador one of the world's biodiversity hotspots. It hosts 6% of the world's biodiversity, with only 0.2% of the surface biodiversity (Pitman et al., 2002; Aguirre and Endara, 2016; Barros-Diaz et al., 2023). In Ecuador, the presence of 25,560 plants has been reported, 5,348 of which are endemic, and comprehensive policies and strategies for biodiversity conservation have been established; however, significant challenges remain, particularly in addressing the environmental impacts of mining activities and the need to incorporate social—ecological interactions into biodiversity management. Further progress is essential to mitigate these threats and strengthen conservation efforts (Roy et al., 2018; Mestanza-Ramón et al., 2020).

In the coastal region, agricultural activities dominate the landscape, covering 62% of the territory, according to Cuesta et al. (2015). This high rate of land conversion has led to the remaining ecosystems being distributed as small islands within an anthropogenic landscape characterized by high levels of fragmentation. The province of Los Ríos, located in the central part of the coastal region, is one of the most altered areas in western Ecuador (Aguirre et al., 2018). The primary drivers of this transformation include poorly directed colonization policies supported by laws that promoted deforestation, such as the Agrarian Reform Law in effect until the 2000s; the economic advantages of crops such as bananas, African palm, and cacao over forest use; and weak governmental control over deforestation. These actions have significantly contributed to the loss of forest resources and the degradation of other biodiversity components. This underscores the profound impact that human activities have on the quality of ecosystems.

To reduce this vulnerability and improve the representativeness and protection of local ecosystems, this study assessed the floristic composition, structure, and diversity of the vegetation units in the La Montaña enclave, a remnant of the tropical rainforest in Ecuadorian Chocó, located in Los Ríos, Ecuador.

MATERIALS AND METHODS

Location of the study area

The research was carried out at the "La Montaña" enclave (Fig. 1), circumscribed at the Pichilingue Tropical Experimental Station (EET-Pichilingue), at the National Institute of Agricultural Research (INIAP), Ecuador. Its area measures 210 hectares, located at km 5 of the Quevedo-El Empalme highway, Los Ríos Province (79°28'06" O, 01°05'24" S), at an altitude between 60 and 90 masl.

The EET-Pichilingue has a humid tropical climate, with a precipitation level of 2,178 mm distributed throughout the year, an average temperature of 24°C, 84% relative humidity, irregular topography, and a monthly average of 76 hours of sunlight (INAMHI, 2018). The predominant type of soil is loam, which is formed from young volcanic ash, is fertile and has high moisture retention properties.

Sampling site and floristic inventory

The temporal sample lots measured 20 × 20 m (400 m^2) and were randomly chosen throughout the "La Montaña" enclave. Thirty-one random samples were selected. The variables used were plant height (h), diameter at breast height ($DBH_{1.30 \geq 1.3\ cm}$) and basal area (BA).

The flora was determined by analysing the characteristics of the leaves, flowers, and fruits of the plant species living at the site. They were subsequently compared with the Vascular Plant Catalogue of Ecuador (Jørgensen et al., 1999). The last version of the Angiosperm Phylogeny Group (APG IV, 2016) system was used for botanical identification and taxonomic classification. The scientific names and accepted titles were taken from this guide. Moreover, the World Flora Online database was used to corroborate the information (https://www.worldfloraonline.org/). The characteristic flora from the Siempreverde Seasonal Forest was taken as a reference (MAE, 2013).

Establishing the vegetation units

The plant units were established in homogenous groups of plant communities that were characterized by having similar compositions, structures, and roles in a specific geographic area. By observing the vegetation in the area of study, it was possible to identify and classify the plant units, following ecological and botanical criteria. The mapping was performed through transects of the enclave and the plant units inside it via QGIS 3.14.15 software and the topographic map provided by the Army's Geographic Institute (IGM). Contour lines were also used for this process. The vegetation areas of the ecosystem were then defined on the basis of the vector maps of the ecosystems provided by the Ministry of Environment of Ecuador.

Assessment of structure and diversity

Frequency distribution tables were used to classify families and species. Principal component analysis (PCA) was performed on the data from the dasometric variables (plant height, diameter at breast height and basal area). Clusters analysis (HCA) was performed between the present species by vegetation unit via the Bray—Curtis similarity index. These analyses were carried out via R Development Core Team software (R core Team, 2024).

For each vegetation unit, the relative abundance (RA), frequency (RF), dominance (RD), and importance value index (IVI) were estimated (Manzanilla et al., 2020; Torres et al., 2024). The richness (S), Simpson_1-D index (H_{SD}), Shannon_H index (H'), Margalef index (D_{mg}) and Chao-1 estimator (Daly et al., 2018; Mulya et al., 2021) were also obtained. These analyses were carried out via Past version 4.12 software (Hammer et al., 2001).

RESULTS AND DISCUSSION

Floristic classification and identification

A total of 23 botanical families, 55 species and 366 individuals were registered in the floristic inventory (Fig. 2). The families with the greatest number of species were Moraceae (nine species), Malvaceae (eight species), Fabaceae (seven species), and Areaceae (five species), which represented 17.4% of all the families. There were families with lower representation: Borginaceae and Laureacea, with three species each; and Meliaceae, Mimosaceae, and Ulmaceae, with two species each. On the other hand, there were 14 families (60.9%) with only one species in the La Montaña enclave. The Moraceae, Malvaceae, Fabaceae, and Areaceae had the greatest number of species, which shows how ecologically important the 'La montaña' enclave is because of its adaptability and success in this forest. The area harbors relatively high diversity, which suggests that this is a complex ecosystem with the potential for diverse microhabitats and ecological niches.

This floristic composition was similar to that reported in the lower montane evergreen forest, Zamora Chinchipe Province, Ecuador, which includes 46 species of 35 genera and 20 families; 33 arboreal and 13 shrubby, the most diverse families in the arboreal stratum, were Lauraceae, Melastomataceae, Rubiaceae and Euphorbiaceae; and, in the shrub layer, Lauraceae, Primulaceae, Chlorantaceae and Rubiaceae (Aguirre et al., 2018). This result was similar to that reported by Jadán et al. (2022), who reported that the five most diverse families were Fabaceae (35 species), Moraceae (17 species), Lauraceae (12 species), Rubiaceae (11 species), and Meliaceae (10 species) in the Bosque Protector Chongón Colonche, a lowland mountain range in coastal Ecuadoria. According to Mosquera (2017), in the municipality of Manungará, Tadó, Chocó, Colombia, Rubiaceae, Arecaceae, Moraceae, Melastomataceae, Annonaceae, Clusiaceae, and botanical families, among others, were found. This would classify the forest as a tropical rainforest life zone (bp-T).

Figure 2 shows a chord diagram, with the relationships and distributions of distinct botanical families according to species composition and the transfer of genetic properties, among other possibilities. Each segment of the outer circle represents a different botanical family, such as Moraceae, Ulmaceae, Arecaceae, and others. The number in parenthesis next to each family is the number of taxa (species) that belong to that family. The inner lines represent the lings between different families, and the thickness of the lines represents the magnitude of interactions or the number of shared species. The diverse colors for each segment helped to identify the different families and interactions.

There is an extensive line between the Ulmaceae, Moraceae, and Mimosaceae families, suggesting a potential close phylogenetic relationship or significant ecological interaction between them. It was also observed that families such as Fabaceae and Arecaceae had fewer connections or interactions with each other. The thickness of these lines suggests the intensity or magnitude of the relationship between those families (Fig. 2).

This shows that the two families share a high number of shared species and individuals in the inventory, which implies a close relationship or high proportion in the forest. The results also revealed high equality in terms of the ecological conditions preferred by these families, such as the type of soil, available light, or level of humidity. These conditions allow them to live in the same microhabitats. Similarly, there is a greater intensity of ecological interactions, such as competition or facilitation, between connected families. On the other hand, when considering the relative contributions of these families to the ecosystem/biomass and ecosystem services, the thick lines suggest that these highly connected families have a greater influence on the structure and processes inside the forest.

Vegetation units

Three vegetation units were identified: the forest zone, flood zone and swamp zone. During the rainy season (Fig. 1), each type of plant is essential to the conservation of the ecosystem, while the diversity of species varies according to the weather conditions, other studies have shown that this pattern is also present in other forest regions, such as the Chocó Forest in Colombia. Álvarez-Dávila et al. (2016) presented three physiographic characteristics of forests: well-drained (hill), permanently flooded (terrace), and swamp zones. In the Bosque Protector Chongón Colonche (protected forest), a lowland mountain range in coastal Ecuadorian, six forest communities were found, each of which has a distinct floristic composition, structure, and environmental optima (Jadán et al., 2022).

The PCA of the 55 species (366 individuals) from several vegetation units revealed that the self-values of PC1 and PC2 explained 98.2% of the data variation (Fig. 3). The first major component explained 74.0% of the variability through DBH (-0.64) and BA (-0.62), whereas the second component explained 24.2% of the variability, explained by PH (-0.43). It is possible to observe the distribution of individuals across all quarters, which revealed high variability in tree size in the La Montaña enclave. The individuals *Anacardium excelsum* (AEX-F), *Pithecellobium micradenium* (PMIC-F), *Ficus* sp. (FIC-F) and *Samanea saman* (SSA-S) presented relatively high DBH (129–180 cm) and BA (1.3–2.5 m) values. For the individuals found in the woodland areas, *A. excelsum* (AEX-F), *Bactris gasipaes* (BGA-F), *Attalea colenda* (ACO-F), *Aspidosperma excelsum* (AEXC-F), *P. micradenium* (PMIC-F), *Clarisia racemosa* (CRA-F), *Gustavia superba* (GSU-F) and *Erythrina poeppigiana* (EPO-F) presented the greatest heights of the plants (35–40 m).

Anacardiaceae is an ecologically and economically important plant family of approximately 200 species in 32 genera in the Neotropics (Mitchell et al., 2022). *Anacardium excelsum*, commonly known as caracolì in Ecuador, Colombia, and Venezuela, is a forest species found in the dry and humid American tropics, as well as in gallery forests, from Costa Rica to northern South America. This species is associated with other species, and sometimes, in pure forests, it is dominant or codominant (Santander and Albertin, 1980). In Colombia, the restoration of forests through the translocation of native species has regained importance, and *A. excelsum* represents a good candidate for local and national restoration programs for seasonally dry tropical forests (Bocanegra-González and Guillemin, 2018). According to Mitchell et al. (2022), in some Neotropical cities, this species is planted as a street tree.

According to the principal component analysis, in the forest zone, there were three important groups on the basis of the importance value index (IVI). The first group included 39 species (86.7%), with IVIs between 0.36 and 3.3%; the second group (11.1%) included the species *C. alliadora, E. poeppigiana, Ficus* sp., *Pseudolmedia rigida* and *T. cumingiana*, with IVIs between 4.71 and 7.57%; and the third group, which included the species *A. excelsum*, had the highest IVI (28.32%), making it the most dominant species in the forest zone (Table 1). In a similar study in the Sumaco Biosphere Reserve (Ecuador), which aimed to determine tree diversity and its ecological importance value in silvopastoral systems, the use of the IVI helped identify the most important tree species in pastures, with trees dispersed along the altitudinal gradient studied representing more than 70% of the IVI in the low and middle zones and up to 96% in the high zone (Torres et al., 2024).

The species in the forest zone with the highest IVIs were generally timber. According to Quiroz (2010), the timber species Palo Prieto (*E. poeppigiana* (Walp.) o.f. Cook), Yuca de Ráton (*Gliricidia sepium* (Jacq.) Walp.), Laurel (*C. alliodora* (Ruiz & Pav.) Oken), adapted to the vast ecological zones and provided additional economic income to cacao producers; thus, it is recommended that these species be grown with cacao. Likewise, Laurel (*C. alliodora*), Fernán Sánchez (*Triplaris guayaquilensis* Weed), Pachaco (*Schizolobium parahyba* (Vell.) S.F. Blake), Guachapelí (*Albizia guachapele* (Kunth) Dugand), and Moral Fino (*Maclura tinctoria* (L.) D. Don ex Steud) are timber species associated with cacao production as well Prieto-Benavides et al., 2012).

Table 1
Floristic inventory in several areas in the enclave La Montaña, showing the values of abundance (RA), frequency (RF), dominance (RD), and IVI, for the speci
zone and swamps zone. INIAP, Ecuador.

Species	Common name	Forest zone				Group	Flood zone				Group	Swamp zone	
		RA (%)	RF (%)	RD (%)	IVI		RA (%)	RF (%)	RD (%)	IVI		RA (%)	RF (%)
Anacardium excelsum (Bertero ex Kunth) Skeels.	Marañón	24.90	11.33	48.74	28.32	3	6.41	6.00	1.61	4.67	1	4.17	5.26
Artocarpus altilis Parkinson ex F.A.Zorn) Fosberg.	Fruta de pan	0.77	1.33	0.29	0.80	1	-	-	-	-	-	-	-
Aspidosperma excelsum Benth	Naranjo de monte	0.38	0.67	0.23	0.43	1	-	-	-	-	-	-	-
Astrocaryum standleyanum L.H.Bailey	Mocora	-	-	-	-	-	1.28	2.00	0.37	1.22	1	-	-
Attalea colenda (O.F.Cook) Balslev & A.J.Hend.	Palma	0.77	1.33	0.16	0.75	1	-	-	-	-	-	-	-
Bactris gasipaes Kunth	Palma	0.77	1.33	0.17	0.76	1	-	-	-	-	-	-	-
Bactris sp.	Chonta	1.53	1.33	0.10	0.99	1	-	-	-	-	-	-	-
Brosimun alicastrum Sw. 1788.	Tillo dulce	0.38	0.67	0.11	0.39	1	1.28	2.00	0.14	1.14	1	-	-
Castilla elastica Cerv.	Caucho	0.77	0.67	1.24	0.89	1	-	-	-	-	-	-	-
C. tunu Hemsl.	Cauchillo	1.15	2.00	0.10	1.08	1	10.26	10.00	2.22	7.49	1	8.33	10.53
Cecropia peltata (L.) *Gaertn.*	Guarumo						26.92	20.00	7.60	18.18	2	50.00	52.63
Cedrela odorata L.	Cedro	1.15	2.00	0.25	1.13	1	-	-	-	-	-	-	-
Ceiba pentandra (L.) Gaertn.		-	-	-	-	-	-	-	-	-	-	4.17	5.26
Centrolobium ochroxylum Rose ex Rudd.	Amarillo lagarto	0.77	1.33	0.15	0.75	1	-	-	-	-	-	-	-
Chrysophyllum lucentifolium Cronquist		-	-	-	-	-	1.28	2.00	0.08	1.12	1		
Clarisia racemosa Ruiz & Pav.	Moral bobo	2.68	3.33	1.61	2.54	1	-	-	-	-	-	-	-
Cordia alliadora (Ruiz & Pav.) Oken	Laurel	8.81	8.00	1.57	6.13	2	-	-	-	-	-	-	-
C. hebeclada I.M.Johnst.	Tutumbe	3.45	2.67	1.24	2.45	1	3.85	6.00	1.63	3.83	1	-	-
C. macrantha Chodat.	Laurel negro	3.07	2.67	0.56	2.10	1						-	-
Cupania cinerea Poepp		1.92	2.00	0.34	1.42	1	2.56	4.00	0.31	2.29	1	-	-
Erythrina glauca L. Willd	Palo prieto	0.77	1.33	2.81	1.64	1	17.95	20.00	65.82	34.59	3	33,33	26.32
E. poeppigiana (Walp.) O.F.Cook	Bombón	4.98	4.67	6.37	5.34	2	2.56	4.00	5.49	4.02	1		
Ficus luschnathiana (Miq.) Miq.	Higueron	1.15	2.00	0.42	1.19	1	-	-	-	-	-	-	-
Ficus sp.	Mata palo	3.07	4.67	14.97	7.57	2	-	-	-	-	-	-	-
Gmelina arborea Roxb.	Melina	0.77	0.67	0.09	0.51	1	-	-	-	-	-	-	-
Gustavia superba (Kunth) O. Berg	Menbrillo	0.77	1.33	0.05	0.72	1	-	-	-	-	-	-	-
Handroanthus chrysanthus (Jacq.) S.O.Grose	Guayacan	0.38	1.33	0.23	0.65	1	-	-	-	-	-	-	-
Herrania purpurea Goudot	Cacao de mano	0.38	0.67	0.03	0.36	1	-	-	-	-	-	-	-
H. umbratica R.E.Schult.	Cacao de monte	0.38	0.67	0.04	0.36	1	-	-	-	-	-	-	-
Hieronyma alchorneoides Allemão		-	-	-	-	-	1.28	2.00	0.34	1.21	1	-	-
Inga edulis Mart.	Guaba	-	-	-	-	-	1.28	2.00	0.16	1.,15	1	-	-

Species	Common name	Forest zone				Group	Flood zone				Group	Swamp zone	
		RA (%)	RF (%)	RD (%)	IVI		RA (%)	RF (%)	RD (%)	IVI		RA (%)	RF (%)
I. spectabilis (Vahl) Willd.	Guaba	0.38	0.67	0.04	0.36	1	1.28	2.00	0.23	1.17	1	-	-
Maclura tinctoria (L.) D.Don ex Steud.	Moral fino	1.15	2.00	3.59	2.25	1	-	-	-	-	-	-	-
Muntingia calabura L.	Niguito	0.38	0.67	0.16	0.40	1	-	-	-	-	-	-	-
Nectandra reticulata (Ruiz & Pav.) Mez	Jigua	0.38	0.67	0.06	0.37	1	-	-	-	-	-	-	-
Ochroma pyramidale (Cav. ex Lam.) Urb.	Balsa	4.21	4.00	0.55	2.92	1	-	-	-	-	-	-	-
Ocotea cernua (Nees) Mez	Palo largo	-	-	-	-	-	1.28	2.00	0.16	1.15	1	-	-
Phyllantus juglandifolia Willd		-	-	-	-	-	2.56	2.00	0.47	1.68	1	-	-
Phytelephas seemannii O.F.Cook	Mococha	0.38	0.67	0.06	0.37	1	-	-	-	-	-	-	-
Pithecellobium micradenium Benth.	Bantano	1.53	2.67	5.69	3.30	1	-	-	-	-	-	-	-
Pseudobombax millei (Standl.) A. Robyns	Beldaco	0.77	1.33	0.14	0.75	1	-	-	-	-	-	-	-
Pseudolmedia rigida (Klotzsch & H.Karst.) Cuatrec	Guion	9.20	7.33	1.45	5.99	2	1.28	2.00	0.14	1.14	1	-	-
Pseudosamanea guachapele (Kunth) Harms	Guachapeli	1.15	2.00	1.80	1.65	1	-	-	-	-	-	-	-
Samanea saman (Willd.) Merrill	Saman	0.77	1.33	0.45	0.85	1	1.28	2.00	7.66	3.65	1	-	-
Sassafras albidum (Nutt.) Nees.	Sassafras	0.38	0.67	0.24	0.43	1	-	-	-	-	-	-	-
Schizolobium parahyba (Vell.) S.F.Blake	Pachaco	0.77	0.67	0.26	0.57	1	-	-	-	-	-	-	-
Swartzia haughtii R, S. Cowan.	Mea sangre	0.38	0.67	0.16	0.40	1	-	-	-	-	-	-	-
Swietenta macrophylla King.	Caoba	0.38	0.67	0.23	0.43	1	-	-	-	-	-	-	-
Theobroma grandiflorum (Willd. ex Spreng.) K.Schum.	Theobroma	0.77	0.67	0.04	0.49	1	-	-	-	-	-	-	-
T. cacao L.	Cacao nacional	2.68	4.00	0.22	2.30	1	-	-	-	-	-	-	-
T. subincanum Mart.	Cacao de monte	0.38	0.67	0.08	0.38	1	-	-	-	-	-	-	-
Trema micrantha (L.) Blume	Sapan de paloma	2.30	2.67	0.53	1.83	1	-	-	-	-	-	-	-
Triplaris cumingiana Fisch. & C.A.Mey.	Fernan Sanchez	5.75	6.00	2.37	4.71	2	8.97	4.00	4.60	5.86	1	-	-
Virola spp.	Carachacoco, Llora sangre	-	-	-	-	-	1.28	2.00	0.34	1.21	1	-	-
Zanthoxylum rhoifolium Lam.		-	-	-	-	-	5.13	4.00	0.65	3.26	1	-	-

In the flood zone, during the rainy season, the majority of species (90%) reported IVI levels lower than 7.49%. The species *Cecropia peltata* and *E. glauca* were the most dominant, as demonstrated by their IVIs of 18.2 and 34.6%, respectively (Table 1). This might be due to their ability to tolerate flood conditions and compete with other species for resources efficiently. These species also play important roles in preserving the biodiversity and ecological stability of the area. Meanwhile, the species *C. peltata* and *E. glauca*, belonging to the swamp zone, stood out, with IVIs of 41.31 and 44.36%, respectively (Table 1). In the forest zone, there were species of economic and ecological importance. For example, cacao has important implications for the diversity of vascular epiphytes, and shaded cacao plantations preserve a portion of the diversity, suggesting that some management practices might improve vascular epiphytic conservation in cocoa agroforests (Haro-Carrión et al., 2009).

The timber species of *T. guayaquilensis* Weed (Fernán Sánchez), *Cybistax donnell-smithii* Rose (Guayacán Blanco), *Colubrina arborescens* (Mill.) Sarg (Caoba de Montaña) and *Cordia macrantha* Chodat (Laurel Prieto) have been employed in studies on cacao associations, where *T. guayaquilensis* and *C. donnell-smithii* obtained the highest accumulated volume of wood. The association of *T. guayaquilensis* with cacao resulted in the highest yield relative to dry cacao during the dry season, which makes it an excellent alternative for agroforest systems (Tapia-Vera et al., 2021). The maintenance of large shade trees could also help preserve understorey and canopy vascular epiphyte diversity even in intensely managed plantations. Trunk epiphytes and hemiepiphytes, which are typically tolerant of habitat transformation, are also likely to benefit from the retention of large forest trees for shade in agroforestry plantations (Haro-Carrión et al., 2009).

In the forest zone, there are species native to the region. The species *C. macranta* Chodat (Laurel Prieto) belongs to the Boraginaceae family and is a symbolic species of the Guayas Province and the country. It is an endemic species of the dry deciduous forest of the Ecuadorian Pacific coast and has been used for a long time as an agroforest ecosystem species (Cornejo, 2015). This species is used for house building by the local population in rural zones (Macará and Zapotillo, Provincia de Loja) with dry forests (Sánchez et al., 2006). It is also a timber species of the Seasonal Dry Forests of Ecuador and Perú, is found mainly in the provinces of Guayas and Loja, and is highly ecologically important (Aguirre et al., 2006; Aguirre and Kvist, 2009). The species *T. guayaquilensis* (Fernan Sánchez), from the Polygonaceae family, is native to Ecuador, where there is genetic diversity. The species is well distributed throughout coastal regions and near the Andes Mountains, where it shows rapid vegetative growth (Nieto-Rodríguez et al., 2013). It is one of the species that affects the floristic composition and structure of dry forests in Ecuador. It is in high demand for the construction, agroforestry and furniture industries (Aguirre and Kvist, 2009, Nieto-Rodríguez et al., 2013).

The composition of the vegetation was dramatically different across the three areas; the forest, flood and swamp zones represented 83.6%, 36.4% and 9.0%, respectively, of the reported species in the La Montaña enclave (Table 2). The biodiversity indicators revealed that the forest zone had the highest diversity of species (H_{SD}= 0.9103, H'= 3.114 and D_{mg}= 8.087), followed by the flood zone (H_{SD}= 0.8724, H'= 2.512 and D_{mg}= 4.348) and the swam unit (H_{SD}= 0.6923, H'= 1.335 and D_{mg}= 1.228). The Chao-1 index suggests that the sampling efforts were appropriate because the observed species are close to the expected species per zone. These results showed that, in the La Montaña enclave, the diversity of species was high in the forest zone and decreased in the flood and swamp zones.

The dendrogram for each vegetation unit, analysed via the Bray—Curtis similarity index (Fig. 4), shows the effects of the vegetation unit on the species composition. Thus, the flood and swamp zones are similar in terms of species abundance and diversity, whereas the forest zone has different values. This indicates that this unit possesses distinct characteristics that make it different from the other vegetation units in this study.

Table 2
Diversity indexes per vegetation unit in the La Montaña enclave.

Diversity Index	**Vegetation Unit**		
	Forest zone	**Flood zone**	**Swamp zone**
Richness (S)	46	20	5
Individuals	261	79	26
Simpson_1-D Index (H_{SD})	0.9103	0.8724	0.6923
Shannon_H Index (H')	3.114	2.512	1.335
Margalef Index (D_{mg})	8.087	4.348	1.228
Chao-1	54.72	38.51	5.962

According to Ferreira-Júnior et al. (2016), the moisture gradient is a determining factor that explains floristic variations in plant communities. Hence, flood and soil water table oscillations are key environmental (abiotic) variables that define plant community patterns in the Pantanal landscape (Brazil). The coexistence of species with very contrasting environmental requirements in Pantanal is only possible because of the proximity of large adjacent phytogeographical spaces (Chaco, Cerrado and Amazonia).

A similar result was reported by Álvarez-Dávila et al. (2016) in three plant associations in the San Juan River delta, Chocó, Colombia, who reported a high diversity of species and, in the same way, a high density of small- and medium-sized trees in the terrace and hill, in contrast to the low richness in the swamp zone, with a predominance of one species and a relatively high basal area. In Brazil's forests, decreases in species richness and diversity as a function of increasing flood duration and intensity have been reported (Ferreira 2000; Ferreira-Júnior et al., 2016). With respect to swamp vegetation in Peruvian Amazonia, Kalliola et al. (1991) reported that the number of species in the category of shrub swamps was low, whereas *C. latiloba* Miq. (Cecropiaceae) had the greatest number of species

According to Kurtz et al. (2013), swamp forests (Southeastern Brazil) are associated with soils that are saturated or flooded because of a high-water table; ecological conditions and geographic proximity are key to determining floristic composition. In swamp forests in Southeast Brazil, a stronger floristic resemblance to their closest neighbors (areas of dry, open resting within the same park) and to a few other swamp forests than to the adjacent Atlantic Forest in the mountain chains and flooded riparian forests at the regional or national level.

Among the total registered species in the La Montaña enclave (55 species), 61.8% are found exclusively in forest areas; seven species (12.7%) are found exclusively in flood zones; and only one species is unique to swamp areas (*Ceiba pentandra* - CPE) (Fig. 4). The species *A. excelsum* (AEX), *Castilla tunu*

(CTU) and *E. glauca* (EGL) are present in the three conservation units; meanwhile, the species *Brosimum alicastrum* (BAL), *C. hebeclada* (CHE), *Cupania cinerea* (CCI), *E. poeppigiana* (EPO), *Inga edulis* (IED), *Nectandra hihua* (NHI), *P. rigida* (PRI), *S. saman* (SSA) and *T. cumingiana* (TCU) are found in the forest and flood zones. Among the total species found at the enclave, 44% can be used for timber in Ecuador: *C. pentandra, A. excelsum, Castilla tunu, B. alicastrum, E. poeppigiana, N. hihua, P. rigida, S. saman* and *T. cumingiana* (Palacios, 2011).

The timber species are characterized by their large size, which makes them adaptable to flood zones. In the Ucayali River (Peru), forest species such as *Adenaria floribunda* H.B.K. (Lytharaceae), *Alchornea catanaefolia* A. Juss (Euphrobiaceae), and *Salix martiana* Leyb. (Salicaceae) were observed in the outermost shrub swamps (Kalliola et al., 1991). The differences in the distributions of the dominant species in the flooded forests in the Jaú and Tarumã-Mirim floodplains (Brazil) are likely related to their ability to tolerate seasonal floods (Ferreira-Júnior et al., 2016).

The flood and swamp zones at La Montaña both have the species *C. peltata*, CPEL (Fig. 4). *Cecropia* species have been reported in other studies to be tolerant to flood zones (Kalliola et al., 1991; Kurtz et al., 2013). For example, in Manaus, Brazil, *C. latiloba* Miq. (Cecropiaceae) is considered one of the most efficient colonizers of open areas in the Amazonian floodplain; its main strategy to be successful is high tolerance towards waterlogging and submergence and fast vertical growth and reiteration capacity (Parolin, 2002). Species of the genus *Cecropia* present important ecological relationships, with biological interactions reported, for example, the predation of ants by birds (Mangini and Thomas, 2020).

The findings of this study underscore the urgency of implementing public policies aimed at conserving the "La Montaña" enclave, a stronghold of biodiversity in Ecuadorian Chocó. The broad diversity of species, including endemic and ecologically significant species, highlights the need to establish protected areas and promote the restoration of ecological connectivity with other forest fragments. Moreover, it is crucial to integrate local communities into sustainable management strategies, ensuring that the conservation of the enclave aligns with regional socioeconomic development.

CONCLUSSION

La Montaña is a significant biodiversity reservoir that harbors species of Chocó forests. The forest zone is the most diverse zone, followed by the flood and swamp zones. The species *Anacardium excelsum*, *Castilla tunu* and *Erythrina glauca* were present in all three conservation units. The species *Ceiba pentandra* is unique to the swamp zone.

Declarations

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Availability of data

The data are available upon request from the authors.

Credit authorship contribution statement

Raúl Valentin Mora Yela: conceptualization, data curation, investigation, formal analysis, writing – original draft. **Cesar Tapia Bastidas:** Supervision, Writing – review & editing. **Joaquin Gimenez de Azcarate:** Supervision, Writing – review & editing. **Fernando David Sánchez-Mora:** Formal analysis, Writing – original draft. **Adriana Beatriz Sánchez-Urdaneta:** Visualization, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Figures

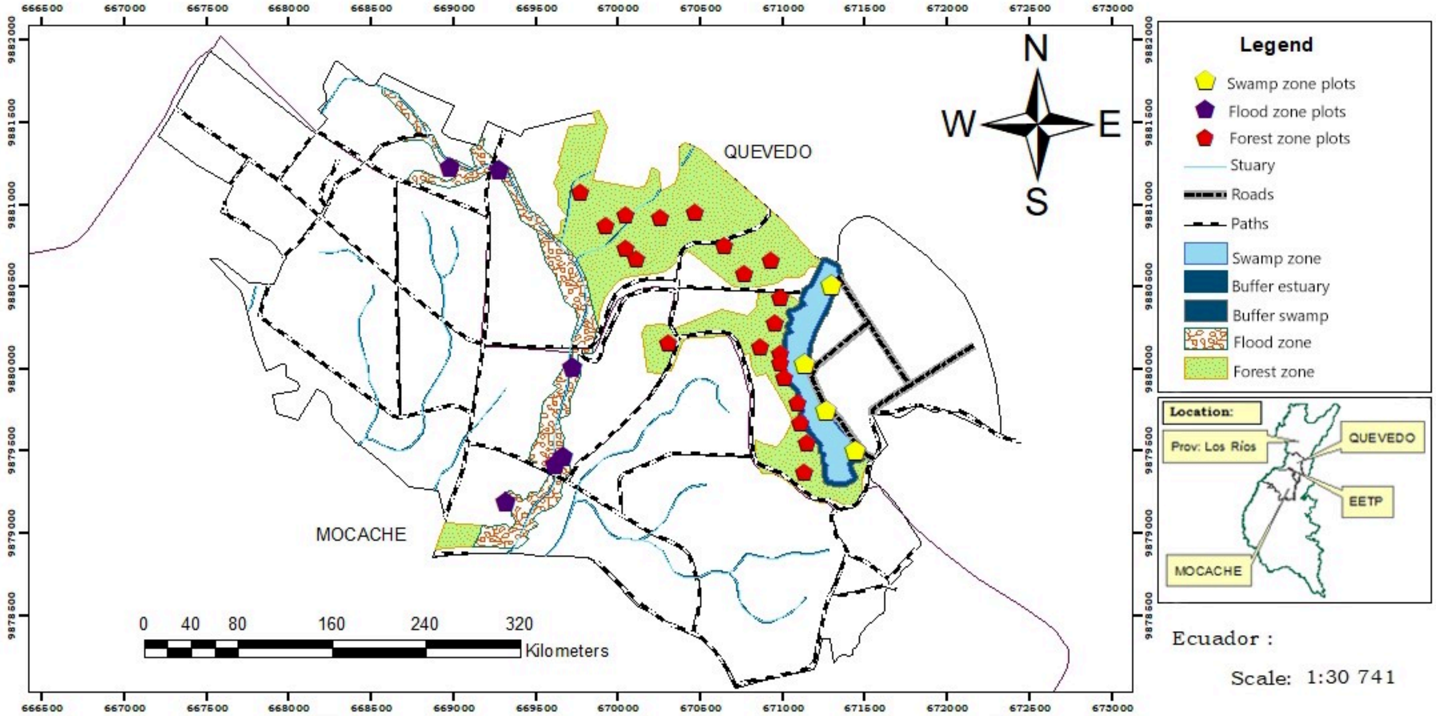

Figure 1

Planimetric survey in the La Montaña enclave. EET-Pichilingue Los Ríos Province, Ecuador.

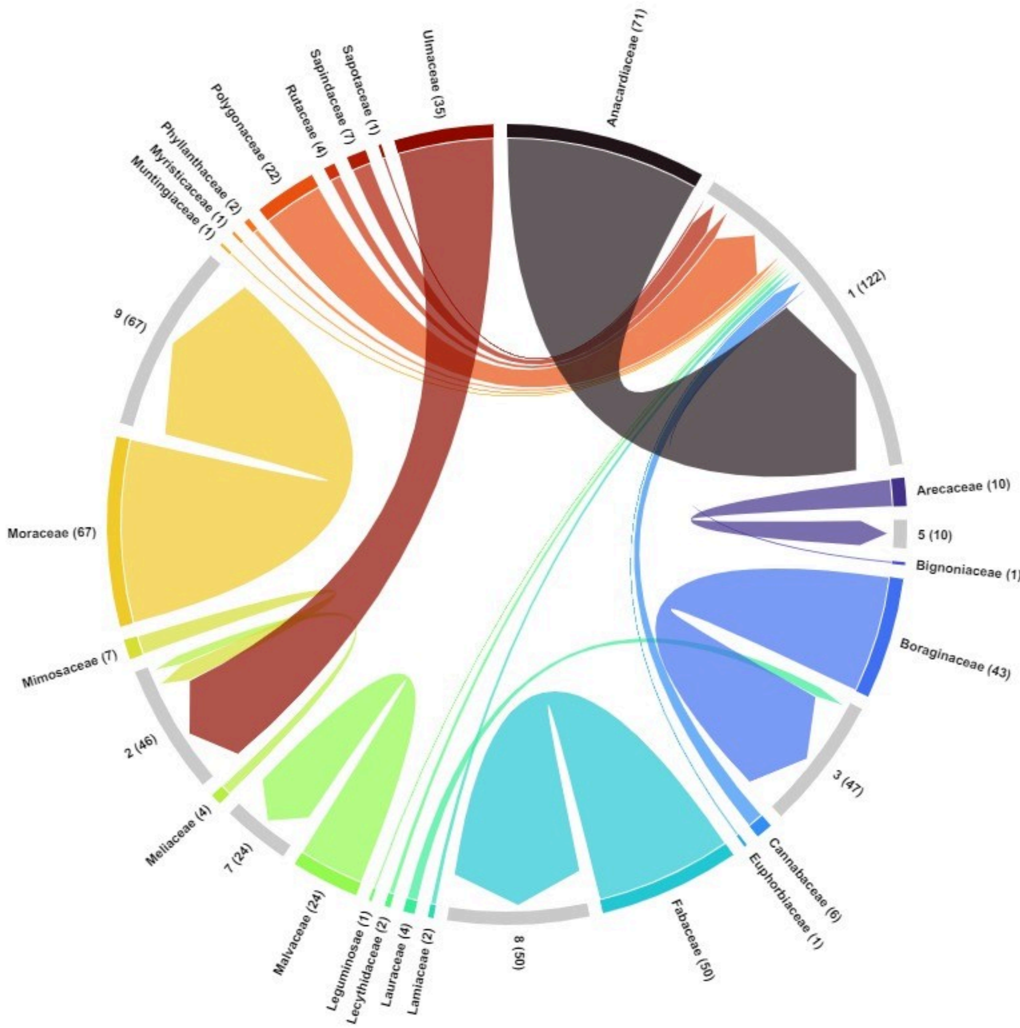

Figure 2

Number of botanical families registered in the La Montaña enclave. The number of species is in parenthesis.

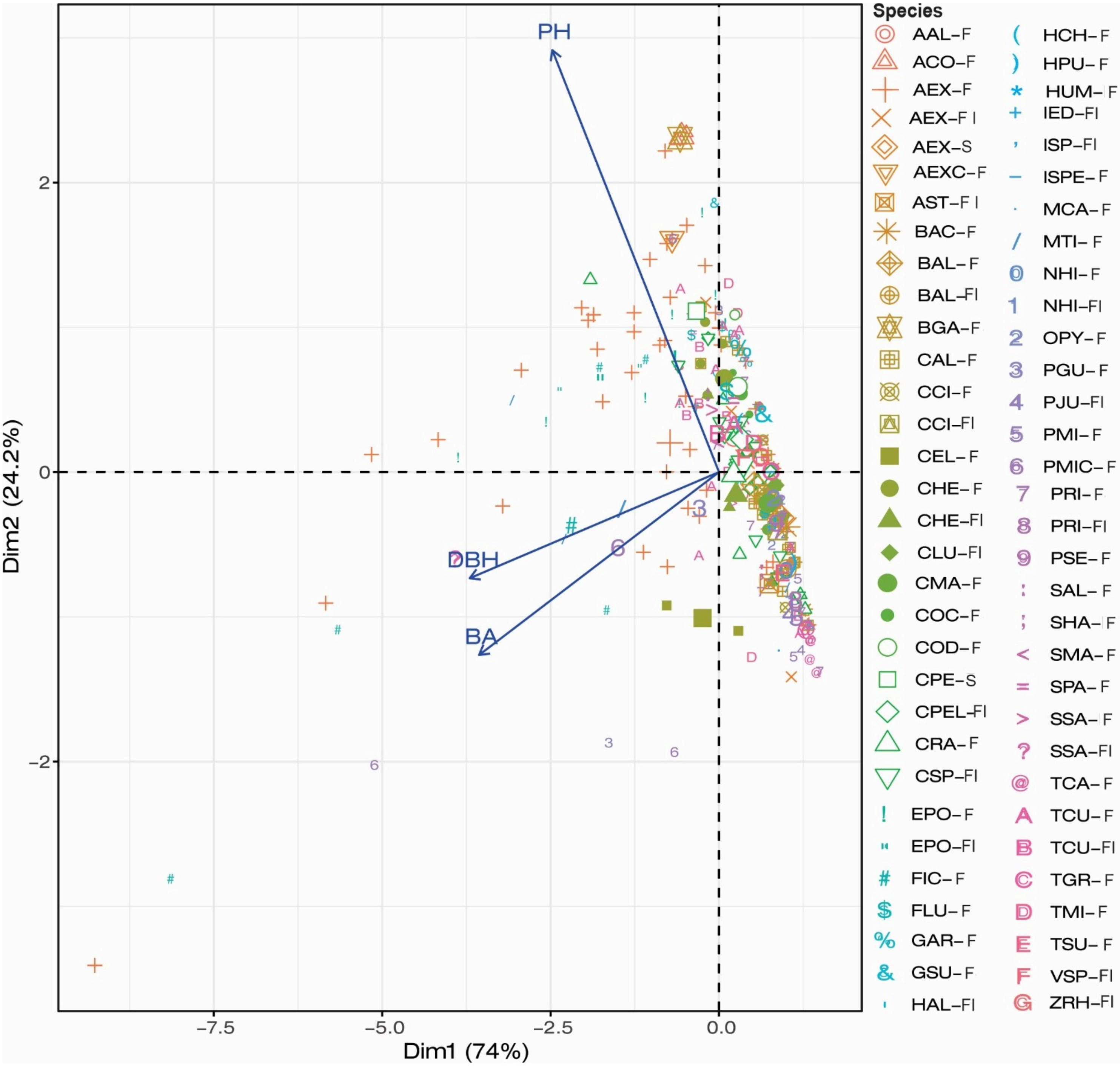

Figure 3

Principal component analysis was carried out with the dasometric variables in the floristic inventory of the La Montaña enclave, 366 individuals of 55 species in the different vegetation units. *Anacardium excelsum* (AEX), *Artocarpus altilis* (AAL), *Aspidosperma excelsum* (AEXC), *Astrocaryum standleyanum* (AST), *Attalea colenda* (ACO), *Bactris gasipaes*(BGA), *Bactris* sp. (BAC), *Brosimun alicastrum* (BAL), *Castilla elastica* (CEL), *C. tunu* (CTU), *Cecropia peltata* (CPEL), *Cecropia* spp.- (CSP), *Cedrela odorata* (COD), *Ceiba pentandra* (CPE), *Centrolobium ochroxylum*(COC), *Chrysophyllum lucentifolium* (CLU), *Clarisia racemosa*(CRA), *Cordia alliadora* (CAL), *C. hebeclada* (CHE), *C. macrantha* (CMA), *Cupania cinerea* (CCI), *E. glauca* (EGL), *E. poeppigiana* (EPO), Ficus *luschnathiana* (FLU), *Ficus* sp. (FIC), *Gmelina arborea* (GAR), *Gustavia superba* (GSU), *Herrania purpurea* (HPU), *H. umbratica* (HUM), *Hieronyma alchorneoides*(HAL), *Inga edulis* (IED), *I. spectabilis* (ISPE), *Inga*spp. (ISP), *Maclura tinctoria*(MTI), *Muntingia calabura* (MCA), *Nectandra hihua* (NHI), *Ochroma pyramidale* (OPY), *Phyllantus juglandifolia* (PJU), *Phytelephas seemannii* (PSE), *Pithecellobium micradenium* (PMIC), *Pseudobombax millei* (PMI), *P. rigida* (PRI), *Pseudosamanea guachapele* (PGU), *Samanea saman* (SSA), *Sassafras albidum* (SAL), *Schizolobium parahyba* (SPA), *Swartzia haughtii*(SHA), *Swietenta macrophylla* (SMA), *Tabebuia chrysantha* (TCH), *Theobroma grandiflorum*(TGR), *T. cacao* (TCA), *T. subincanum* (TSU), *Trema micrantha*(TMI), *Triplaris cumingiana* (TCU), *Virola* spp. (VSP) y *Zanthoxylum rhoifolium* (ZRH). F= forest zone, FI= flood zone and S= Swamp zone.

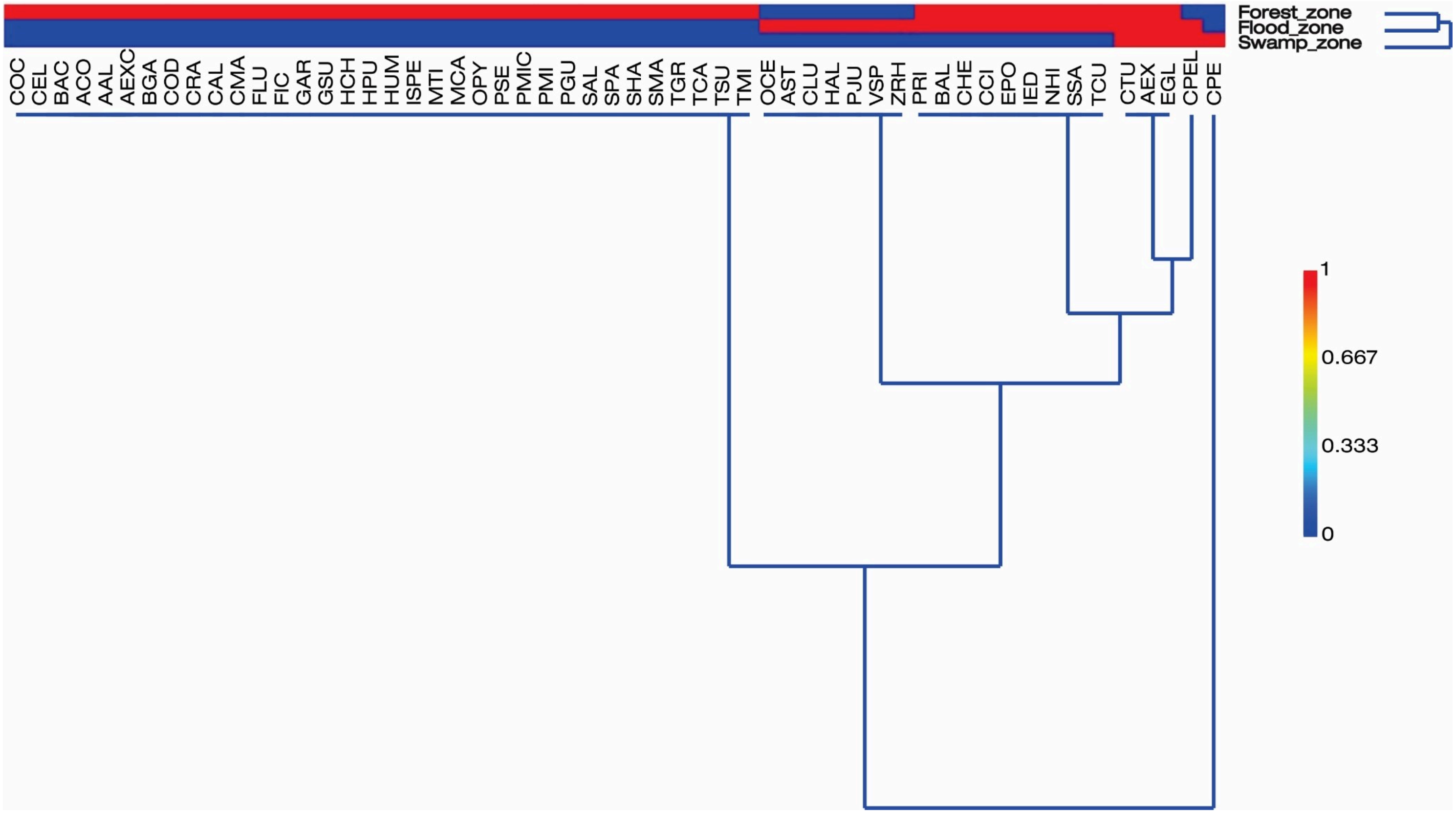

Figure 4

Cluster analysis of several zones of vegetation at the La Montaña enclave. *Anacardium excelsum*- (AEX), *Artocarpus altilis*(AAL), *Aspidosperma excelsum* (AEXC), *Astrocaryum standleyanum* (AST), *Attalea colenda*(ACO), *Bactris gasipaes* (BGA), *Bactris* sp. (BAC), *Brosimun alicastrum* (BAL), *Castilla elastica* (CEL), *Castilla tunu* (CTU), *Cecropia peltata* (CPEL*), Cecropia* spp. (CSP), *Cedrela odorata* (COD), *Ceiba pentandra*(CPE), *Centrolobium ochroxylum* (COC), *Chrysophyllum lucentifolium* (CLU), *Clarisia racemosa*(CRA), *Cordia alliadora* (CAL), *C. hebeclada* (CHE), *C. macrantha* (CMA), *Cupania cinerea* (CCI), *Erythrina glauca*(EGL), *E. poeppigiana* (EPO), *Ficus luschnathiana* (FLU), *Ficus*sp. (FIC), *Gmelina arborea* (GAR), *Gustavia superba* (GSU), *Herrania purpurea* (HPU), *H. umbratica* (HUM), *Hieronyma alchorneoides* (HAL), *Inga edulis* (IED), *Inga spectabilis* (ISPE), *Inga* spp. (ISP), *Maclura tinctoria* (MTI), *Muntingia calabura* (MCA), *Nectandra hihua* (NHI), *Ochroma pyramidale*(OPY), *Phyllantus juglandifolia* (PJU), *Phytelephas seemannii*(PSE), *Pithecellobium micradenium* (PMIC), *Pseudobombax millei*(PMI), *P. rigida* (PRI), *Pseudosamanea guachapele* (PGU), *Samanea saman* (SSA), *Sassafras albidum* (SAL), *Schizolobium parahyba* (SPA), *Swartzia haughtii*(SHA), *Swietenta macrophylla* (SMA), *Tabebuia chrysantha* (TCH), *Theobroma grandiflorum*(TGR), *T. cacao* (TCA), *T. subincanum* (TSU), *Trema micrantha*(TMI), *T. cumingiana* (TCU), *Virola*spp. (VSP) y *Zanthoxylum rhoifolium* (ZRH).