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Floristic and structural composition of secondary native forest remnants in the western Cordillera of the Ecuadorian Andes

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***Abstract*---**This study aims to diagnose the floristic and structural composition of the secondary native forest of Jalligua Alto, Cotopaxi province. Seven sampling units were installed, considering the area covered by the secondary forest, at an altitude above 1000 meters above sea level. Indicators of diameter, total height of individuals, species, family, and importance value index (IVI) were used to demonstrate the floristic composition and structure of the vegetation. In this study, a total of 637 individuals belonging to 47 species and corresponding to 30 families were recorded, with *Lauraceae* being the most diverse, with 6 species, followed by the *Meliaceae* family, with 4 species. The most abundant species was *Cecropia sciadophylla Mart.* followed by *Croton lechleri* and *Trema micrantha*. However, from an ecological point of view, *Guarea trichiloides* is the most important species in the area with 29.85 %, due to its dominance (greater basal area). In the study area, 71 timber trees greater than 7.5 cm DBH were recorded, with a basal area of 3.76 m2, a total volume of 79.17 m3, and a commercial volume of 48.15 m3, the highest volume belongs to *G. trichiloides*, with 24.11 m3 followed by *Nectandra sp* with 17.32 m3.

***Keywords*---**heterogeneity, strata, sampling units, dominance.

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Introduction

Ecuador's floral diversity is largely represented by the variety of ecosystems it possesses. It is considered among the most diverse countries in the world. In Ecuador, knowledge of the flora, and the different uses and functions in the forest structure will allow the conservation of native forests with appropriate policies and regulations (Puente, 2008). Ecuador has few detailed studies on the ecology of forest ecosystems, despite their great economic, social and cultural importance, which prevents the identification of their productive potential (Ferreira et al., 2002).

Secondary native forests represent an important and, in some cases, the only option for the extraction of timber and non-timber products in areas that have been almost completely deforested (Ferreira et al., 2002). Structural characterization makes it possible to define the state of conservation of the vegetation, which is significant in the Andean region where, together with cultural and economic development, it is evidence of the transformation of the natural landscape into extensive and intensive agrosystems (Gil et al., 2020).

Forest management requires information on the structure, growth, production, and natural regeneration of both commercially valuable species and those of unknown economic value. The structure present in each particular case is the best response of the ecosystem. The study of the structure provides knowledge to develop an adequate Silviculture and Management for the forests of the region (Araujo et al., 2008). The population structure of forests is defined as how different stages of development (seedlings, saplings, juveniles, and adults) of a group of plant species are represented (Díaz et al., 2009).

In this research project, the aim is to collect information on the compassion of a part of the flora in the remnants of native forest above 1000 meters above sea level, verify its diversity, structure, conservation status of forest resources of secondary native forest in the upper zone of the Jalligua Alto area, province of Cotopaxi. For this reason, plots were made to take data in situ, using forest measurement techniques, an inventory in the high zone, which helped to identify the families and species found in the area, variables of the trees (height, diameter), and other factors that were shown in the development of the research.

Materials and Methods

Once the site was selected, plots of 400 m2 were made with the help of a compass and plastic tape, the plots were demarcated and subdivided as shown in Figure 1, based on this internal distribution in the shearwater, the field data collection was carried out as detailed in Table 1.

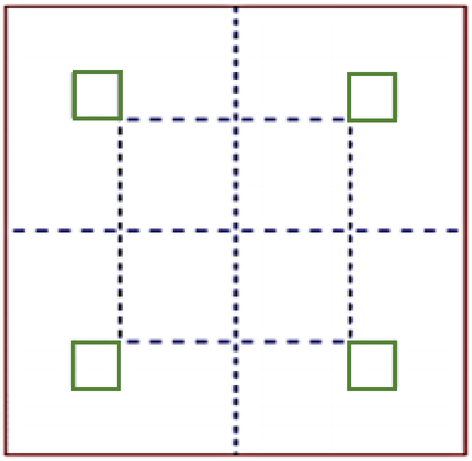

Figure 1. Plot layout design (Aguayo, 2019).

Table 1. Plot layout design and DAP for data logging

Color	Name	Dimensions	DAP Description
Red	Sampling units (SM)	20 x 20 m	Trees with DAP ≥ 7.5
Blue	Subunits (SUM)	10 x 10 m	Trees with DAP > 2.5 and < 7.5
Green	Squares	2 x 2 m	Seedlings < 2.5 cm of DAP

Source: Enriquez and Hernández (2003)

Data collected from trees with DBH ≥ 7.5 cm.

In the 400 m2 plots, information was collected from trees of 7.5 cm DBH. Trees were marked with spray; diameters were measured using a diametric tape and total and commercial heights were recorded with a hypsometer. In addition, the crown diameter and the horizontal (X axis) and vertical (Y axis) distances of each individual were recorded, taking as a starting point the delimitation of the sampling unit, information that was required for the structural profiles.

Data collected from trees with DAP > 2,5 cm and < 7,5 cm

In the 10 x 10 subplot (100 m2), information was collected on trees larger than 2.5 cm and smaller than 7.5 cm DBH, information that allows to see how the forest regeneration and its structure is.

Data collected from seedlings < 2,5 cm, cm of DAP

In the four 4 m2 quadrants, information was collected on seedlings smaller than 2.5 cm, which allows to see how the forest is regenerating.

Results

Floristic diversity, vegetation structure, and regeneration in the secondary native forest of Jalligua Alto

A total of 637 individuals were recorded in the study area, of which 71 individuals with a DBH greater than 7.5 cm, 155 individuals greater than 2.5 cm and less than 7.5 cm, and 411 individuals with a DBH less than 2.5 cm. Forty-seven species corresponding to 30 families were identified, being *Lauraceae* the most diverse, with 6 species, followed by the *Meliaceae* family, with 4 species respectively.

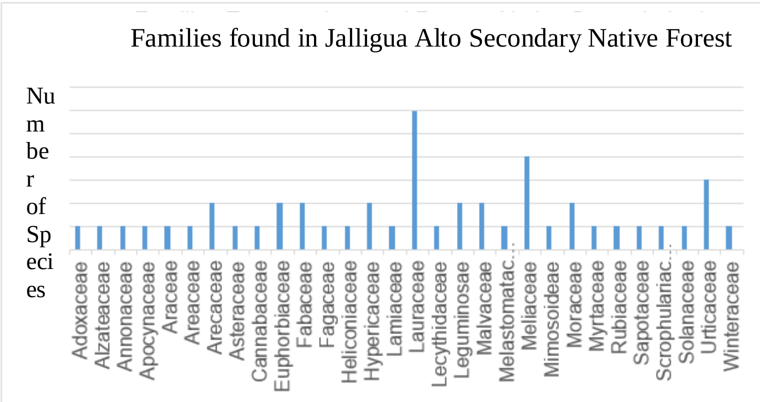

Figure 2. Identified families

With the number of individuals and species in the different units of the 7 plots, it was observed that sample unit 1 had the greatest abundance of individuals and the greatest diversity of species, followed by sample unit 4 with the greatest diversity of species.

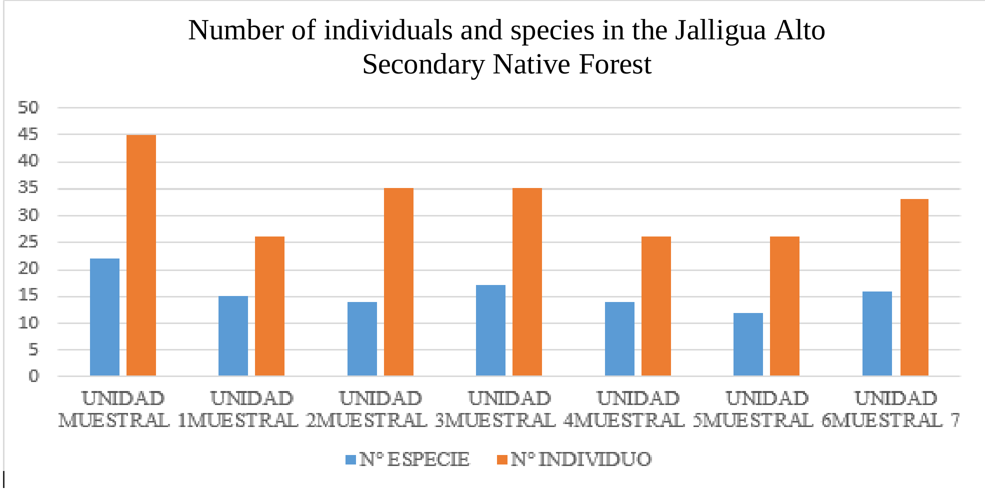

Figure 3. Graphical presentation of individuals and species.

Ecological Parameters

The most abundant species is *Cecropia sciadophylla Mart.* with 9 individuals, followed by *Croton lechleri* and *Trema micrantha* (L.) Blume with 8 individuals. However, from an ecological point of view, *Guarea trichiloides* is the most important species in the area with 29.85 %, due to its dominance (greater basal area). The species *Cecropia sciadophylla Mart, Luma apiculata, Trema micrantha* (L.) Blume and Croton lechleri, also had representative ecological importance with values of 24.48 %, 25.02 %, 22.08 %, and 22.01 % respectively.

The most representative families are Urticaceae with 10 individuals, also *Cannabaceae* and *Euphorbiaceae* with 8 individuals each. Regarding the importance value of families, the *Lecythidaceae* family had the highest value with 69.73 % followed by the families *Urticaceae* with 19.15 %, *Meliaceae* with 18.09 %, and *Lauraceae* with 17.63 %. According to the Shannon index, a value of 2.95 was obtained, showing a significant floristic richness.

Dasometric parameters of the sample unit, total volume by species, total volume by species.

Table 2. The volume determined for each of the tree species is shown below

N°	Common name	Scientific name	Family	N° Ind	AB	Vol. To (m^3)	Vol. Com (m^3)
1	Mama juana	Adenostemma platyphyllum	Asteraceae	2	0.02	0.13	0.08
2	Lulo	Aegiphila alba Moldenke	Lamiaceae	5	0.06	0.38	0.19
3	Trebol	Amburana cearensis	Fabaceae	1	0.01	0.05	0.02
4	Palma	Astrocaryum	Arecaceae	3	0.02	0.09	0.06

	chontilla	vulgare					
5	Visola chonta	Bactris Gasipaes Kunth	Areaceae	3	0.02	0.17	0.13
6	Sandi blanco	Brosimum utile (H.B.K.) Pittier spp utile	Moraceae	1	0.01	0.09	0.05
7	Sapan	Caesalpinia sappan	Fabaceae	3	0.02	0.13	0.07
8	Guarumo	Cecropia sciadophylla Mart.	Urticaceae	9	0.10	0.63	0.35
9	Guarumo blanco	Cecropia sp.	Urticaceae	1	0.01	0.05	0.03
10	Caimito	Chrysophyllum cainito	Sapotaceae	1	0.01	0.02	0.01
11	Sangre de drago	Croton lechleri	Euphorbiaceae	8	0.19	3.42	2.04
12	Cocobola	Dalbergia retusa	Fabaceae	1	0.00	0.02	0.01
13	Canelo blanco	Drimys winteri	Winteraceae	1	0.12	3.00	2.14
14	Sabroso tete	Eschweilera sp.	Lecythidaceae	2	0.23	4.42	3.02
15	Bil	Guarea trichiloides	Meliaceae	3	0.97	24.11	12.53
16	Balsa macho	Heliocarpus americanus L	Malvaceae	1	0.01	0.08	0.04
17	Colta	Henriettea tuberculosa (Donn. Sm.) L.O. Williams	Melastomataceae	2	0.01	0.05	0.03
18	Guabo negro	Inga sp.	Mimosoideae	1	0.00	0.02	0.01
19	Arrayan	Luma apiculata	Myrtaceae	1	0.35	8.60	4.91
20	Tabasquiro	Nectandra sp	Lauraceae	5	0.72	17.32	10.78
21	Balsa	Ochroma pyramidale	Malvaceae	1	0.14	4.00	3.00
22	Canelo amarillo	Ocotea insularis (Meisn.) Mez	Lauraceae	2	0.02	0.23	0.15
23	Tomate de arbol	Solanum betaceum	Solanaceae	1	0.00	0.02	0.01
24	Sapan de paloma	Trema micrantha (L.) Blume	Cannabaceae	8	0.44	8.50	5.28
25	Pechuga	Vismia sp.	Hypericaceae	1	0.18	3.51	3.13

	de gallina						
26	Camacho	Xanthosoma sagittifolium	Araceae	4	0.06	0.14	0.08
Total				71	3.76	79.17	48.15

According to the results presented in Table 2, 71 timber trees greater than 7.5 cm DBH were recorded in the study area, with a basal area of 3.76 m2, the total volume of 79.17 m3, and a commercial volume of 48.15 m3. The highest volume belongs to *Guarea trichiloides*, with 24.11 m3 followed by *Nectandra sp* with 17.32 m3 and *Luma apiculata* with 8.60 m3. It is important to emphasize that none of the species with predominant volume was influenced by abundance, but rather by the dominance of the species, since, despite having a smaller number of individuals, the diameters and height were greater.

Volume by diameter classes

In diameter class VI, the largest amount of volume can be observed with 5 individuals that would be in the dominant trees of the site, while in diameter class I the second largest volume can be seen with the particularity that there are 41 individuals in this category, which shows a good insitu regeneration.

Table 3. Diameter classes

Class	Diametric classes	N° Trees	Basal Area	Vol. Total m^3	Vol. Com m^3
I	7,3 - 14,3	41	0.90	17.0439	8.3742
II	14,3 - 21,3	9	0.20	1.7630	1.1304
III	21,3 - 28,3	3	0.12	2.0595	1.1869
IV	28,3 - 35,3	8	0.65	12.7122	7.8121
V	35,3 - 42,3	1	0.12	2.9978	2.1413
VI	42,3 - 49,3	5	0.83	18.0468	12.4393
VII	49,3 - 56,3	2	0.47	12.2745	7.5314
VIII	62,3 - 95,6	2	0.47	12.2745	7.5314
		71	3.763	79.1722	48.147

Vegetation strata

In the high stratum, there were 71 trees larger than 7.5 cm in diameter, in the middle stratum 155 trees larger than 2.5 cm and smaller than 7.5 cm in diameter, and in the low stratum 411 seedlings with a diameter smaller than 2.5 cm in diameter, it is notorious that in the low stratum the largest number of individuals is concentrated, as shown in Figure 4.

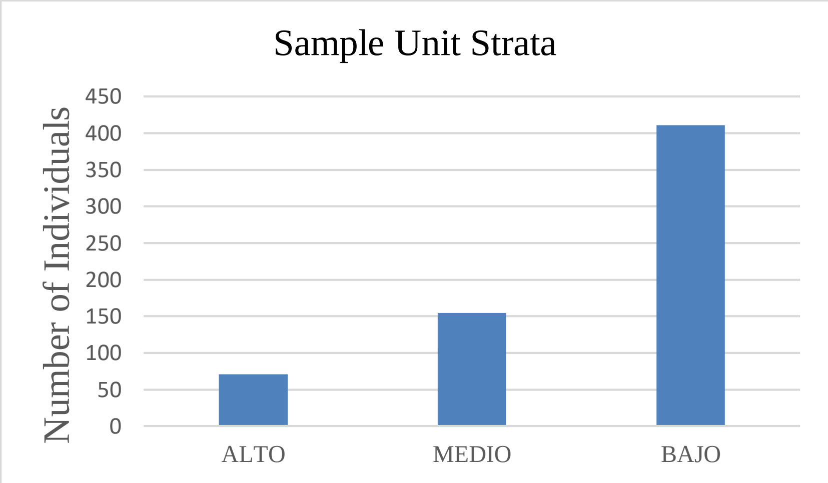

Figure 4. Abundance in the different strata

Jaccard similarity index

This dendrogram shows a similarity in sampling units 1 and 2 - 3 and 7.

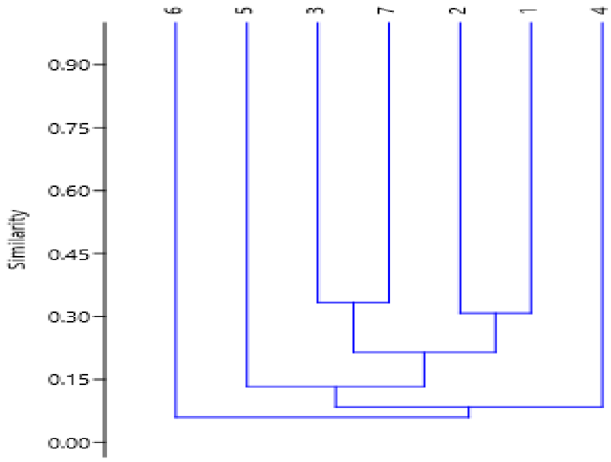

Figure 5. Jaccard similarity dendrogram

Structural profile
Plot 1
The structural indices of plot 1 showed 2 trees exceeding 25 meters in total height and most of the individuals obtained a total height of less than 10 meters (Figure 6).

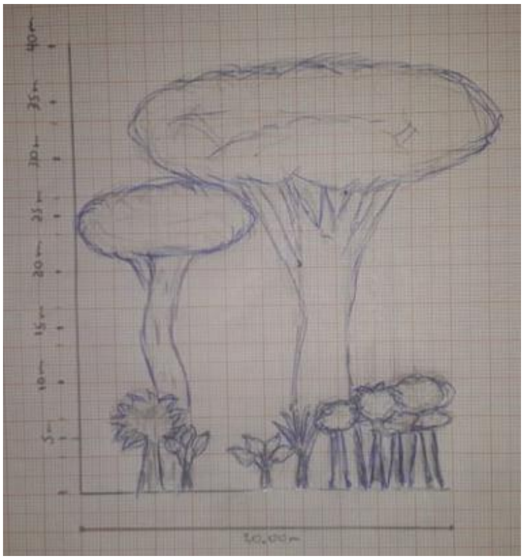

Figure 6. Vertical structure of plot 1.

Discussion

The results obtained from the work in the upper zone of the secondary native forest of Jalligua Alto, belonging to the province of Cotopaxi, allowed obtaining data through the installation of seven sampling units installed in the area where the native forest was considered, registering a total of 637 individuals and 47 species corresponding to 30 families were identified, being *Lauraceae* the most diverse, with 6 species, followed by the *Meliaceae* family. This contrasts with the results obtained by Gomez Coello (2016) in the Murocomba Protected Forest, where he found 996 individuals, with a high abundance of species (92) and 33 families, the most representative being the Asteraceae and *Euphorbiaceae* families. In other studies, conducted by Suatunce (2009) in the province of Cotopaxi in remnant forests, 24 families, 42 genera, 56 species and 686 individuals were recorded. This indicates that the area has a high abundance. Patiño et al. (2015) through a floristic, ecological and structural study in five permanent transects in a montane evergreen foothill forest in the Piatúa river basin between 600 - 700 masl identified 32 families and 68 species in 288 individual trees. The most diverse families were: *Arecaceae*, *Fabaceae,* and *Moraceae* with 5 species; followed by *Lauraceae* and *Urticaceae* with 4 species.

In the study area, the most abundant species were: *Cecropia sciadophylla Mart.* with 9 individuals, followed by *Croton lechleri* and *Trema micrantha* (L.) Blume with 8 individuals. The results indicated in the study area differ from those found by Lema et al. (2021) where the most dominant species were: Sapium sp (rubber) with 23 individuals followed by Benthamiana sp (canelo) and Syaploccos sp (motilón blanco) with 15 individuals, these species are considered to have no commercial value and are mostly used as firewood. Another aspect of this research that differs from the present study is the lower abundance of: Eugenia yasuniana (quita sol), Persea kunth (aguacatillo), Cecropia (guarumo), ficus sp (higueron), Guaracea kunthiana (aliso) 1 individual, these species mentioned are of high commercial value due to the high resistance of their wood. The height is a determinant for the presence of certain species within a forest.

Regarding the Importance Value Index (IVI), ecologically the *Guarea trichiloides* species is the most important in the area with 29.85 %, according to its dominance (greater basal area). The species *Cecropia sciadophylla* Mart, *Luma apiculata*, *Trema micrantha* (L.) *Blume* and *Croton lechleri*, also had representative ecological importance with values of 24.48 %, 25.02 %, 22.08 %, and 22.01 % respectively. These results contrast with what was found by Leiton (2018), who determined that *Trichanthera sp.*, *Cinnamomum triplinerve*, *Cecropia sciadophylla*, and Vochysia sp. were the most representative with 32.68 %, 28.05 %, 24.57 %, and 23.41 % respectively in the lower Murocomba zone. Lema et al. (2021) indicate that the species with the highest ecological weight are: *Casearia Sylvestris* with 30.4% belonging to the *Salicaceae* family and *Faramea Occidentalis* of the *Rubiaceae* family with 29.04% in addition they are the most abundant, frequent, dominant and those with the largest basal area, it is believed that they have a high index because they are not of great utility and they have been allowed to develop without any difficulty.

Concerning the volume recorded in the sampling units carried out in the Jalligua Alto area, the highest volume belonged to *G. trichiloides*, with 24.11 m^3 followed by *Nectandra sp* with 17.32 m^3 and *L. apiculata* with 8.60 m^3. These species were the same that obtained the highest values of importance index (IVI). This relationship coincides with what was determined by Aguayo (2019) who recorded the highest volume in *Guarea sp.* with 22.94 m^3, followed by *Ocotea javitensis* with 3.10 m^3 and *Myrcianthes rhopaloides* with 1.52 m^3 in the sampling units conducted in the upper zone of the Murocomba Protected Forest. In contrast to the study conducted by Leiton (2018) in the Murocomba Protected Forest (lower zone), in which a higher volume was recorded in *Trichanthera sp.* with 8.43 m^3; *Cinnamomum triplinerve.* with 5.34 m^3 and *Vochysia sp.* with 4.41 m^3. It is important to emphasize that none of the species with predominant volume was influenced by abundance, but rather by the dominance of the species, since, despite having a smaller number of individuals, the diameters and height were greater.

The analysis of diameter classes in the upper zone of Jalligua Alto showed that the largest volumes were recorded in classes VI with 12.44 m3. However, the highest number of individuals was recorded in class I (41). These results differ from those of Mite (2016), who in his research on the 0 to 5 cm diameter interval describes the highest number of individuals in the five sampling units, demonstrating that this is a primary forest formation and little intervened.

According to Hubbell and Foster (1987), there is a young distribution over time when the stems of smaller diameter are larger than the rest of the categories, which agrees with the results of this study. The works of Araujo et al. (2005) and Uday and Bussmann (2004) obtain “backward” J distributions and state that these are patterns established especially in natural or young forests or forests in the process of recovery. Therefore, we establish that according to its floristic composition and its diameter distribution it is a secondary forest.

Conclusions

The composition, characterization, and conservation status of the floristic resources in the secondary native forest of Jalligua Alto, for the 7 sampling units, a total of 637 individuals, 30 families, and 99 species were recorded, the most representative families were *Lauraceae* with 6 species and *Meliaceae* with 4 species, regarding the value of the importance of families (VIF) are *Lecythidaceae* with 69.73 % and Urticaceae with 19.15 %.

The general exploration of the ecological value of the sampling units in the study area concluded that the species with more (IVI) are *Guarea trichiloides* with 29.85 %, *Luma apiculata* with 25.02 %, and *Cecropia sciadophylla* Mart. with 24.48 % respectively, according to abundance, frequency, and dominance.

In the analysis of diameter classes, it was observed that the interval of 7.30 to 21.30 cm in diameter with 50 individuals in total, explains the largest number of individuals among the seven sampling units, showing that this is a secondary and little intervened forest formation.

In the vertical profile of the Jalligua Alto Secondary Native Forest, the floristic composition within the sampling units describes three stratifications: high (Stratum 1), medium (Stratum 2), and low (Stratum 3), with the low stratum having the greatest number of individuals (411) and the greatest number of species (41).

According to Shannon's diversity indexes, the sample units registered a value of 2.95, so they are considered high diversity, and the similarity index below 0.3 indicates that there is not much similarity among the seven sample units.

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