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Floristic Composition, Structure, and Aboveground Biomass of the Moraceae Family in an Evergreen Andean Amazon Forest, Ecuador

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Abstract: The current study determined the floristic composition, structure, and aboveground biomass (AGB) of the individuals of the Moraceae family. This occurred in order to value them as a source of biomass carbon, which itself is dependent on the altitudinal gradient (601–1000 m.a.s.l.) in the evergreen foothill forest of the Ecuadorian Amazon. The study encountered 117 individuals belonging to the Moraceae family, which was grouped into 32 species. Hereby, the most abundant were the genus Ficus sp., with 9.40% relative abundance, *Brosimun alicastrum* with 6.84%, and *Aucleopsis* sp. with 5.98%. Forest structural characteristics, such as the horizontal and vertical structure, diameter at breast height (DBH), and the diameter of the tree crown, were considered for the analysis. The horizontal profile determined that the crowns of the species of the Moraceae family cover approximately 16.43% of the upper canopy within the sampling unit area. The trees of the Moraceae family have a carbon capture capacity in the projected AGB per hectare of 35.09 (Mg ha^{-1}), with the *Ficus cuatracasana* Dugand species being the species with the highest projected capture per hectare, with 15.737 (Mg ha^{-1}). These results highlight the relevance of similar studies assessing the carbon accumulation capacity of species from other families, emphasizing high commercial value species due to their timber resource.

Keywords: floristic diversity; horizontal structure; AGB; Moraceae; Ecuadorian Amazon

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Citation: García-Cox, W.; López-Tobar, R.; Herrera-Feijoo, R.J.; Tapia, A.; Heredia-R, M.; Toulkeridis, T.; Torres, B. Floristic Composition, Structure, and Aboveground Biomass of the Moraceae Family in an Evergreen Andean Amazon Forest, Ecuador. *Forests* **2023**, *14*, 1406. https://doi.org/10.3390/f14071406

Academic Editor: Ernesto I. Badano

Received: 28 April 2023
Revised: 8 June 2023
Accepted: 12 June 2023
Published: 10 July 2023

1. Introduction

The tropical forests located in the Amazon basin are areas of great relevance due to their biological diversity, especially with regard to the richness of plant species [1–6]. It is very important to highlight that these forests have been estimated to contain about 43% of all existing tree species [7]. Additionally, these forests play a fundamental role in the conservation of biodiversity and in mitigating the effects of climate change as it is estimated that they have the capacity to capture around 13% of the total annual emissions of carbon dioxide (CO_2) generated by human activities at a global level [8]. Therefore, several studies have demonstrated that forests located in tropical regions provide various alternatives in terms of planning and applying sustainable strategies for forest conservation [9].

These forests exhibit remarkable biomass productivity and represent a substantial proportion of the total carbon and nutrient stocks [10–12]. Biomass, a crucial element in ecosystems, results from the balance between the productivity rate, which includes photosynthesis and seed germination, and the losses caused by respiration and mortality [13,14]. In this context, the quantification of biomass plays a crucial role by the providing relevant information required to understand the responses of vegetation to climate and environmental changes at the local and global levels [15–17]. Specifically, biomass estimates in tropical forests are essential for assessing forest carbon stocks and air emissions related to deforestation and land cover change, as well as their global implications [18–21]. Several studies have indicated that the estimation of carbon stocks, for example, provides useful indicators of environmental change and ecological functioning [22–24].

Information on the level of tree biomass production is insufficient in most tropical regions, which restricts efforts to assess and conserve these ecosystems [25–27]. In addition, comprehensive studies addressing biomass production and its influence on carbon stocks are still lacking [28,29]. This limitation can be attributed, in part, to the scarcity of estimates of live biomass and the marked variability observed between different regions [30,31]. Therefore, it is essential to perform more detailed and systematic research to better understand the patterns of biomass production in tropical forests in order to effectively support the valuation and conservation of these valuable ecosystems [28].

In Ecuador, very few studies have focused on the estimation of the biomass area in forest ecosystems. These forest ecosystems are a large part of those developed in the Andes and the Ecuadorian Amazonian lowlands [32–35]. Particularly in the Amazon region, these investigations have examined the variation in tree communities and their contributions to biomass and carbon storage in the elevation gradient [33–36], reporting that the Fabaceae and Moraceae families have the highest species richness. Regarding the Moraceae family, it comprises approximately 1100 species and 40 genera [37–40]. This family stands out for its abundance of individuals and the richness of species [36,41,42]. Therefore, researchers suggest that the Moraceae family is one of the ten families with the largest number of tree species in the world and that their species are highly conspicuous elements in the Amazon [4,43]. In addition, the Moraceae family is recognized for the high economic value of its timber species [44,45] and its medicinal uses [46,47], while its fruits are food for a wide variety of frugivores, which benefits the natural succession dynamics of forests [48,49]. Furthermore, for Gentry [50] and Ter Steege et al. [51], Amazonian soils belonging to the Neotropics have a favorable biological quality that make them easier for families such as the Moraceae to become one of the most diverse and abundant [52–54]. This coincides with Torres et al. [33], who suggested that the Moraceae and Fabaceae families were the most species-rich, based on a study conducted in a piedmont evergreen forest of the Ecuadorian Amazon [55–57]. However, there have been few research efforts on this family in Amazonian forests, as well as little research on the richness and structure at the botanical family level [58,59].

In Ecuador, Caranqui [60] conducted a comparative study between two localities on the Ecuadorian coast and one locality in the Amazon region, with a focus on plant formations that are within the category of lowland evergreen forests. From his results, it can be deduced that they obtained a record of 156 species, corresponding to 39 botanical families, registering the Moraceae family as the most diverse, with 18 identified species. Nonetheless, little is known about their contribution as the species with the greatest timber potential [61]. The contribution of these species to carbon sequestration has not been studied to date, but these forests may act as important carbon sinks.

The present study considers the Sumaco Biosphere Reserve (SBR) as a sampling area, which was recognized as a biosphere reserve by UNESCO in 2000, and later by the Ecuadorian government in 2002. The SBR is made up of around one million ha of native forest (53%), secondary forest (28%), and grasslands (9%) [62]. Its core area is the Sumaco Napo Galeras National Park (PNSNG), which covers 205.751 ha [63]. This reserve has been widely studied as it is recognized as a megadiverse area due to its biological

richness [1,64] and, additionally, for the multiple environmental services it provides as a carbon sink [34,65]. However, despite its great importance for biological conservation and in the mitigation of the effects of climate change [66], the SBR is threatened due to the alteration of its habitat caused by high rates of deforestation, changes in the use of the land [67–71], and even illegal mining [72,73]. In the SBR, deforestation is particularly associated with wood carving for the establishment of agricultural crops and intensive livestock [34,74,75]. In terms of deforestation, between 2008 and 2013, the SBR lost 93,853 hectares of native forest. This represents a 10.8% shift to other land uses in a 5-year period, with a deforestation rate of 2.16% across the SBR [76].

Considering the ecological changes and the increase in the rate of deforestation in the aforementioned region, the main purpose of this research was to understand the contribution of species belonging to the Moraceae family to carbon storage in the country, especially in the Amazon region of Ecuador. To this end, three specific objectives were set out. Firstly, we sought to characterize the geographical distribution of the Moraceae family in the Ecuadorian continental territory. Secondly, the floristic composition and the structure of the species belonging to this family were determined. Finally, we focused on quantifying the amount of stored biomass (AGB) in the species of the Moraceae family.

2. Materials and Methods

2.1. Geographic Setting

The study was conducted to the south of the RBS in an Evergreen Andean Amazon Forest in Ecuador (Figure 1). The predominant ecosystem is the montane evergreen forest (BsMn01) [62], where the temperature ranges between 18 °C and 22 °C, with a precipitation average of 2939 mm and a relative humidity of 89% [77]. Within the RBS appears an active volcano with a unique plant diversity [78,79]. Six protected areas overlap in the RBS (Table 1), as registered in the National System of Protected Areas of Ecuador (SNAP), in addition to many other similar areas [80–83].

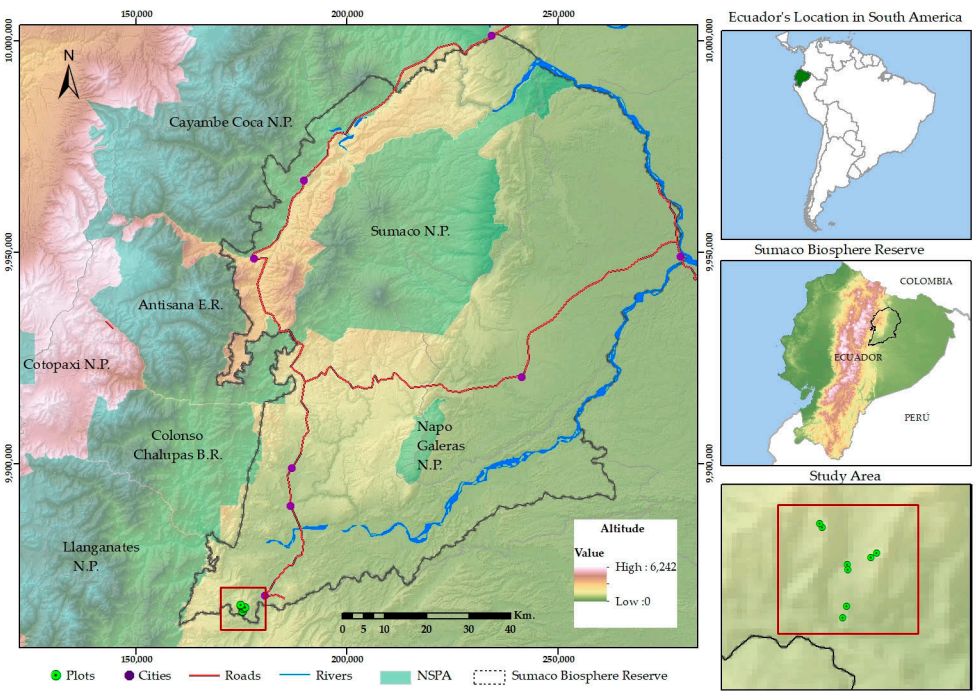

Figure 1. Geographic location of the study plots of the Moraceae family in an Evergreen Andean Amazon Forest, inside the Sumaco Biosphere Reserve, in northeastern Ecuador.

Table 1. Protected areas that overlap in the Sumaco Biosphere Reserve of the Ecuadorian Amazon.

Protected Área	Extension (ha)	Year of Creation	Overlapping Area in RBS (%)
Cayambe Coca National Park	403,103	17 November 1970	8.57
Sumaco National Park	205,249	2 March 1994	100
Antisana Ecological Reserve	120,000	21 July 1993	2.65
Colonso Chalupas Biological Reserve	93,163	3 April 2014	0.51
LLanganates National Park	219,700	18 January 1996	8.57

2.2. Geographical Distribution of the Moraceae Family

The georeferenced and validated records of the Moraceae family were obtained from the Botanical Information and Ecology Network (BIEN) database. They are reported in botanical specifications as they are of crucial importance to clarifying the taxonomy of plants and their main habitats [84], which provides a great potential for the conservation of species [85–87]. To ensure the quality of the presence records, the cleaning protocol of Cobos et al. [88] was applied; that is, the records that presented the same geographic coordinates and with less than two decimal places were eliminated in order to improve the spatial precision of the recorded data.

All the records collected were projected using a WGS 84 datum and from the intersection between the points and the vector layers of Ecuador and its regions. The number of records of the presence of the Moraceae family were estimated, and the intersect and zonal functions of the Terra package were used as developed for R [89]. In order to estimate the environmental conditions linked to the records of the presence of the Moraceae family in Ecuador, all the points were used as a mask to extract the values of three variables: mean annual temperature (bio1), annual precipitation (bio12), and altitude. The climatic variables used in this analysis were obtained from Worldclim version 2 at a resolution of 2.5 arc-minutes (25 km^2) [77]. For the variable altitude, the digital terrain model (DTM) was used with a resolution of 250 m, derived from the Radar Shuttle Topographic Mission (RSTM) [90]. Finally, the environmental values obtained were represented individually by means of a frequency diagram with their respective mode value in order to identify the environmental preferences where the Moraceae family has a greater representativeness in the presence records.

2.3. Floristic Composition, Structure and Carbon Stored in the Biomass of the Species of the Moraceae Family

Temporary transects generally used in rapid exploratory sampling, called Gentry-type sampling [91,92], were installed, modifying the original 500 × 2 m plots to 100 × 10 m plots, where each plot was 0.1 ha. All the species of the Moraceae family were inventoried, marked, measured, and collected. The dasometric variables were recorded as height and diameter for those greater than 10 cm, while for those less than 10 cm, the number of individuals was recorded.

2.4. Data Analysis

The data analysis was divided into two sections: the description of the floristic composition and describing the contribution to carbon absorption of the Moraceae family. This has been realized by means of an allometric equation for forests, using the Excel version 18.0.

2.4.1. Floristic Composition

The characterization of the species of the Moraceae family was conducted from the comparison of the botanical collections available in the Amazon Herbarium of the Amazon State University in Pastaza, located in central Ecuador. This process allowed us to define the floristic diversity of this family, as well as determining the relative abundance, through a predefined equation [93]:

$$AR = \frac{\text{\# Ind species}}{\text{\# total individuals}} \times 100 \quad (1)$$

2.4.2. Horizontal and Vertical Structure

The horizontal structure of the forest according to the altitudinal gradient was determined based on the calculation of the following dasometric and ecological parameters:

Basal area

$$\text{Basal area} = 0.7854 \times (\text{DAP})^2 \tag{2}$$

where:

DAP = Diameter at breast height (1.30 m)

Volume

$$\text{Volume} = \text{Ab} \times \text{h} \times \text{ff} \tag{3}$$

where:

Ab = basal area

h = height

ff = form factor

Relative dominance

$$\text{DR} = \frac{\text{basal area sp}}{\text{total basal area}} \times 100 \tag{4}$$

2.4.3. Ecologically Important Value Index

For the graphic representation of the horizontal and vertical structure of the forest, the ArcGis version 10.2 computer tool was used. This allowed the distribution of individuals within the transect, according to the variables (x; y), taken in the field.

$$\text{IVI} = \text{Ab Rel} + \text{Dom Rel} \tag{5}$$

2.4.4. Floristic Richness

The Margalef index is based on the relationship between the number of species and the total number of individuals observed. It increases with the increasing sample size [94].

$$\text{D} = \frac{\text{S} - 1}{\ln \text{N}} \tag{6}$$

where:

S = number of species

N = total number of individuals

2.4.5. Species Diversity

The Shannon-Wiener (H′) measures the average degree of uncertainty in order to predict the species to which an individual taken at random within the MUs belongs.

$$\text{H}' = -\sum(\mathbf{pi} \times \frac{\mathbf{log\ pi}}{\mathbf{log\ 2}}) \tag{7}$$

where:

Σ = number of species

P_i = proportion of individuals of the species i

The higher the value of H′, the greater the diversity of species.

2.4.6. Aboveground Biomass Carbon

To estimate the carbon stock of the aerial biomass, an allometric equation was used, applied to the tree measurements, and generated for tropical humid forest conditions [95].

$$\mathbf{AGB} = (p \times \exp(-1.499 + (2.148\ \text{In (D)}) + (0.207 \times \text{In (D)}^2) - (0.0281 \times \text{In (D)}^3))\ 0.001 \tag{8}$$

where:

AGB = Above ground biomass (tree)

p = is the density of Wood (g/cm^3).
D = is the diameter at breast height (cm).

3. Results and Discussion

3.1. Geographical Distribution and Environmental Preferences of the Moraceae Family in Continental Ecuador

There are 43,449 records of the Moraceae family distributed on the five continents (Figure 2B), of which 783 have been registered thus far in continental Ecuador. They are distributed in the regions Amazon, Andean highlands, and Coastal lowland with 460, 173, and 150 records, respectively (Figure 2A).

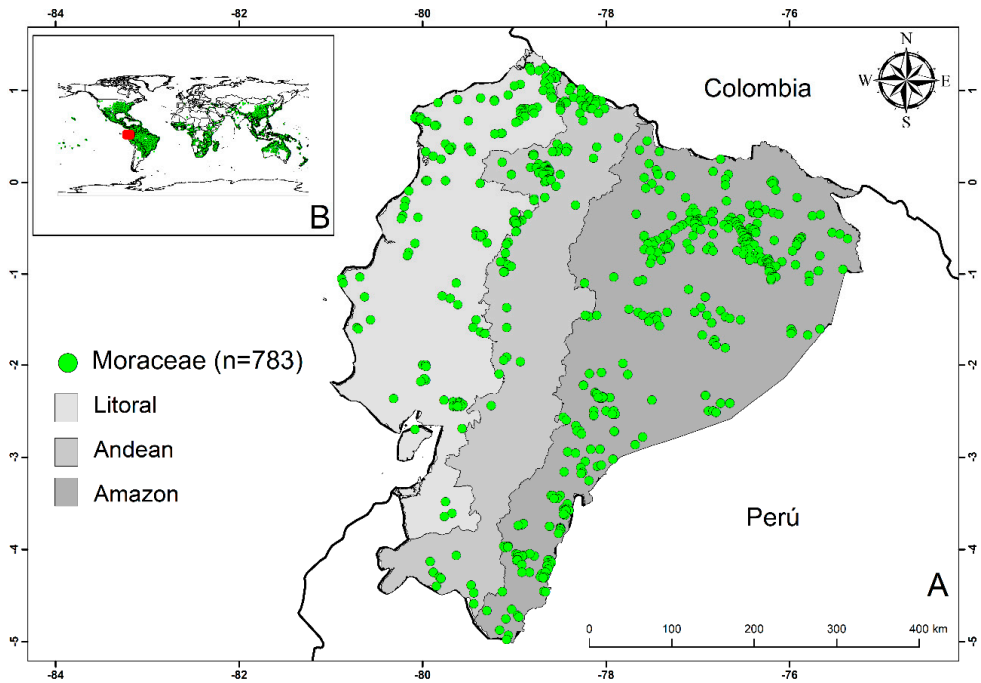

Figure 2. Geographic distribution of the records of the Moraceae family by regions of Ecuador (**A**) and worldwide (**B**).

From the estimation of the environmental preferences based on the presence records and environmental data, it is estimated that individuals belonging to the Moraceae family occupy a wide range of environmental conditions. For example, it is estimated that it could be found in areas characterized by altitudinal ranges between 1 and 3435 m.a.s.l. The values observed for the mean temperature are between 9.9 and 25.8 °C, while the observed annual precipitation in the forecast areas ranged between 250 and 4379 mm (Figure 3).

3.2. Composition and Structure (Horizontal and Vertical)

Due to the wide range of diameters of the trees of the Moraceae family, five diameter classes were established, where the largest number of these trees are concentrated in the first class, which ranges between 10.0 and 20.0 cm DAP, grouping 56.4% of the total number of individuals. The second diameter class (20.01 to 30.0 cm) groups 26.5% of the trees, followed by the class of 30.01 to 40.0 cm with a representativeness of 8.5%. Finally, the last two diameter classes group 4.3% of the trees, with five individuals each (Figure 4).

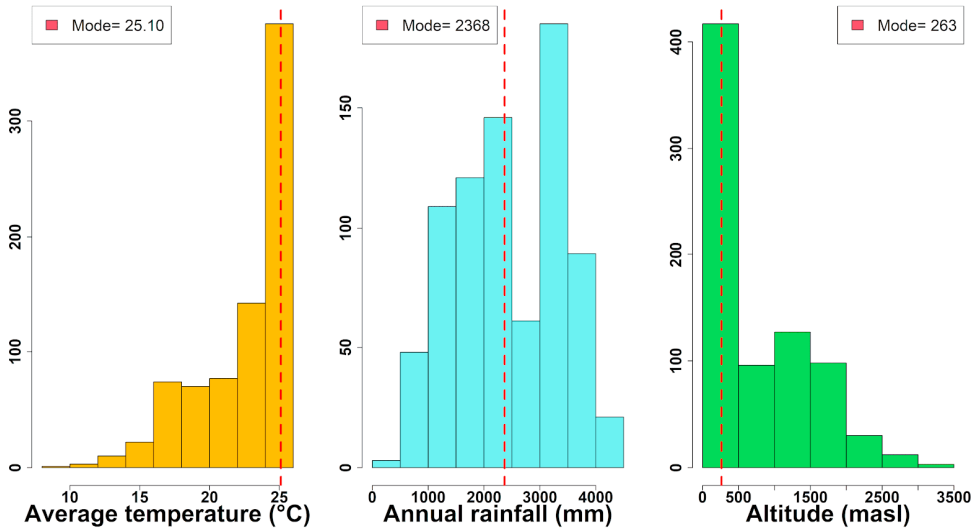

Figure 3. Environmental preferences of the Moraceae family in continental Ecuador.

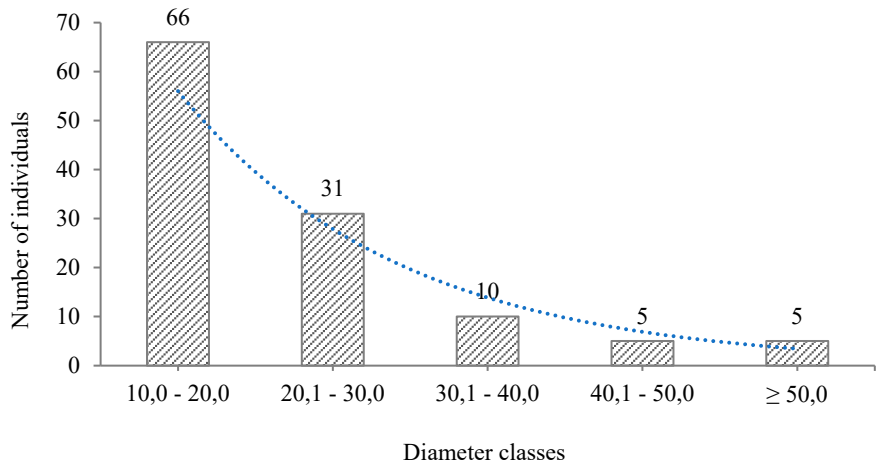

Figure 4. Distribution of individuals of the Moraceae family by diameter class, in the piedmont evergreen forest in the Sumaco Biosphere Reserve of the Ecuadorian Amazon.

This behavior is the typical resemblance to an inverted "j", which highlights the heterogeneity of the forest, composed of individuals with disetanic ages and with ample potential for natural regeneration and self-preservation. This trend is similar to that previously obtained in an analysis of the structure of the species of the Arecaceae family in an evergreen Piedmont forest in the province of Napo (central Ecuadorian Amazon) [96]. These authors determined that the largest number of individuals was grouped in the diameter class of 0–10 cm with a representativeness of 86.6%.

The horizontal profile of the species of the Moraceae family of transect number 11—located between 801–900 m.a.s.l., whose crowns are marked with red borders (Figure 5)—are distributed along the transect, demonstrating that they develop dispersedly, covering an approximate area of 164 m^2, which represents around 16.43% of the total area of the transect. In addition, we noted the important coverage of the species of the Arecaceae family; despite its low abundance, the species *Iriartea deltoidea* has a crown diameter of up to 12 m. The clearings that are evident are due to the non-existence of nine individuals that were considered in the first data collection that was recorded. Their absence is attributed to ecological factors typical of the forest as they are dead due to their age, or failing that, they have fallen. Within the forest, there are individuals with diameters less than 10 cm DAP, but these were excluded in the present study. Finally, certain clearings may also be from treetops that are outside of the transect area.

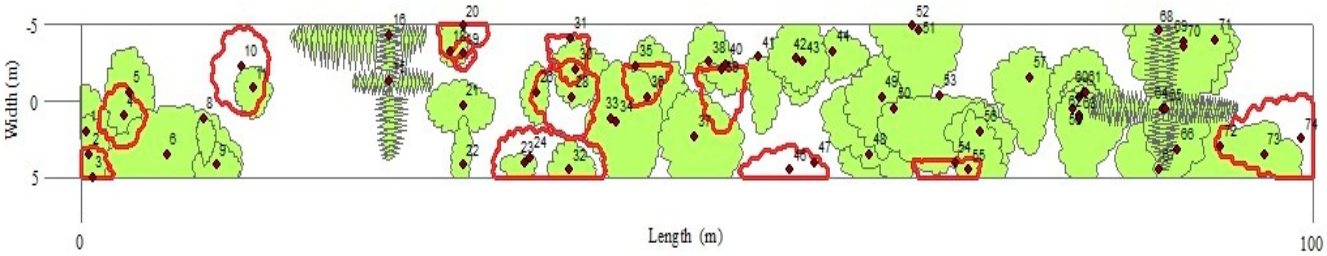

Figure 5. Distribution of individuals (transects) of the Moraceae family in the horizontal profile of the piedmont evergreen forest in the Sumaco Biosphere Reserve of the Ecuadorian Amazon.

In the vertical profile of the forest (Figure 6), it is observed that the individuals of the Moraceae family are distributed in the upper, middle, and lower strata. The species *Brosimun lactescens* (S. Moore) C.C. Berg predominates in the upper canopy, while *Maquira guianensi* subsp costaricana (Standl.) C. C. Berg, *Sorocea steinbachii* C. C. Berg, *Pseudolmedia* sp., and *Ficus* sp. trees are stagnated in the lower canopy. This behavior is attributed to ecological factors typical of the forest, such as competition between trees of other species and families for the nutrients available in the soil and due to competition for the light factor. These are key elements for their development, as well as due to the morphological and genetic characteristics of each species.

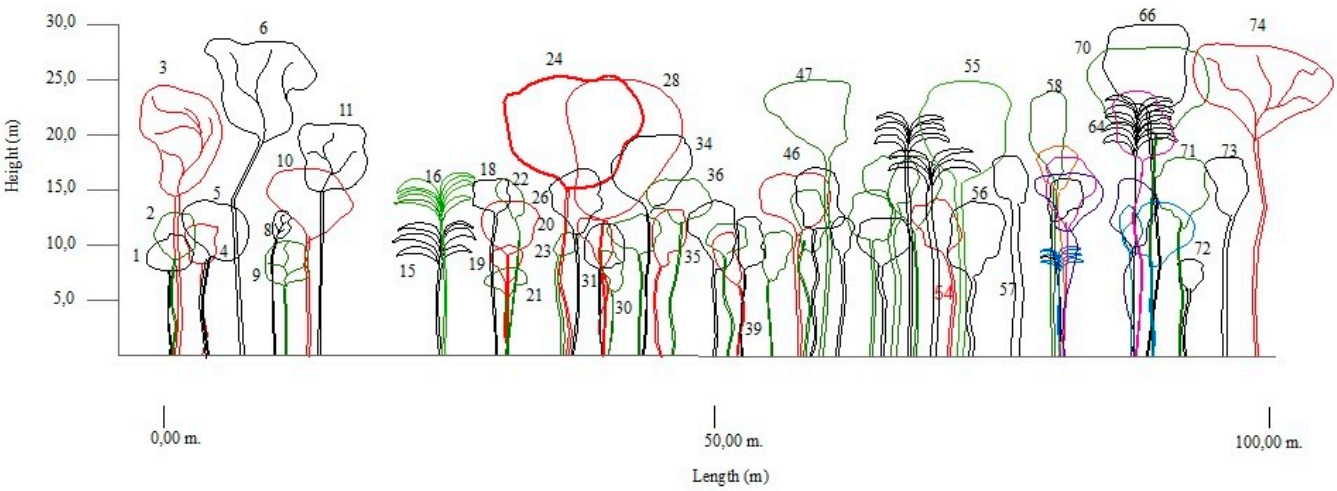

Figure 6. Distribution of individuals (transects) of the Moraceae family in the horizontal profile of the piedmont evergreen forest in the Sumaco Biosphere Reserve of the Ecuadorian Amazon.

3.3. Ecological Importance Value Index (IVI)

Considering the percentage values of the ecological parameters, *Ficus* sp. is registered as the most important, with 23.96 of IVI, followed by *Ficus cuatrecasana* Dugand with 20.56 of IVI; in the decreasing measure range, *Brosimun lactescens* (S.Moore) C.C. Berg with 11.81, *Naucleopsis* sp., with 11.33, *Brosimun alicastrum* with 10.82 of IVI, while the remaining species register a value of less than 10.00 of IVI (Table 2).

The species with the lowest determined importance value index is *Sorocea muriculata* Miq., with an IVI of 1.04. These results corroborate the proposal of Patiño et al. [97], who also determined it as the species with the lowest IVI, with a value of 0.11, as realized within five transects established between 600 and 700 m of altitude in a piedmont evergreen forest of the Napo province of the Ecuadorian Amazon.

Fundamental studies have been performed in the tropical forests of South America [98]. Three types of forests of the Caparú Biological Station in Colombia were analyzed, in two of which the Moreaceae family is among the most important, with 118, 9 and 93.7 of IVI in the Colina and Terraza forests, respectively, and occupying, in the same order, the second

and fifth places in terms of ecological importance. In the same study, at the species level, *Brosimun lactescens* (S.Moore) C.C. Berg holds the sixth place of ecological importance within the forest of the Hill, with 35.2 of IVI. The species *Brosimun utile* is also registered within the 15 most important species in the terrace forest, with an IVI of 36.6. This reflects the wide distribution of species of the Moraceae family in Neotropical forests.

Table 2. Individuals (N° Ind), basal area (BA), abundance (Abund), dominance (Dom) and IVI.

	Species	N° Ind	BA	Abund (%)	Dom (%)	IVI
1	*Ficus* sp.	11	0.96	9.40	14.56	23.96
2	*Ficus cuatracasana* Dugand	2	1.24	1.71	18.85	20.56
3	*Brosimum lactescens* (S. Moore) C.C. Berg	2	0.67	1.71	10.10	11.81
4	*Naucleopsis* sp.	7	0.35	5.98	5.35	11.33
5	*Brosimum alicastrum*	8	0.26	6.84	3.98	10.82
6	*Sorocea* sp.	6	0.20	5.13	3.10	8.22
7	*Sorocea steinbachii* C. C. Berg	6	0.16	5.13	2.43	7.56
8	*Batocarpus orinocensis* Karst.	5	0.19	4.27	2.87	7.14
9	*Ficus guianensis* Des. ex. Ham	3	0.30	2.56	4.55	7.12
10	*Calliandra carbonaria*	6	0.11	5.13	1.74	6.86

3.4. Floristic Wealth

3.4.1. Relative Abundance

A total of 117 trees with a DBH $\geq$ 10 cm were distinguished as belonging to the Moraceae family, which correspond to 32 identified species. A group of 23 individuals was determined as unidentified species because they lacked fertile botanical samples that allow them to be identified with the use of the Amazon Herbarium collection. The species identified with the greatest abundance were *Ficus* sp. with an abundance of 9.24%, *Brosimun alicastrum* with 6.72%, *Naucleopsis* sp. with 5.88%, and *Calliandra carbonaria, Sorocea* sp. *Sorocea steinbachii* C.C.Berg with 5.04% (Figure 7). In a previous study [97], it has been stated that the Moracacea family presented itself as one of the most diverse, with 7.14%, with the species *Brosimun alicastrum* being the most abundant, with seven individuals within a floristic study of five transects of 1000 m^2 in an evergreen foothill forest at an altitude of between 600 and 700 in the province of Napo.

The Moraceae family is widely distributed in the tropical and subtropical region; therefore, between 2009 and 2010, the status of the populations of the genera *Ficus, Maclura*, and *Brosimun* in the mineral ecological reserve of Nuestra Señora de la Candelaria in Sinaloa, Mexico, was evaluated. This is an area in which five study routes were established, between 400 and 800 m above sea level, where the species *Brosimun alicastrum* registered the highest abundance with 71.81%, followed by *Maclura tinctoria* with 17.02%, and *Ficus mexicana* with 4.26% [99]. On the other hand, Calzadilla-Tomianovich and Cayola [100] analyzed the floristic composition and structure of an Amazonian foothill forest in the Madidi Integrated Management Area in La Paz, Bolivia, at an altitude of 360 m above sea level, where the Moraceae family is the second most abundant, with 33 individuals. There, they have been distributed in eight species, where among the species that were determined are *Ficus cuatrecasana* Dugand, *Pseudolmedia laevis* (Ruiz and Pav.) J.F. Macbr., and *Clarisia biflora* (Ruiz and Pav.), among others.

3.4.2. Dominance

It was determined that within the ten most dominant species of the Moraceae family, the species *Ficus cuatrecasana* Dugand predominates with a relative abundance of 18.85%, where only two individuals were recorded. Its high dominance is due to the fact that they have a basal area of 1.24 m^2. *Ficus* sp., with 0.96 m^2, occupy the second place in dominance with 14.56%. In third place appears the species *Brosimun utile* with 0.66 m^2, representing 10.10%. It is followed by *Naucleopsis* sp. with 0.35 m^2 (5.35%), *Ficus guianensis* Des. ex. Ham with 0.30 m^2 (4.55%), *Brosimun alicastrum* with 0.26 m^2 (3.98%), *Sorocea* sp with 0.20 m^2

(3.10%), *Clarisia racemosa* Ruiz and Pav. with 0.19 m^2 (2.94%), and *Batocarpus orinocensis* Karts with 0.19 m^2 (2.87%).

Compared to the aforementioned study [100], the species *Ficus cautrecasana* Dugand does not appear among the most dominant due to a single recording of a unique individual, with a basal area of 0.009 m^2, equivalent to 0.032%. The species with the least dominance is *Sorecea muriculata* Miq., with 0.012 m^2, which represents 0.19%. The dominance value of this species is similar to that determined by Patiño et al. [97], ranking as the least dominant species—with 0.01 m^2, equivalent to 0.09%—within a study performed between 601 and 700 m.a.s.l. in an evergreen foothill forest in the province of Napo.

3.5. Diversity Indices

Applying the Shannon diversity equation, which measures specific biodiversity, we determined that the diversity index of the Moraceae family is 4.35. This index corroborates the high diversity that exists in the montane evergreen forests of the Ecuadorian Amazon. Our result is higher than that obtained by Estrella [101], who determined an index of 3.71 in 20 MUs established in a lowland evergreen forest of the Ecuadorian Amazon. However, it is also interpreted as a region of high floristic diversity. On the other hand, the Margalef index, or specific diversity index, was determined based on the number of individuals of different species. The calculation of this parameter yielded a value of 6.51, which allowed us to determine the high biodiversity of the existing forest species in the studied vegetation cover.

3.6. Accumulated Aboveground Biomass of the Moraceae Family

The accumulated aboveground biomass (AGB) of the species of the Moraceae family is reflected in a total average of 36.09 Mg ha^{-1} along the altitudinal gradient. There is wide variability in the average accumulation of aerial biomass between the four floors, with the highest carbon concentration on floor 3 (801–900 m) with 74.63 Mg ha^{-1}, while the lowest carbon concentration has been determined to be on floor 1 (601–700 m) with 16.45 Mg ha^{-1} (Table 3).

Table 3. Average Carbon of the Aboveground Biomass of the species of the Moraceae family of the piedmont evergreen forest in the Sumaco Biosphere Reserve of the Ecuadorian Amazon.

Variable	Average by Altitudinal Gradients				
	P1 (601–700)	**P2 (701–800)**	**P3 (801–900)**	**P4 (901–1000)**	**Average (601–1000)**
AGB (Mg ha^{-1})	12.34	36.21	74.63	17.06	35.09

The species with the highest carbon accumulation in the biomass is *Ficus cuatrecasana* Dugand, which, despite only registering two individuals, registered an AGB of 157.36 Mg ha^{-1}, followed by *Ficus* sp., with an AGB of 90 Mg ha^{-1}. The species *Brosimun utile* reflects important carbon accumulation values, reporting 59.98 Mg ha^{-1} of AGB (Figure 7).

Based on the realized calculation, it was determined that the species of the Moraceae family reported along the altitudinal gradient of the evergreen foothill forest accumulate a total of 35.09 Mg ha^{-1}. Nonetheless, in a comparative analysis with the data itself, considering the abundance by diameter class and the AGB, it was determined that the relationships of their projections are not proportional. This occurred in the view that the accumulated Biomass values will not always be a function of the number of individuals by diameter class (Figure 8). Such is the case that the present investigation reflected the highest concentration of AGB in individuals with a DBH equal to or greater than 50 cm, accumulating a total of 24.16 Mg ha^{-1}, with five individuals. This same number of trees constitute the class from 40.1–50.0 cm DAP, reflecting the lowest accumulation of AGB with a value of 7.82 Mg ha^{-1}. The diameter class of 10.0–20.0 cm DAP, despite having the highest number of individuals, only accumulates an ABG of 11.16 (Mg ha^{-1}).

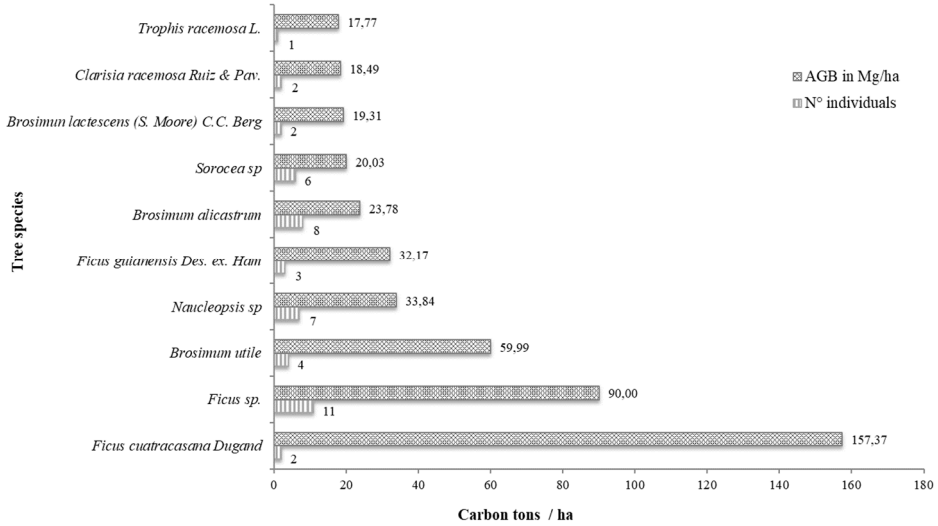

Figure 7. Species of the Moraceae family with the highest AGB per hectare of the piedmont evergreen forest in the RBS of the Ecuadorian Amazon.

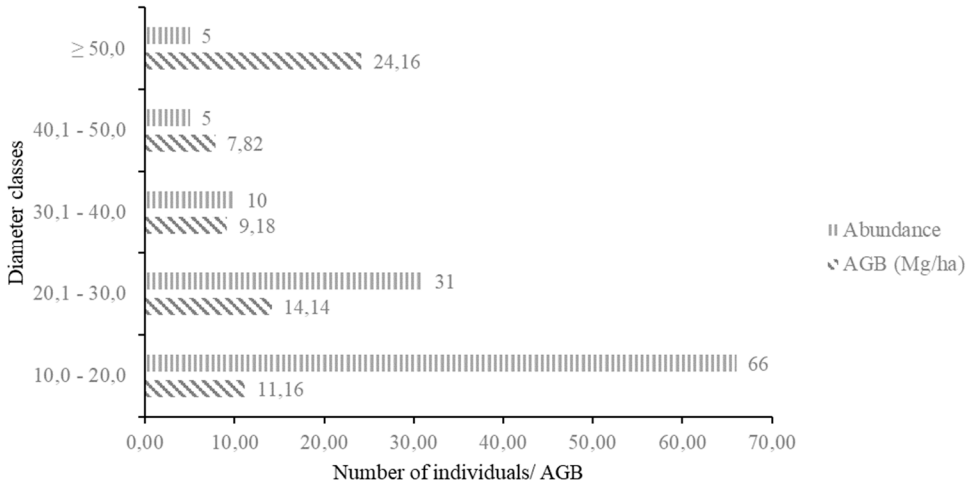

Figure 8. Abundance and Aerial Biomass by diameter class of the piedmont evergreen forest in the Sumaco Biosphere Reserve of the Ecuadorian Amazon.

3.7. Limitations and Future Research

One of the main limitations of the study lies in the sample size, due to the use of a reduced number of transects and sampling plots. In addition, as the focus is solely on the SBR, the generalizability of the findings to other forest types or geographic regions is limited. To overcome these limitations, it is suggested to expand the sample size by conducting additional sampling of the Moraceae family in different regions of Ecuador, other than the Amazon. This would allow us to obtain a broader and more diverse view of the distribution, composition, and structure of the Moraceae family in the country, as well as to evaluate possible geographic variations in its aerial biomass and conservation.

4. Conclusions

The floristic composition of the Moraceae family is made up of 32 species, distributed in 117 individuals that cover the 20 transects established between 601 and 1000 m.a.s.l. The genus *Ficus* sp. is the most abundant, registering 11 individuals, equivalent to 9.40% of relative abundance. At the structural level, the species *Ficus cuatracasana* Dugand behaved as the most dominant, achieving a position based on its basal area, but not based on the number of individuals, being also the species with the second highest index of importance value, preceded by *Ficus* sp.

The horizontal and vertical profiles indicated the homogeneous distribution of the trees of the Moraceae family along the altitudinal gradient, grouping in greater quantities in the diameter class of 10.0 to 20.0 cm DBH. This is due to the heterogeneous nature of the forest in terms of the diversity and age of its individuals. It was possible to estimate the area of coverage of the crowns of all the individuals of the Moraceae family, covering approximately 16.4% in relation to the sampling area. The transect with the largest number of individuals of the family was selected and it was projected with an accurate approximation of the distribution of the trees, which directly affects the capture of carbon in the aerial biomass.

By applying an allometric equation, it was determined that the 117 individuals of the Moraceae family present an AGB accumulation of 35.06 Mg ha^{-1}. These data will serve as a starting point for future research and projects aimed at the protection and conservation of native forest cover.

Author Contributions: Conceptualization, W.G.-C., M.H.-R. and B.T.; methodology, W.G.-C. and B.T.; software, R.J.H.-F., A.T., and R.L.-T.; validation, W.G.-C., B.T. and M.H.-R.; formal analysis, W.G.-C. and B.T.; investigation, W.G.-C., B.T., R.L.-T., M.H.-R., R.J.H.-F. and T.T.; data curation R.L.-T., A.T. and T.T.; writing—original draft preparation, W.G.-C., M.H.-R., T.T., R.J.H.-F., A.T. and R.L.-T.; writing—review and editing, W.G.-C., B.T., R.J.H.-F., T.T., M.H.-R. and R.L.-T.; supervision, W.G.-C. and B.T. All authors have been involved in developing, writing, commenting, editing, and reviewing the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: This is not applicable as the data is not in any data repository of public access; however, if editorial committees need access, we will happily provide them with it. Please use this email: wgarciac@uteq.edu.ec.

Acknowledgments: The authors would like to thank the Faculty of Agricultural and Forestry Sciences, Quevedo State Technical University (UTEQ).

Conflicts of Interest: The authors declare no conflict of interest.

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