Original Research Article
Composition, structure and ecological importance of Moraceae in a residual forest of Ucayali, Peru
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ABSTRACT

Species of the Moraceae family are of great economic, medicinal and ecological importance in Amazonia. However, there are few studies on their diversity and population dynamics in residual forests. The objective was to determine the composition, structure and ecological importance of Moraceae in a residual forest. The applied method was descriptive and consisted of establishing 16 plots of 20 m × 50 m (0.10 ha), in a residual forest of the Alexander von Humboldt substation of the National Institute of Agrarian Innovation-INIA, Pucallpa, department of Ucayali, where individuals of arboreal or hemi-epiphytic habit, with DBH ≥ 2.50 cm, were evaluated. The floristic composition was represented by 33 species, distributed in 12 genera; five species not recorded for Ucayali were found. Structurally, the family was represented by 138 individuals/ha with a horizontal distribution similar to an irregular inverted “J”. However, there were different horizontal structures among species. It was determined that 85% of the species were in diameter class I (2.50 to 9.99 cm), being the most abundant Pseudolmedia laevis (Ruiz & Pav.) J.F. Macbr. (41.88 individuals/ha); and the most dominant were Brosimum utile (Kunth) Oken (1.71 m2/ha) and Brosimum alicastrum subsp. bolivarense (Pittier) C.C.Berg (0.90 m2/ha). Likewise, P. laevis and B. utile were the most ecologically important. The information from the present research will allow the establishment of a baseline, which can be used to propose the management of Moraceae in residual forests in the same study area.

Keywords: Residual Forest; Abundance; Dominance; IVI; New Records

1. Introduction

Peru has an arboreal richness of 4,618 species, grouped in 148 families[1], which represents an incomparable opportunity and an urgent priority for floristic research. In addition, it is considered one of the most biologically diverse countries in the world[2]. However, large forest areas remain unexplored[3], and records are still incomplete and fragmented[4]. Moraceae presents considerable abundance and species richness[5-7], which influences it to be considered ecologically important in the different forests of Amazonia[8-13]. Recent studies found that Brosimum utile (Kunth) Oken is the species with the greatest ecological weight, at 107 masl in Colombia[13]; while, in Ecuador, Ficus cuatra-casana Dugand dominates the horizontal space, between 601 to 1,000 masl[14]. In Peru, the Moraceae family is represented by 19 genera, 128 species, with the genus Ficus being the most diverse with 102 species and 20 subspecies[1,15-17], which has been complemented by the discovery of new species and new reports for the Peruvian flora[18,19], which
together group all the names recognized to date; while, for the Ucayali region there are a total of 58 species and 6 subspecies[4].

The Moraceae are of economic importance mainly for the value of their wood[3,20,21], being the most used species, in primary processing, Brosimum utile subsp. ovatifolium (Ducke) C.C. Berg “Panguana”, Maquira coriacea (H. Karst.) C.C. Berg “Capinuri” and Clarisia racemosa Ruiz & Pav. “Mashonaste, Tulpay”[22]. In addition, there are species with medicinal[20,23,24] and food use[25]. The fruits produced by several species are indispensable for numerous species of vertebrate frugivores, which significantly influences forest dynamics[26-28]. Other authors mention that Moraceae are among the top ten families, in terms of number of tree species[1], with Pseudolmedia laevis (Ruiz & Pav.) J.F. Macbr. being the fourth most abundant species in the Amazon[29]; however, Licona et al.[30] indicate that there are not many studies on the dynamics of Amazonian forests and the ecology of their species. Likewise, Calvi[6] points out that one of the main factors affecting the distribution and species richness of the Moraceae family in the Madidi National Park in Bolivia is the conservation status of the forests.

The objective of this study was to know the composition, structure and ecological importance of Moraceae in a residual forest of the Alexander von Humboldt substation of the National Institute of Agrarian Innovation Ucayali (Peru).

2. Materials and methods

2.1 Study area

The work was developed in a residual primary forest at the Alexander von Humboldt substation of INIA, Von Humboldt district, in the province of Padre Abad, department of Ucayali (Peru), between 8°49′31.7″S and 75°3′19.5″W. The study sector belongs to the lowland rainforest Ecozone[31] and is physiographically undulating (profile with regular waves of 5 to 10 m in height) with good drainage[32]. It has an estimated precipitation of 3,600 mm and the average temperature is 26 °C[33]. Based on topographic charts, the study area was preliminarily defined where, due to the degree of forest fragmentation, 16 sampling units of 0.10 ha (20 m × 50 m) were selectively located in an altitudinal range from 211 to 286 m following the methodology of Calvi[6] (Figure 1). Each woody individual of arboreal or semi-epiphytic habit, belonging to the Moraceae family, with diameter at breast height (DBH) ≥ 2.50 cm was evaluated. The herborization protocol of Bridson and Forman[34] was used to collect and transfer the samples.

2.3 Taxonomic identification

A review was made of the Moraceae collections from the Alexander von Humboldt Experimental Annex, located in the Forest Herbarium of INIA-Pucallpa, as well as virtual catalogs, specialized bibliography and databases: The Plant List (http://www.theplantlist.org), Missouri Botanical Garden (http://www.tropicos.org), Global Biodiversity Information Facility-GBlF (https://www.gbif.org), NYBG Steere Herbarium (http://sweetgum.nybg.org) and the Field Museum (https://plantidtools.fieldmuseum.org). Subsequently, the identification was corroborated at the Herbarium Selva Central Oxapampa (HOXA), biological station of the Missouri Botanical Garden, located in Oxapampa. Finally, the exsiccatae were deposited in the Biological Depository of INIA-Pucallpa.

2.2 Species inventory

Figure 1. Diagram of the plot used for the study of Moraceae in a residual forest.

2.4 Data analysis

To represent the floristic composition, the species existing at the site were considered[35-37]. To calculate sampling efficiency, a species accumulation curve was elaborated using the non-parametric CHAO 2 estimator[38], which considers the distribution of species by sampling[39]. The analysis was performed using Estimates v.9.1.0[40].
The horizontal structure for the 16 plots (1.6 ha) was represented by the number of individuals per diameter class and the abundance of species; basal area was also calculated to know the distribution of the family and species dominance\cite{36,37,41}. The data were grouped into the following diameter classes: I (2.50 to 9.99 cm), II (10 to 19.99 cm), III (20 to 29.99 cm), IV (30 to 39.99 cm), V (40 to 49.99 cm), VI (50 to 59.9 cm), VII (60 to 69.99 cm), VIII (70 to 79.99 cm), IX (80 to 89.99 cm), X (90 to 99.99 cm), XI (100 to 109.99 cm), XII (110 to 119.99 cm), XIII (120 to 120.99 cm) and XIV (130 to 139.99 cm).

Ecological importance was determined by calculating the species Importance Value Index (IVI) expressed as a percentage\cite{42}, the formula is shown below:

$$IVI = IVI_j = AbR_j + FR_j + DoR_j$$

Where:
- Relative abundance: \( AbR_j = \frac{100 \times Ab_j}{\Sigma Ab_j} \)
- Relative Frequency: \( FR_j = \frac{100 \times F_j}{\Sigma F_j} \)
- Relative dominance: \( DoR_j = \frac{100 \times Do_j}{\Sigma Do_j} \)

Being:
- \( Ab_j \): Total number of individuals of species \( j \) in all plots.
- \( F_j \): Number of plots where species \( j \) is present.
- \( Do_j \): Total basal area of species \( j \) in all plots.

3. Results

3.1 Floristic composition of the family Moraceae

In the 16 sampling plots (1.6 ha), 33 species were identified, while according to CHAO 2 the expected species were 44 (Figure 2). Accordingly, the richness (\( S \)) observed represented 75% of the species that constitute the residual forest.

The species composition was distributed in 12 genera: Batocarpus, Brosimum, Clarisia, Ficus, Helicostylis, Maquira, Naucleopsis, Perebea, Poulsenia, Pseudolmedia, Sorocea and Trophis. Three genera presented the highest richness: Ficus (8 species), Brosimum (6 species) and Perebea (4 species), grouping 54.55% of the total number of species (Figure 3).


3.2 Horizontal structure of the family Moraceae

In 1.6 ha, 221 individuals were recorded and evaluated, 138 individuals/ha from 2.50 cm DBH; while from 10 cm DBH the density was 41.25 individuals/ha. The average DBH was 13.32 cm and the maximum was 136 cm. The individuals were grouped in 11 of the 14 diameter classes considered for the structural analysis, showing an irregular discetaneous diameter distribution similar to an inverted “J” (Figure 4).

Figure 3. Richness of genera of the Moraceae family in a residual forest.

Figure 4. Irregular inverted horizontal structure of species of the Moraceae family in a residual forest.

Figure 5. Species of the Moraceae family with bimodal horizontal structures in a residual forest.
Another group of species were distributed only in classes I and II. Helicostylis tomentosa (Poepp. & Endl.) Rusby, Perebea angustifolia (Poepp. & Endl.) C.C. Berg and Pseudolmedia laevigata Trécul presented horizontal structures of discetaneous appearances; while, Brosimum guianense (Aubl.) Huber and Batocarpus costaricensis Standl. & L.O. Williams showed horizontal structures with bimodal appearances.

3.3 Abundance of species

The six most abundant species were: Pseudolmedia laevis (41.88 individuals/ha), Brosimum utile (11.25 individuals/ha), Clarisia biflora (8.75 individuals/ha), Poulsenia armata (8.75 individuals/ha) and C. racemosa (6.25 individuals/ha), representing 55.7% of the total number of individuals.

The species that were present only in class I and were represented by only one individual (0.63 individual/ha) were: Ficus tonduzii vel. sp. aff., Ficus paraensis (Miq.) Miq, Perebea guianensis subsp. hirsuta, Naucleopsis glabra Spruce ex Pittier and Sorocea briquetii J.F. Macbr. While Perebea longipedunculata C.C. Berg, Sorocea steinbachii C.C. Berg, Naucleopsis ulei (Warb.) Ducke and Maquira calophylla (Poepp. & Endl.) C.C. Berg presented 1.88, 2.50, 4.38 and 5.63 individuals/ha in class I, respectively. On the other hand, F. ursina and F. schultesii were distributed in classes III and VI, with 0.63 individuals/ha each; on the other hand, Ficus insipida subsp. insipida and Ficus popenoei Standl. presented 0.63 individuals/ha each in class VII.

3.4 Basal area

The total basal area of the species evaluated was 5.81 m²/ha. The distribution, by diameter class of the species, showed a discontinuous increase in the last classes (Figure 6). The genus Brosimum represented 61.1% of the total basal area (3.55 m²/ha). A co-dominance of species was found, the first was Brosimum utile with 1.71 m²/ha and the second was B. alicastrum subsp. bolivarense with 0.89 m²/ha, despite being represented by only one individual in class I and another in class X. Both species represented 44.80% of the total basal area.

![Figure 6. Cumulative distribution of basal areas by diameter class of the Moraceae family in a residual forest.](attachment:image)

<table>
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<tr>
<th>Species</th>
<th>AbA</th>
<th>AbR</th>
<th>FA</th>
<th>FR</th>
<th>DoA</th>
<th>DoR</th>
<th>IV (300%)</th>
<th>IIV (100%)</th>
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<td>29.34</td>
<td>46.42</td>
<td>15.47</td>
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<td>19.51</td>
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Table 1. (Continued)

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<th>DoR</th>
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<td>9.20</td>
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<td>0.34</td>
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<td>0.09</td>
<td>7.72</td>
<td>2.57</td>
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<td>0.03</td>
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<td>100.00</td>
<td>9.31</td>
<td>100.00</td>
<td>300.00</td>
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</tr>
</tbody>
</table>

Note: AbA (Absolute abundance), AbR (Relative abundance), FA (Absolute frequency), FR (Relative frequency), DoA (Absolute dominance), DoR (Relative dominance), IVI (Importance Value Index = AbR + FR + DoR).

3.5 Ecological importance of the species of the Moraceae family

The ecological weight of the first six species represented 53.49% of the IVI. The most important were *Pseudolmedia laevis* and *Brosimum utile*, the former due to its abundance (30.32) and frequency (12.50); while, the latter due to its abundance (8.14) and dominance (29.34). The species *B. alicastrum* subsp. *bolivarense* and *B. acutifolium* subsp. *obovatum* were also important, but due to their dominance (15.47) and (7.11), respectively; while *Clarisia racemosa* and *C. biflora* were important due to their abundance (4.52) and frequency (6.25) (Table 1).
4. Discussion

4.1 Floristic composition

When studying the composition of Moraceae, in the Madidi forest in Bolivia, between 100 to 250 m altitude, using plots of 20 m × 50 m and 10 m × 100 m, with a sampling area of 4.9 ha, 24 species and 11 genera were found[6], being this richness lower than that obtained in the present study, 33 species and 12 genera in 1.6 ha in a residual primary forest. As in the investigations of Calvi[6] and Marcelo-Peña and Reynel[12], Ficus was the genus that reported the highest floristic richness.

4.2 Horizontal structure

According to Louman et al.[41], this occurs because some diameter classes have few or many individuals. However, this type of distribution showed that the forest has a good reserve of small individuals, at the family level, in class I, 70% of the total number of individuals and 85% of the species, which is abundant enough to replace large individuals. Lam-Precht[35] mentions that the aforementioned distribution guarantees the sustainable yield of humid tropical forests, so it can be affirmed that the harvesting of all or most of the species of the Moraceae family in the forest under study could be carried out in compliance with the ecological dimension of sustainable forest management. Pseudolmedia laevis was the most abundant species, thus agreeing with ter Steege et al.[20].

The complete discetaneous structures of Pseudolmedia laevis and Poulsenia armata indicate that these species will not present problems to regenerate; whereas, species with irregular discetaneous structures (such as Brosimum lactescens, Clarisia biflora, C. racemosa, B. acutifolium subsp. obovatum, B. multinervium and B. utile) and with bimodal structures (such as Ficus maxima vel. sp. afi, F. americana sbsp. guianensis, Pseudolmedia macrophylla, Brosimum alicastrum subsp. bolivarense and Perebea mollis subsp. mollis) will need large clearings to regenerate[41].

The discontinuous increase in the basal area of Moraceae in the last classes reflects the degree of intervention in the study area. According to Louman et al.[41], undisturbed forests generally show an accumulation of basal area in the last class. Orozco and Brümmer[43] explain that if a species has the largest basal area of a site, it is dominating, even if it is not abundant, as was the case of Brosimum utile and B. alicastrum subsp. bolivarense.

4.3 Ecological importance

Brosimum utile was the second species with the greatest ecological weight, after Pseudolmedia laevis, obtaining a similar result to the study conducted by Mena-Mosquera et al.[13]. Licona et al.[30] point out that there is not much information on the dynamics of Amazonian forests and the ecology of their species. On the other hand, we do not know other biological processes associated with richness and diversity, such as the effects caused by dispersers and competition between plants, which could help to understand many concepts.

5. Conclusions

The residual forest of the Alexander von Humboldt substation of INIA harbors an important richness of species of the Moraceae family, with five new reports for Ucayali.

There are different horizontal structures between species belonging to the same family, with notorious implications for the identification and planning of silvicultural interventions; suggesting for this type of forest, that management be diversified (or multiple use) in terms of species utilization and the generation of timber and non-timber goods.

The differences in structure and ecological importance are a manifestation of the individuality of each species; however, Pseudolmedia laevis and Brosimum utile are noteworthy because they presented the highest ecological weights.

Conflict of interest

The authors declared no conflict of interest.

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