Advancing Amazonian botanical knowledge: a detailed ecological characterization of an open ombrophile forest, southwest Amazonian Brazil

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ABSTRACT

Biodiversity inventories present excellent opportunities for ecological investigations and the classification of different threats to the community, nonetheless these applications are not frequently employed. Our main objective was to determine the tree and palm community within a one-hectare areas, also exploring the association between functional attributes and the projected threat of category for the future (by 2050) in a conservation unit situated within the Brazilian Amazon Deforestation Arc. We established a rectangular plot (10x1000m) to assess the community structure. Information on seed and fruit size attributes was obtained from the literature, along with data on the projected threat category. Overall, two taxa (Rubiaceae sp.and Rhizophoraceae sp.) were characterized only at the family level, 106 at the genera level (morpho-species) and 124 until binomial name. We found information about seed size for 55 genera. Medium-sized seeds were the most frequent, occurring in 22 genera, followed by large seeds (16), small seeds (6), and very small seeds (5). As for the projected threat status for 2050, we found that 28 species were classified as vulnerable and 16 species as endangered. In our plot we founded a few numbers of species with many individuals. We conclude that importance of improving regional floristic knowledge to address existing shortfalls in understanding about species distribution, ecology interactions, like dispersal characteristics, and threat status.

Keywords: plant inventories, biodiversity, Brazilian Amazon, traits attribute, threat status

INTRODUCTION

The Amazon region is renowned for its extraordinary biodiversity, making it one the most ecologically diverse regions in the world. Moreover, the acknowledgment of its essential contribution to critical ecosystem services has propelled the Amazon to attain global conservation eminence, commanding the attention of national and international scholars alike (Malhado et al. 2014; Santos et al. 2015). Regardless this premise, substantial portions of this biome remain unexplored. The vastness and isolation of the Amazon present formidable challenges for conducting systematic and regular investigations within the region, even when employing appropriate technological advancements (Ladle & Whittaker 2014). It is estimated that 40% of the Amazonian domain remains untouched by scientific inquiry (Schulman et al. 2007), indicating a significant research shortfall. Accessibility, primarily limited by poor riverine and terrestrial transportations routes, as well as the scarcity of scientific and technological facilities and infrastructure projects (*e.g.*, hydroelectric installations), restrict research efforts in the Amazon basin (Santos et al. 2015; Correia et al. 2016). Consequently, this situation engenders uncertainties regarding the spatial distribution of numerous species owing to prevalent sampling biases (Hortal et al. 2015).

Nevertheless, the Amazon confronts formidable obstacles characterized by alarming rates of habitat degradation and species extinctions (Assis et al., 2019). In the southern and southeastern regions, the presence of gaps is attributed to a long history of deforestation for pastureland, commonly referred to as the "Deforestation Arc", which has hindered specimen collections in this area (Stropp et al. 2020). This region has experienced cumulative higher taxa of deforestation through the years, resulting in loss of numerous species, some of which may have become extinct even before being scientifically documented, rendering previously collected records obsolete (Stropp et al. 2020). Long-term floristic inventories play a crucial role in advancing our understanding of diversity patterns, the distribution of flora in the Amazon region and their dynamics. Some studies of tree species in the Amazonian region, currently estimated to range from approximately 7000 to 10 000 species (Cardoso et al. 2017; ter Steege et al. 2020), remains far from complete, with the potential for as many as 5000 new species trees yet to be discovered (ter Steege et al. 2016).

Even with the availability of diverse estimation methods of species surveys, it is essential to recognize that the data are susceptible to temporal degradation. Temporal losses of data can arise from the inherent dynamism of natural systems, encompassing local extinctions, immigration patterns, and biological invasions (Tessarolo et al. 2017) Additionally, alterations in the taxonomic relationship of biodiversity categories {Formatting Citation} and natural shifts in species distribution and composition (Dornelas et al. 2012) can contribute to such temporal variations.

The literature extensively addresses the knowledge gaps surrounding species occurrences, commonly referred to as the Wallacean shortfall (Brown & Lomolino 2006; Ladle & Whittaker 2014; Hortal et al. 2015). This term refers to the insufficiency of existing knowledge about species distribution and geographical dynamics. From the standpoint of conservation and policy, it becomes imperative to prioritize extensive data collection efforts in regions characterized by high conservation value or facing imminent risks of habitat destruction, particularly where sampling completeness remains low. The Raunkiaer shortfall refers to the lack of knowledge regarding ecologically relevant species traits, encompassing both intra-specific and inter-specific trait variations (Hortal et al. 2015). Furthermore, this shortfall extends to comprehending the ecological functions associated with each trait, as well as elucidating how these functions are affected by such interactions. In addition, it aims to identify the specific combination of traits that collectively contribute to the performance of distinct ecosystem functions, thus emphasizing the significance of trait bundling (Díaz et al. 2013). Significant progress has been made in stablishing a shared repertoires of valuable traits applicable to various taxa, particularly in plants, alongside the implementation of standardized sampling protocols (Hortal et al. 2015). Nevertheless, it is important to acknowledge the existence of substantial shortfall in both taxonomic coverage and geographic representation, highlighting the need for further research and exploration. Our study aims to: (i) characterize the structure and composition of a one-hectare open ombrophile forest area within the Jamari National Forest, located in the southwestern Brazilian Amazon, within the Deforestation Arc; (ii) analyse the literature about seed size of genera found in our sampling units (Malhado et al 2015); (iii) investigate the biogeographical distribution of vegetation types associated with the species present in our plot; and (iv) assess the future projected threat status of the species for the year 2050.

MATERIAL AND METHODS

Study area

This study was conducted in the National Forest (Flona) of Jamari, located in the state of Rondônia, in the southwestern Brazilian Amazon (Figure 1). The research was carried out within the PPBio (Biodiversity Research Program) research module 'Potosi', a permanent plot infrastructure designed for long-term ecological monitoring. This conservation unit is characterized by a unique combination of protected status and active resource use, encompassing both sustainable timber harvesting concessions and cassiterite (tin ore) mining operations. Its location within the deforestation arc, a region under intense anthropogenic pressure, makes it a critical area for biodiversity research. The choice of this site provides valuable baseline data on forest structure and composition in a complex and strategically important Amazonian landscape.

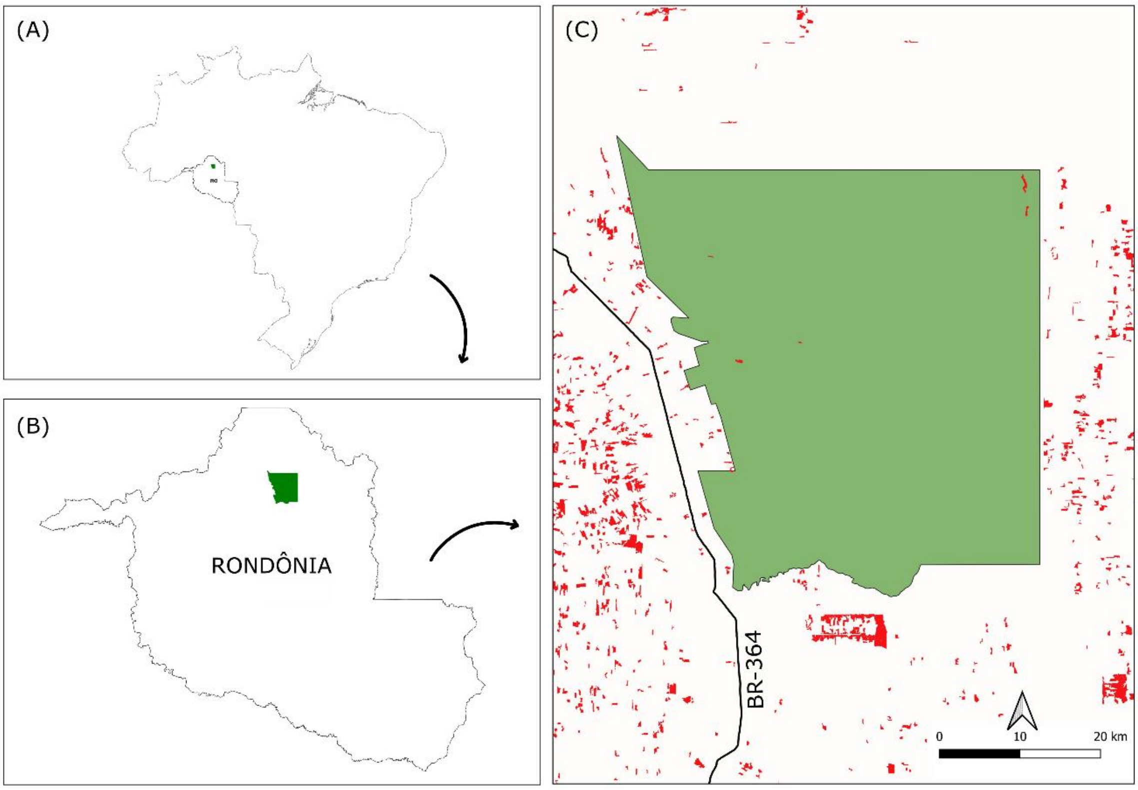

Figure 1 Maps showing the location of the Jamari National Forest (Flona do Jamari) in the state of Rondônia, Brazilian Amazon. (A) Brazil, (B) the state of Rondônia, and (C) the Jamari National Forest. The red areas in panel C represent deforested areas, based on data from PRODES (2008-2015) (Assis et al., 2019).

Plant inventory plot and botanical identification

We set up a one-hectare plot for plant inventory in September of 2014. We establish one hundred consecutive sample units measuring 10x1000m transect within the Jamari National Forest (Floresta Nacional do Jamari – Flona do Jamari). In each sample unit, we measured the diameter of all trees and palms ≥ 10cm at breast height (approximately at 1.3m high). The trees were identified in the field with aid of parataxonomists, and material was sent to specialists for identification for confirmation. Herbarium voucher numbers of all species sampled were collected and incorporated into the Herbarium Rondoniense João Geraldo Kuhlmann of the Universidade Federal de Rondônia. The dataset is available in the open database SpeciesLink (https://specieslink.net/search/) and can be accessed using the following search query [(coll_groups:(botanical)) AND (coll_ids:(((764) OR (765) OR (257)))) AND (county:((Itapuã do Oeste))) AND (locality.normal:((Módulo Potosí)))]. We tagged trees of all morpho-species (fertile and/or sterile) and collected at least one sample per morpho-species. Species names follow the standard nomenclature provided by Brazilian Flora Checklist (BFG, 2021).

Analysis of forest structure and plants species diversity

We characterized forest structure by estimating the following parameters for families and species of plot: absolute density (AD), relative density (RD), absolute frequency (AF), relative frequency (RF), absolute dominance (ADo), relative dominance (RDo) and importance value (VI). The Payandeh index was used to investigate patterns of tree spatial aggregation, which measures deviations from a random spatial distribution (Payandeh 1970; Carvalho 1983; Caldato 1998). To complement this structural analysis, we also calculated the Shannon-Weaver (H') index as a measure of species diversity and Pielou's evenness (J') to determine the equitability of species abundances within the community. All analysis concerned with forest structure were carried out on Fitopac 2.1 software by Shepherd (2010). The Payandeh, Shannon Weaver and Pielou equability indices were calculated with Microsoft Excel 2019.

Seed size

We classified seed sizes for all genera in our plot using the categorical framework from Malhado et al. (2015). According to this framework, seeds are classified into four size levels: large (≥2.0 cm), medium (1.0-1.99 cm), small (0.5-0.99 cm), and very small (<0.5 cm). It is important to clarify that while those authors provide the classification system, we applied it to the genera in our dataset. This methodology was necessary due to the lack of published seed size data for most of the individual species we encountered. Using the genus as a functional unit is a reliable approach in such cases, as it leverages trait conservatism.

Distribution and threat status

For all taxa identified to the species level, we collected data on their distribution across Brazilian phytogeographic domains and vegetation types according to the Flora do Brasil (BFG, 2021). Furthermore, we compiled a list of all Brazilian states where each taxon has been documented, using both the Flora do Brasil (BFG, 2021) and the SpeciesLink platform (CRIA, 2016). Additionally, we verified the presence of these taxa in the checklist of Brazilian Amazon tree taxa (ter Steege et al. 2016).

Threat status

We retrieved for all taxa identified at species level the current threat status according to IUCN using the Flora do Brasil (BFG, 2021) and the list provided by Ministério do Meio Ambiente (MMA) (PORTARIA MMA Nº 148, DE 7 DE JUNHO DE 2022). Additionally, we incorporated the projected threat status for 2050 based on ter Steege et al. (2015). We used the R package 'flora' (Carvalho 2017) to retrieve information from the Brazilian Flora Checklist.

RESULTS

Forest structure and plants species diversity

We sampled 465 trees and palms belonging to 39 families, 100 genera and 220 species. Overall, two taxa (Rubiaceae sp.and Rhizophoraceae sp.) were characterized only at the family level, 106 at the genera level (morpho-species) and 124 until binomial name. The richest genera were *Protium* (52), *Eschweilera* (33), *Licania* (31), *Pouteria* (17) and *Iryanthera* (16). One hundred and thirty-three species (60.7%) presented absolute density equal to one. Shannon (H') index to species was 5.11 nats.ind-1 and Pielou equability index was 0.94 (Table 1). Fabaceae represented approximately 18,58% of the importance value while another 24 families accounted for a little more than 10%. We found that, 13 families were monospecific and no species presented high relative values for any of the phytosociological parameters. All species studied exhibited a value Payandeh index value below 1, there by indicating random spatial distribution.

Table 1 Phytosociological parameters in decreasing of importance value for tree species recorded in one hectare of open ombrophylous forest of Flona do Jamari, Itapuã do Oeste, Rondônia state - 2019. Absolute density (AD), relative density (RD), absolute frequency (AF), relative frequency (RF), absolute dominance (ADo), relative dominance (RDo) and importance value (IV).

Species	**AD**	**RD**	**AF**	**RF**	**ADo**	**RDo**	**IV**
Licania macrophylla Benth.	9	1.88	9	1.96	1.11	4.99	2.94
Protium cf. gallosum Daly	13	2.71	12	2.61	0.49	2.18	2.5
Eschweilera bracteosa (Poepp. ex O.Berg) Miers	13	2.71	13	2.83	0.42	1.87	2.47
Erisma bicolor Ducke	6	1.25	6	1.3	1.06	4.74	2.43
Copaifera multijuga Hayne	9	1.88	8	1.74	0.72	3.23	2.28
Goupia glabra Aubl.	2	0.42	2	0.43	1.2	5.37	2.07
Qualea paraensis Ducke	4	0.83	3	0.65	0.8	3.58	1.69
Vatairea sp3	9	1.88	9	1.96	0.22	0.98	1.61
Protium grandifolium Engl.	10	2.08	9	1.96	0.17	0.77	1.6
Euterpe precatoria Mart.	10	2.08	9	1.96	0.12	0.55	1.53
Licania rodriguesii Prance	7	1.46	6	1.3	0.32	1.43	1.4

Species	**AD**	**RD**	**AF**	**RF**	**ADo**	**RDo**	**IV**
Iryanthera lancifolia Ducke	8	1.67	7	1.52	0.15	0.68	1.29
Cespedesia spathulata (Ruiz & Pav.) G.Planch.	9	1.88	7	1.52	0.09	0.41	1.27
Oenocarpus bataua Mart.	7	1.46	6	1.3	0.21	0.93	1.23
Lueheopsis sp2	1	0.21	1	0.22	0.71	3.2	1.21
Protium polybotryum subsp. blackii (Swart) Daly	7	1.46	7	1.52	0.14	0.61	1.2
Licania micrantha Miq.	5	1.04	4	0.87	0.36	1.63	1.18
Eugenia sp.	4	0.83	4	0.87	0.36	1.63	1.11
Helicostylis tomentosa (Poepp. & Endl.) Rusby	6	1.25	6	1.3	0.14	0.61	1.05
Aspidosperma sp3	2	0.42	2	0.43	0.42	1.86	0.9
Cedrelinga cateniformis (Ducke) Ducke	6	1.25	4	0.87	0.12	0.55	0.89
Aspidosperma carapanauba Pichon	2	0.42	2	0.43	0.39	1.73	0.86
Eschweilera sp1	4	0.83	4	0.87	0.2	0.89	0.86
Alchorneopsis cf. floribunda (Benth.) Müll.Arg.	3	0.63	3	0.65	0.29	1.28	0.85
Astronium lecointei Ducke	1	0.21	1	0.22	0.47	2.12	0.85
Theobroma cf. *subincanum*	5	1.04	5	1.09	0.1	0.43	0.85
Brosimum rubescens Taub.	2	0.42	2	0.43	0.37	1.66	0.84
Eschweilera micrantha (O.Berg) Miers	3	0.63	3	0.65	0.26	1.17	0.82
Virola calophylla Warb.	5	1.04	5	1.09	0.07	0.32	0.82
Caryocar glabrum (Aubl.) Pers.	2	0.42	2	0.43	0.34	1.54	0.8
Peltogyne paniculata Benth.	2	0.42	2	0.43	0.31	1.39	0.75
Swartzia sp4	2	0.42	2	0.43	0.3	1.33	0.73

Species	**AD**	**RD**	**AF**	**RF**	**ADo**	**RDo**	**IV**
Virola sp2	2	0.42	2	0.43	0.29	1.28	0.71
Endopleura sp.	1	0.21	1	0.22	0.38	1.68	0.7
Iryanthera sagotiana (Benth.) Warb.	3	0.63	3	0.65	0.18	0.82	0.7
Aniba sp2	2	0.42	2	0.43	0.28	1.23	0.69
Zygia racemosa (Ducke) Barneby & J.W.Grimes	4	0.83	4	0.87	0.07	0.33	0.68
Bowdichia sp1	3	0.63	3	0.65	0.16	0.71	0.66
Protium paniculatum var. riedelianum (Engl.) Daly	4	0.83	4	0.87	0.05	0.22	0.64
Bowdichia sp2	3	0.63	3	0.65	0.14	0.61	0.63
Helicostylis scabra (J.F.Macbr.) C.C.Berg	4	0.83	4	0.87	0.04	0.18	0.63
Tetragastris panamensis (Engl.) Kuntze	4	0.83	3	0.65	0.09	0.4	0.63
Naucleopsis macrophylla Miq.	4	0.83	3	0.65	0.08	0.37	0.62
Brosimum guianense (Aubl.) Huber	3	0.63	3	0.65	0.12	0.54	0.61
Andira sp.	2	0.42	2	0.43	0.21	0.95	0.6
Pseudolmedia laevis (Ruiz & Pav.) J.F.Macbr.	3	0.63	3	0.65	0.1	0.46	0.58
Eschweilera tessmannii R.Knuth	3	0.63	3	0.65	0.1	0.43	0.57
Vatairea sp1	3	0.63	3	0.65	0.1	0.43	0.57
Pouteria caimito (Ruiz & Pav.) Radlk.	3	0.63	3	0.65	0.07	0.33	0.54
Pouteria cf. torta (Mart.) Radlk.	3	0.63	3	0.65	0.08	0.34	0.54
Virola sp1	3	0.63	3	0.65	0.07	0.32	0.53
Heisteria densifrons Engl.	3	0.63	3	0.65	0.06	0.28	0.52
Pouteria cf. guianensis Aubl.	2	0.42	2	0.43	0.16	0.7	0.52

Species	**AD**	**RD**	**AF**	**RF**	**ADo**	**RDo**	**IV**
Pseudolmedia sp.	3	0.63	3	0.65	0.06	0.29	0.52
Aspidosperma spruceanum Benth. ex Müll.Arg.	3	0.63	3	0.65	0.05	0.25	0.51
Swartzia sp2	3	0.63	3	0.65	0.05	0.24	0.51
Abarema jupunba (Willd.) Britton & Killip	2	0.42	2	0.43	0.15	0.66	0.5
Tachigali paniculata Aubl.	3	0.63	3	0.65	0.05	0.22	0.5
Vochysia sp4	2	0.42	2	0.43	0.14	0.64	0.5
Tachigali sp2	3	0.63	3	0.65	0.05	0.2	0.49
Iryanthera carinata	3	0.63	3	0.65	0.04	0.16	0.48
Iryanthera juruensis Warb.	3	0.63	3	0.65	0.03	0.13	0.47
Lueheopsis sp3	2	0.42	2	0.43	0.12	0.53	0.46
Swartzia sp6	1	0.21	1	0.22	0.2	0.88	0.44
Attalea butifariz	2	0.42	2	0.43	0.1	0.43	0.43
Hymenaea courbaril	1	0.21	1	0.22	0.19	0.87	0.43
Indet sp1	2	0.42	2	0.43	0.1	0.43	0.43
Pouteria sp2	2	0.42	2	0.43	0.1	0.43	0.43
Sterigmapetalum cf. obovatum Kuhlm.	2	0.42	2	0.43	0.1	0.45	0.43
Aniba sp3	2	0.42	2	0.43	0.08	0.37	0.41
Attalea cf. maripa (Aubl.) Mart.	2	0.42	2	0.43	0.08	0.36	0.4
Batesia floribunda Benth.	2	0.42	2	0.43	0.08	0.35	0.4
Chrysophyllum sp1	2	0.42	2	0.43	0.08	0.34	0.4
Eschweilera grandiflora (Aubl.) Sandwith	2	0.42	2	0.43	0.07	0.33	0.39

Species	**AD**	**RD**	**AF**	**RF**	**ADo**	**RDo**	**IV**
Pouteria sp1	2	0.42	2	0.43	0.07	0.31	0.39
Rhizophoraceae sp.	1	0.21	1	0.22	0.16	0.73	0.39
Erisma sp.	1	0.21	1	0.22	0.16	0.72	0.38
Eschweilera andina (Rusby) J.F.Macbr.	2	0.42	2	0.43	0.06	0.28	0.38
Protium sp1	2	0.42	2	0.43	0.06	0.28	0.38
Vitex cymosa Bertero ex Spreng.	2	0.42	2	0.43	0.06	0.29	0.38
Brosimum parinarioides Ducke	2	0.42	2	0.43	0.06	0.27	0.37
Couepia sp.	2	0.42	1	0.22	0.1	0.46	0.37
Abarema adenophora (Ducke) Barneby & J.W.Grimes	1	0.21	1	0.22	0.14	0.65	0.36
Eschweilera truncata A.C.Sm.	2	0.42	2	0.43	0.05	0.24	0.36
Machaerium sp.	2	0.42	2	0.43	0.05	0.22	0.36
Pseudolmedia macrophylla Trécul	2	0.42	2	0.43	0.05	0.22	0.36
Unonopsis sp.	2	0.42	2	0.43	0.05	0.22	0.36
Neea floribunda Poepp. & Endl.	2	0.42	2	0.43	0.04	0.19	0.35
Pterocarpus officinalis Jacq.	2	0.42	2	0.43	0.05	0.21	0.35
Oxandra sp.	2	0.42	2	0.43	0.04	0.16	0.34
Protium crassipetalum Cuatrec.	2	0.42	2	0.43	0.03	0.16	0.34
Protium sp2	2	0.42	2	0.43	0.04	0.17	0.34
Swartzia sp1	2	0.42	2	0.43	0.04	0.18	0.34
Erisma bracteosum Ducke	2	0.42	2	0.43	0.03	0.15	0.33
Lecythis sp2	1	0.21	1	0.22	0.12	0.55	0.33

Species	AD	RD	AF	RF	ADo	RDo	IV
Licania canescens Benoist	2	0.42	2	0.43	0.03	0.14	0.33
Vouacapoua americana Aubl.	2	0.42	2	0.43	0.03	0.13	0.33
Clarisia racemosa Ruiz & Pav.	2	0.42	2	0.43	0.02	0.1	0.32
Licania lata J.F.Macbr.	2	0.42	2	0.43	0.02	0.11	0.32
Picramnia sp.	2	0.42	2	0.43	0.02	0.1	0.32
Pouteria filipes Eyma	2	0.42	1	0.22	0.07	0.32	0.32
Protium ferrugineum (Engl.) Engl.	2	0.42	2	0.43	0.02	0.11	0.32
Protium sp5	2	0.42	2	0.43	0.02	0.11	0.32
Pseudopiptadenia sp.	1	0.21	1	0.22	0.12	0.52	0.32
Psychotria sp.	2	0.42	2	0.43	0.02	0.11	0.32
Swartzia sp5	2	0.42	2	0.43	0.02	0.1	0.32
Virola sp3	2	0.42	2	0.43	0.02	0.1	0.32
Micropholis cylindrocarpa (Poepp.) Pierre	2	0.42	2	0.43	0.02	0.09	0.31
Micropholis guyanensis (A.DC.) Pierre	2	0.42	2	0.43	0.02	0.09	0.31
Peltogyne excelsa Ducke	2	0.42	2	0.43	0.02	0.09	0.31
Mouriri sp.	1	0.21	1	0.22	0.1	0.46	0.3
Lueheopsis sp1	1	0.21	1	0.22	0.08	0.37	0.27
Tachigali sp4	1	0.21	1	0.22	0.08	0.38	0.27
Aspidosperma sp1	1	0.21	1	0.22	0.07	0.31	0.25
Brosimum sp2	1	0.21	1	0.22	0.07	0.32	0.25
Ocotea sp6	1	0.21	1	0.22	0.07	0.31	0.25

Species	AD	RD	AF	RF	ADo	RDo	IV
Peltogyne cf. venosa subsp. densiflora (Spruce ex Benth.) M.F.Silva	1	0.21	1	0.22	0.07	0.31	0.25
Tapirira guianensis Aubl.	1	0.21	1	0.22	0.07	0.33	0.25
Vatairea sp2	1	0.21	1	0.22	0.07	0.31	0.25
Vochysia sp2	1	0.21	1	0.22	0.07	0.33	0.25
Aniba sp4	1	0.21	1	0.22	0.07	0.3	0.24
Indet sp1	1	0.21	1	0.22	0.07	0.3	0.24
Licania gracilipes Taub.	1	0.21	1	0.22	0.07	0.3	0.24
Nectandra sp2	1	0.21	1	0.22	0.06	0.28	0.24
Ocotea sp4	1	0.21	1	0.22	0.06	0.26	0.23
Licania sp2	1	0.21	1	0.22	0.05	0.23	0.22
Couepia guianensis Aubl.	1	0.21	1	0.22	0.05	0.21	0.21
Ecclinusa sp.	1	0.21	1	0.22	0.04	0.2	0.21
Lecythis sp3	1	0.21	1	0.22	0.05	0.21	0.21
Pouteria anomala (Pires) T.D.Penn.	1	0.21	1	0.22	0.05	0.21	0.21
Pseudopiptadenia psilostachya (DC.) G.P.Lewis & M.P.Lima	1	0.21	1	0.22	0.04	0.2	0.21
Qualea sp1	1	0.21	1	0.22	0.04	0.19	0.21
Apeiba sp2	1	0.21	1	0.22	0.04	0.18	0.2
Eschweilera coriacea (DC.) S.A.Mori	1	0.21	1	0.22	0.04	0.17	0.2
Eschweilera sp2	1	0.21	1	0.22	0.04	0.17	0.2
Minquartia guianensis Aubl.	1	0.21	1	0.22	0.04	0.16	0.2

Species	**AD**	**RD**	**AF**	**RF**	**ADo**	**RDo**	**IV**
Platymiscium sp.	1	0.21	1	0.22	0.04	0.17	0.2
Alchornea sp1	1	0.21	1	0.22	0.03	0.14	0.19
Anacardium cf. giganteum W.Hancock ex Engl.	1	0.21	1	0.22	0.03	0.14	0.19
Astronium sp.	1	0.21	1	0.22	0.03	0.14	0.19
Glycydendron amazonicum Ducke	1	0.21	1	0.22	0.03	0.13	0.19
Lecythis sp1	1	0.21	1	0.22	0.03	0.14	0.19
Licania sothersiae Prance	1	0.21	1	0.22	0.03	0.14	0.19
Micropholis trunciflora Ducke	1	0.21	1	0.22	0.03	0.13	0.19
Myrcia sp.	1	0.21	1	0.22	0.03	0.14	0.19
Nectandra pulverulenta Nees	1	0.21	1	0.22	0.03	0.13	0.19
Ocotea sp2	1	0.21	1	0.22	0.03	0.13	0.19
Ocotea sp3	1	0.21	1	0.22	0.03	0.14	0.19
Pouteria campanulata Baehni	1	0.21	1	0.22	0.03	0.13	0.19
Protium sp3	1	0.21	1	0.22	0.03	0.13	0.19
Ruizterania cassiquiarensis (Spruce ex Warm.) Marc.-Berti	1	0.21	1	0.22	0.03	0.14	0.19
Tachigali sp1	1	0.21	1	0.22	0.03	0.15	0.19
Vochysia sp1	1	0.21	1	0.22	0.03	0.13	0.19
Alchornea sp2	1	0.21	1	0.22	0.02	0.1	0.18
Apeiba sp1	1	0.21	1	0.22	0.02	0.11	0.18
Casearia javitensis Kunth	1	0.21	1	0.22	0.02	0.1	0.18
Chimarrhis duckeana Delprete	1	0.21	1	0.22	0.02	0.1	0.18

Species	**AD**	**RD**	**AF**	**RF**	**ADo**	**RDo**	**IV**
Dalbergia sp.	1	0.21	1	0.22	0.03	0.12	0.18
Dialium guianense (Aubl.) Sandwith	1	0.21	1	0.22	0.02	0.1	0.18
Indet sp.	1	0.21	1	0.22	0.02	0.11	0.18
Inga sp1	1	0.21	1	0.22	0.02	0.11	0.18
Leonia glycycarpa Ruiz & Pav.	1	0.21	1	0.22	0.02	0.11	0.18
Machaerium multifoliolatum Ducke	1	0.21	1	0.22	0.03	0.12	0.18
Pradosia decipiens Ducke	1	0.21	1	0.22	0.02	0.1	0.18
Siparuna sp.	1	0.21	1	0.22	0.03	0.12	0.18
Tachigali sp5	1	0.21	1	0.22	0.02	0.1	0.18
Trattinnickia glaziovii Swart	1	0.21	1	0.22	0.03	0.11	0.18
Virola mollissima (A.DC.) Warb.	1	0.21	1	0.22	0.02	0.11	0.18
Xylopia nitida Dunal	1	0.21	1	0.22	0.02	0.11	0.18
Caryodendron sp.	1	0.21	1	0.22	0.02	0.07	0.17
Couma utilis (Mart.) Müll.Arg.	1	0.21	1	0.22	0.01	0.07	0.17
Eschweilera sp3	1	0.21	1	0.22	0.01	0.07	0.17
Hymenolobium sp.	1	0.21	1	0.22	0.02	0.07	0.17
Iryanthera sp2	1	0.21	1	0.22	0.02	0.08	0.17
Licania caudata Prance	1	0.21	1	0.22	0.01	0.07	0.17
Naucleopsis caloneura (Huber) Ducke	1	0.21	1	0.22	0.02	0.07	0.17
Protium altsonii Sandwith	1	0.21	1	0.22	0.02	0.07	0.17
Qualea sp2	1	0.21	1	0.22	0.02	0.08	0.17

Species	AD	RD	AF	RF	ADo	RDo	IV
Tachigali sp3	1	0.21	1	0.22	0.01	0.07	0.17
Vochysia citrifolia Poir.	1	0.21	1	0.22	0.02	0.07	0.17
Abuta dwyeriana Krukoff & Barneby	1	0.21	1	0.22	0.01	0.04	0.16
Aniba sp1	1	0.21	1	0.22	0.01	0.05	0.16
Aparisthmium cordatum (A.Juss.) *Baill.*	1	0.21	1	0.22	0.01	0.05	0.16
Aspidosperma sp3	1	0.21	1	0.22	0.01	0.06	0.16
Brosimum lactescens (S.Moore) C.C.Berg	1	0.21	1	0.22	0.01	0.04	0.16
Brosimum sp1	1	0.21	1	0.22	0.01	0.04	0.16
Cariniana micrantha Ducke	1	0.21	1	0.22	0.01	0.05	0.16
Cecropia cf. *polystachya* Trécul	1	0.21	1	0.22	0.01	0.04	0.16
Combretum assimile Eichler	1	0.21	1	0.22	0.01	0.04	0.16
Copaifera glycycarpa Ducke	1	0.21	1	0.22	0.01	0.04	0.16
Cybianthus sp.	1	0.21	1	0.22	0.01	0.06	0.16
Dinizia excelsa Ducke	1	0.21	1	0.22	0.01	0.06	0.16
Erisma floribundum Rudge	1	0.21	1	0.22	0.01	0.04	0.16
Eschweilera ovalifolia (DC.) Nied.	1	0.21	1	0.22	0.01	0.05	0.16
Guarea sp.	1	0.21	1	0.22	0.01	0.04	0.16
Heisteria sp.	1	0.21	1	0.22	0.01	0.05	0.16
Heisteria spruceana Engl.	1	0.21	1	0.22	0.01	0.06	0.16
Hirtella rodriguesii Prance	1	0.21	1	0.22	0.01	0.05	0.16
Hymenolobium pulcherrimum Ducke	1	0.21	1	0.22	0.01	0.04	0.16

Species	AD	RD	AF	RF	ADo	RDo	IV
Inga leiocalycina Benth.	1	0.21	1	0.22	0.01	0.05	0.16
Inga rubiginosa (Rich.) DC.	1	0.21	1	0.22	0.01	0.04	0.16
Inga sp2	1	0.21	1	0.22	0.01	0.04	0.16
Iryanthera sp1	1	0.21	1	0.22	0.01	0.05	0.16
Lecythis sp4	1	0.21	1	0.22	0.01	0.04	0.16
Licania sp1	1	0.21	1	0.22	0.01	0.06	0.16
Machaerium aureiflorum Ducke	1	0.21	1	0.22	0.01	0.04	0.16
Miconia sp1	1	0.21	1	0.22	0.01	0.06	0.16
Miconia sp2	1	0.21	1	0.22	0.01	0.04	0.16
Micropholis sp.	1	0.21	1	0.22	0.01	0.04	0.16
Naucleopsis glabra Spruce ex Pittier	1	0.21	1	0.22	0.01	0.06	0.16
Naucleopsis stipularis	1	0.21	1	0.22	0.01	0.04	0.16
Nectandra sp1	1	0.21	1	0.22	0.01	0.05	0.16
Nectandra sp3	1	0.21	1	0.22	0.01	0.06	0.16
Ocotea rhodophylla Vicent.	1	0.21	1	0.22	0.01	0.04	0.16
Ocotea sp1	1	0.21	1	0.22	0.01	0.04	0.16
Ocotea sp5	1	0.21	1	0.22	0.01	0.04	0.16
Ouratea cf. densiflora Pilg.	1	0.21	1	0.22	0.01	0.04	0.16
Oxandra xylopioides Diels	1	0.21	1	0.22	0.01	0.04	0.16
Perebea sp.	1	0.21	1	0.22	0.01	0.05	0.16
Protium sp4	1	0.21	1	0.22	0.01	0.05	0.16

Species	AD	RD	AF	RF	ADo	RDo	IV
Protium tenuifolium (Engl.) Engl	1	0.21	1	0.22	0.01	0.05	0.16
Quararibea guianesis Aubl.	1	0.21	1	0.22	0.01	0.04	0.16
Quiina florida Tul.	1	0.21	1	0.22	0.01	0.04	0.16
Rubiaceae sp.	1	0.21	1	0.22	0.01	0.06	0.16
Salacia sp.	1	0.21	1	0.22	0.01	0.06	0.16
Simarouba amara Aubl.	1	0.21	1	0.22	0.01	0.05	0.16
Swartzia sp3	1	0.21	1	0.22	0.01	0.06	0.16
Symphonia sp.	1	0.21	1	0.22	0.01	0.05	0.16
Taralea sp.	1	0.21	1	0.22	0.01	0.04	0.16
Theobroma sp.	1	0.21	1	0.22	0.01	0.05	0.16
Toulicia pulvinata Radlk.	1	0.21	1	0.22	0.01	0.04	0.16
Vochysia sp3	1	0.21	1	0.22	0.01	0.05	0.16
Xylopia sp.	1	0.21	1	0.22	0.01	0.04	0.16

Seed size

We found information about seed size for 55 genera. Medium-sized seeds were the most frequent, occurring in 22 genera, followed by large seeds (16), small seeds (6), and very small seeds (5). Additionally, six genera had seeds that varied between small/medium (3) and medium/large (3). The most richness genera in our plot, such as *Brosimum* (3 species), *Iryanthera* (2 species), and *Pouteria* (2 species), were characterized by medium-sized seeds. Genera like *Licania* (8 species), *Eschweilera* and *Iryanthera* (3 species each), *Pouteria* (4 species), and *Aspidosperma* (2 species) exhibited the largest seeds, whereas *Protium* (5 species) and *Virola* (1 species) had the smallest seeds (Table 2).

Table 2 Seed size and size category of tree species belonging to the 55 genera recorded at one hectare of open ombrophylous forest of Flona do Jamari, Itapuã do Oeste, Rondônia. Seed size category follows Malhado et al. (2015): large (≥2.0 cm), Medium (1.0-1.99 cm), Small (0.5-0.99 cm), Very Small (<0.5 cm). There were genera with two category sizes.

Family	**Genera**	**Seed size**
Anacardiaceae	Anacardium	Large
Arecaceae	Attalea	Large
Burseraceae	Theobroma	Large
Caryocaraceae	Caryocar	Large
Euphorbiaceae	Goupia	Large
Fabaceae	Couepia	Large
Fabaceae	Endlicheria	Large
Fabaceae	Iryanthera	Large
Fabaceae	Symphonia	Large
Lauraceae	Aniba	Large
Lauraceae	Eschweilera	Large
Melastomataceae	Minquartia	Large
Moraceae	Clarisia	Large

Quiinaceae	Salacia	Large
Rubiaceae	Glycydendron	Large
Violaceae	Licania	Large
Annonaceae	Virola	Medium
Arecaceae	Ouratea	Medium
Burseraceae	Unonopsis	Medium
Celastraceae	Simarouba	Medium
Clusiaceae	Tetragastris	Medium
Goupiaceae	Guarea	Medium
Lamiaceae	Xylopia	Medium
Malvaceae	Quiina	Medium
Melastomataceae	Naucleopsis	Medium
Meliaceae	Heisteria	Medium
Moraceae	Brosimum	Medium
Moraceae	Hirtella	Medium
Moraceae	Nectandra	Medium
Moraceae	Quararibea	Medium
Myristicaceae	Leonia	Medium

Myristicaceae	Vitex	Medium
Nyctaginaceae	Ocotea	Medium
Ochnaceae	Oxandra	Medium
Olacaceae	Helicostylis	Medium
Olacaceae	Mouriri	Medium
Simaroubaceae	Swartzia	Medium
Annonaceae	Pouteria	Medium/Large
Lauraceae	Oenocarpus	Medium/Large
Lecythidaceae	Eugenia	Medium/Large
Burseraceae	Pseudolmedia	Small
Chrysobalanaceae	Cybianthus	Small
Fabaceae	Abarema	Small
Malvaceae	Trattinnickia	Small
Myrsinaceae	Dialium	Small
Myrtaceae	Faramea	Small
Chrysobalanaceae	Inga	Small/Medium
Lauraceae	Neea	Small/Medium
Sapotaceae	Protium	Small/Medium

Euphorbiaceae	Alchornea	Very Small
Malvaceae	Apeiba	Very Small
Chrysobalanaceae	Miconia	VerySmall
Salicaceae	Casearia	VerySmall
Urticaceae	Cecropia	VerySmall

Distribution by vegetation type

The five predominant vegetation types these species occur across the biomes are Floresta de Terra Firme (106), Floresta Ombrófila (53), Campinarana (36), Floresta Ciliar (20) and Floresta de Várzea (17) (Sup. Mat. 1). *Protium panamense* has not been reported to occur in the Amazonian region according to Flora do Brasil (BFG, 2021), but there are occurrences reported on Amazonas state reported on SpeciesLink database and ter Steege et al. 2016. Besides that, *Protium picramnioides* has not occur on the region according to SpeciesLink system platform and ter Steege et al. (2016).

Threat status

Regarding the current threat status, we identified just two species from the Fabaceae family as threatened: *Peltogyne excelsa* Ducke, classified as Vulnerable (VU), and *Vouacapoua americana* Aubl classified as Endangered (EN), among the 124 species recorded in our plot. *Vouacapoua americana* was listed as threatened in both 2014 and 2022 by MMA. For the projected threat status in 2050, based on ter Steege et al. (2015), we found 28 species classified as Vulnerable and 16 as Endangered by 2050 (Sup. Mat. 1).

DISCUSSION

The high number of species classified as rare - based on a single recorded individual per species - underscores the importance of field data in understanding species dynamics and occurrences. Moreover, the significant number of species that have not yet been assigned a threat status by the IUCN underscores the need for accurate assessments of the conservation status of tree species, especially considering the pressures faced by forests across the region. In the entire Brazilian Amazon region, knowledge partners are spatially clustered, predominantly situated near major roads or large rivers (Stropp et al. 2020). The historical speaks in botanical sampling align with prominent research initiatives, particularly the 'Flora projects', which emphasize comprehensive field surveys and precise species documentation (Stropp et al. 2020). This approach is of great significance in regions marked by elevated deforestation rates and ecotonal vegetation, such as the southwestern Brazilian Amazon. However, one question remains: Are protected areas suitable for implementing these projects in such areas? It is likely that they are, particularly when involving international and national research centers, policymakers (*e.g.*, municipal and state governments), indigenous leaders, and securing adequate funding. Such collaborations have the potential to reduce bureaucratic barriers and facilitate the advancement of botanical knowledge in this geographic scale.

The lack of knowledge regarding the threat status for the majority of species recorded in our plot suggests the necessity for a more comprehensive assessment to accurately evaluate the real threats to these species. Our study highlights the importance of improving regional floristic knowledge to address existing shortfalls in understanding about species distribution, ecology interactions, like dispersal characteristics, and threat status. The high number of species with low density and possible new occurrences highlights the importance of gaining knowledge about ecological dynamics. The substantial presence of species exhibiting relatively low population densities, alongside the potential identification of new occurrences, serves to underscore the paramount importance of acquiring comprehensive knowledge concerning the flora, encompassing its composition and distribution, within this conspicuously diverse yet understudied ecological region. Our investigation effectively highlights the indispensable role played by both floristic and phytosociological studies in elucidating the intricate structure and unique floristic aspects of Amazonian forests. Our endeavours, a considerable expanse of the region's floristic composition remains unexplored, necessitating further in-depth inquiries to gain a comprehensive understanding of species distribution. Positioned in an ecotonal area, Rondônia holds significant promise as a contributor in this vital undertaking.

Structure

The number of species recorded in our inventory of the Jamari National Forest was the highest recorded so far in studies carried out in Rondônia state. Woody plants families with the highest densities also showed greater specific richness. In the present study, Fabaceae accounted for 18% of the total number of woody plants, confirming its high representativeness in tropical forests along with Burseraceae, Lecythidaceae and Arecaceae (ter Steege et al. 2016; Cardoso et al. 2017; Beech et al., 2017). The Equability Index was 0.94, suggesting uniformity in the relationship between the number of individuals per species within the plant community. Similar values were found by Oliveira et al. (2008) in one hectare of 'terra firme' forest in Central Amazon, where the diversity index was (H '= 5.1 $nat\ .individual^{-1}$) and the equability (e' = 0.92).

In Amazonian terra firme forests, it is common to find a large number of species with few individuals and few species with a larger number of individuals (ter Steege et al. 2013). This pattern, however, was not found in our plot. Instead, a few species such as *Licania macrophyla* (highest IV, 2.94, with only nine individuals), *Protium* cf. *gallosum*, and

Eschweilera bracteosa were dominant, despite the community being largely composed of a high number of singletons (133) and doubletons (54). Oliveira & Nelson (2001) made study with a 31 tree inventories from 12 sites in the Brazilian Amazon, one site in the Bolivian Amazon and one in the northeast Brazilian Atlantic coastal forest, and they concluded that the western Amazon regions have greater species diversity than inventories in the east. However, inventories of terra firme forest in central Amazon present similar tree species diversity to that found in the inventories of the western Amazon (Valencia et al 1994; Oliveira & Amaral 2004; Hubbell et al. 2008). The importance of the Fabaceae family in our study agrees with findings from terra firme forests across the Amazon (*e.g*., Carim et al. 2013). Similarly, Moraceae ranked among the five most important families in our study area. Both are families widely represented in the structure of Amazonian mainland forests.

Traits attributes

Our finding underscores a higher abundance of genera with smaller and medium-sized seeds compared to larger seeds. Amazonian tree genera with smaller seeds are prevalent in the southwestern and western margins of Amazonia (northern Bolivia and southeast Peru), while genera with larger seeds are more commonly found in central and northern Amazonia (Malhado et al. 2015). This geographic pattern aligns with the climatic correlations found by these authors, who report that larger seeds are associated with warmer and less seasonal environments. These findings are consistent with the observation that forests in the southwestern Amazonian are located in a climatological and ecological region, exhibiting lower temperatures, higher seasonality, and relatively more open canopies (Sombroek 2001; Coe et al. 2013; Saatchi et al. 2012).

The seed size variation maintenance may reflect a balance of seed production costs, differential seedling success, and complex interactions with seed predators and dispersers, consistent with previous research on tropical trees and palms (Pizo et al., 2006). Small seeds tend to produce seedlings with lower vigor and biomass, which may compromise plant survival and success, especially under competitive conditions in the forest understory where seedling density is high (Pizo et al., 2006; Fricke et al., 2019). And also, another challengers to small seeds may be produced in greater numbers, their lack of reserves negatively affects germination success and seedling establishment, influencing the population dynamics of the species (Pizo et al., 2006).

Distributions

According to the Brazilian Flora Checklist (BFG, 2021), seven species occurring in our plot are common across Amazon, Atlantic Forest, Cerrado and Caatinga biomes. However, this number increases to fifteen according to information from SpeciesLink system (CRIA, 2016). This pattern supports the findings of Carvalho & Almeida (2016) who suggest that most species have a restricted geographic distribution with a large number of individuals occurring in small areas and few occurring in many regions. Alternatively, a study highlighted the presence of species shared between biomes, focusing on trees and shrubs (Méio et al. 2003).

Threat status

It is important to note that our research was limited to consulting the IUCN list evaluation criteria due to the absence of a local threat list. Nineteen percent of the inventoried species represent new occurrences in the Rondônia state, indicating that the local flora may still be poorly known. Even species with a wide geographical distribution in the region are not exempt from threats. In this context, the role of protected areas like the Flona do Jamari becomes paramount. Located in the deforestation arc, this forest unit acts as a refuge for biodiversity, including the many newly recorded species. Our research provides essential baseline information that reinforces the conservation value of this unit and supports its long-term management against ongoing regional threats. In a heavily fragmented landscape such as the deforestation arc, the ecological traits we documented are critical for informing species-specific conservation strategies. The seed size assessment serves as a key diagnostic for understanding regeneration niches and dispersal capabilities, which are often disrupted in degraded areas. Furthermore, by mapping the other Brazilian biomes and vegetation types where these species are found, we can identify which taxa are more resilient or vulnerable to regional changes.

CONCLUSION

We must emphasize that our study underscores the necessity for meticulous investigations, where the accurate taxonomic identification of species occupies a central position in research methodologies. The revelation of 220 distinct species within a single hectare raises a pivotal query that warrants consideration: could the estimates of diversity and richness for this particular section of the Amazon be underestimated? What is the impact of unknown species and the inaccuracy of determining them on richness and diversity estimates for the region? Consequently, scientists must urgently address these questions, moving beyond the convenience of easily accessible sites near research bases to obtain a true understanding of Amazonian biodiversity. Instead, there is a pressing need to extend research efforts into regions that are susceptible to the impacts of climate change or deforestation (Carvalho et al. 2023). We conclude that floristic studies carried out in the southwestern region of the Brazilian Amazon are rare and our study, though small scale, provides a significant contribution to biodiversity knowledge of the region. The need for such studies is urgent, given the continuing loss of native vegetation due to development pressures, especially on native vegetation. We emphasize the importance for scientists to conduct studies addressing the new species (Linnean shortfall), spatial under sampling (Wallacean shortfall) and ecology interactions (Raunkiaer shortfall) in relations to plant structure investigations.

author contributions statement

Bruno Umbelino - Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing; **Juliana Stropp** – Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing; **Ingrid Mendes-Silva -** Visualization, Writing – original draft, Writing – review & editing; **Ricardo Aleixo Correia** – Writing – review & editing; **Antônio L. P. Silveira** – Conceptualization, Supervision, Writing – review & editing; **Ana C. M. Malhado -** Conceptualization, Supervision, Writing – review & editing.

conflict of interest statement

The authors declare that they have no known financial conflicts of interest or personal relationships that could appear to have influenced the work reported in this paper.

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