



Floristic similarity of lycophytes and ferns in the Amazonia/Cerrado transition zone in the central region of northern Maranhão state, Brazil

Similaridade florística de licófitas e samambaias na região de transição Amazônia/Cerrado na região central do norte do Maranhão, Brasil

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Floristic similarity studies make it possible to compare species richness between different phytophysiognomies and to assess whether species are typical of a phytophysiognomie or if they are common to two or more phytophysiognomies. The Immediate Geographic Region of São Luís (IGR), in the central region of northern Maranhão, is characterized by the presence of Amazonia, Cerrado, and coastal vegetation phytophysiognomies. The objectives of this work were to verify if the fern and lycophyte species in the IGR are similar to those in another Amazonia and Cerrado phytophysiognomies in Maranhão and Brazil. Sixty-three species of lycophytes and ferns were identified, with a predominance of individuals in the families Pteridaceae and Polypodiaceae. A similarity analysis indicated the study area has a greater affinity with the Amazonia. This is the first floristic similarity study that emphasizes ferns and lycophytes in Maranhão. However, the scarcity of floristic surveys in Maranhão and other ecotonal areas in Brazil hindered a more complex analysis of the floristic similarity of these phytophysiognomies.

Keywords: ecotone, floristic survey, similarity.

Estudos de similaridade florística permitem comparar a riqueza de espécies entre as diversas fitofisionomias e avaliar se as espécies são típicas de uma fitofisionomia ou se são comuns a duas ou mais fitofisionomias. A Região Geográfica Imediata de São Luís (RGI), Centro-Norte do Maranhão, caracteriza-se pela presença das fitofisionomias da Amazônia, Cerrado e vegetação litorânea. O objetivo desse trabalho foi verificar se as espécies de licófitas e samambaias da RGI têm similaridades com aquelas de outras fitofisionomias da Amazônia e do Cerrado de outras áreas do Maranhão e do Brasil. Foram identificadas 63 espécies de licófitas e samambaias, com predominância de indivíduos das famílias Pteridaceae e Polypodiaceae. Utilizando os dados de ocorrência dessas espécies e comparando com estudos realizados em áreas da Amazônia, Cerrado e transições no Maranhão e outras áreas do Brasil, efetuou-se a análise de similaridade florística, que apontou maior afinidade da área de estudo com espécies de ocorrência amazônica. Esse foi o primeiro estudo sobre similaridade florística com ênfase em samambaias e licófitas do Maranhão. Porém, a escassez de amostragens florísticas tanto no Maranhão como em outras áreas ecotonais do Brasil dificultou análises mais complexas sobre a similaridade florística dessas fitofisionomias.

Palavras-chave: ecótono, levantamento florístico, similaridade.

1. INTRODUCTION

Lycophytes and ferns are seedless vascular plants, that reproduce through spores, and occur in two distinct lineages that are estimated to have 11,916 species, although this number increases each year [1]. These plants are more diverse in equatorial regions of the planet, with a decrease in species richness towards the poles [2].

The diversity of lycophytes and ferns in Brazil is estimated to be 1,412 species. Of these, 525 species are endemic [3]. The biomes with the greatest number of species are the Atlantic Forest

(944 species), Amazonia (578 species) and Cerrado (319 species), and these biomes have different physiognomies and water bodies, providing ideal habitats for the diversification and proliferation of species [3].

The state of Maranhão is in the Northeast Region of Brazil, has large areas of the Amazonia and Cerrado, and also contains a small portion of the Caatinga, which has resulted in several transition areas where there is contact between species from different biomes [4]. Maranhão is estimated to have 151 species of lycophytes and ferns [3, 4], but this number is low because the state still has vast areas with no data about these groups [4, 5].

Floristic similarity surveys make it possible to compare species richness between different phytophysiognomies and their transition areas, as well as to assess, among other things, whether species are typical of a phytophysiognomie or if they are common in two or more phytophysiognomies. Based on similarity studies, more information can be obtained to delimit priority areas for preservation and conservation of species [6, 7].

There are few studies about the floristic similarity of lycophytes and ferns in Brazil; some works have been conducted in the Northeast [8, 9], Southeast [10], and South [11] regions. In Maranhão, in addition to the lack of floristic studies of lycophytes and ferns, there have been no studies focused on the floristic similarity of these groups.

Thus, this work aimed to verify if the species of lycophytes and ferns in the Immediate Geographic Region of São Luís, a transitional area between Amazonia, Cerrado, and coastal vegetations are similar to those in other areas of the Amazonia or Cerrado in Maranhão state, Brazil.

2. MATERIAL AND METHODS

2.1 Study Area

The state of Maranhão has a tropical rainy climate (AW), according to the classification by Köppen (1948) [12], with average temperatures between 25° and 26°C and annual precipitation between 1,400–1,800 mm [13]. The present study was carried out in the Immediate Geographic Region of São Luís (Figure 1), which has 13 Municipalities: Alcântara, Axixá, Bacabeira, Cachoeira Grande, Icatu, Morros, Paço do Lumiar, Presidente Juscelino, Raposa, Rosário, Santa Rita, São José do Ribamar, and São Luís. This region is in the central area of the northern part of the state. It has Amazonia, Cerrado, and coastal vegetation phytophysiognomies, as well as transitional areas between them. The rainy period occurs between January and June and the dry period is between July and December, with a variation of one month, more or less [14, 15].

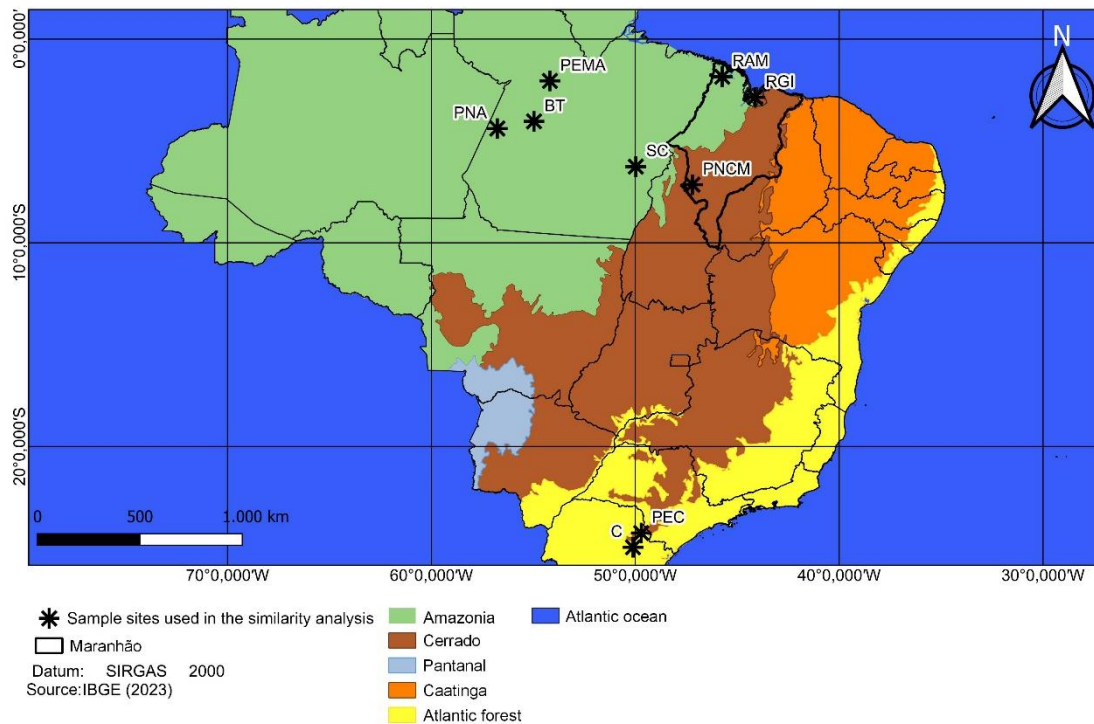


Figure 1. Map of Brazil showing the locations used (indicated by *) in the floristic similarity analysis of lycophytes and ferns in the study region and other areas in Maranhão state, Brazil. PEMA – Parque Estadual Monte Alegre, PNCM – Parque Nacional da Chapada das Mesas e seus arredores, PNA – Parque Nacional da Amazônia, BT – Baixo Tapajós, SC – Serra dos Carajás, IGR – Immediate Geographic Region of São Luís, ARM – Amazonian remnants in Maranhão, C – Carambéi, PEC – Parque Estadual do Cerrado.

2.2 Data collecting

Floristic data were collected during field expeditions between April 2020 and September 2022. The fern and lycophyte species were georeferenced and photographed. The specimens were located using the walking method [16] and processed according to standard techniques used for this type of material [17, 18].

The specimens were mounted in the Orchid Study Laboratory at the Universidade Federal do Maranhão, Campus Cidade Universitária Dom Delgado de São Luís, and deposited in the following herbaria: Herbário Aylton Brandão Joly (HABIT) at the Universidade Estadual do Maranhão, Campus Caxias; Herbário Rosa Mochel (SLUI) at the Universidade Estadual do Maranhão, Campus Paulo VI de São Luís; and Herbário Maria Eneyda P. K. Fidalgo (SP) at the Instituto de Pesquisas Ambientais (Acronyms according to Index Herbariorum 2023 [19]).

The species were identified using specialized literature, such as papers and regional floras (e.g., [4, 5, 20-27]). The classification of life forms follows the proposal by Zuquim et al. 2011 [21], which has the following categories: terrestrial, epiphytic, hemiepiphytic, rupicolous, and aquatic. For the geographic distributions of the species, the Flora and Funga of Brazil (2023) [3] and speciesLink (2023) [28] were consulted.

2.3 Floristic similarity analysis

We used data from articles about floristic surveys of lycophytes and ferns carried out in areas of the Amazonia, Cerrado, or transition areas between them, in Maranhão and other locations in Brazil (Table 1). These papers were selected based on searching online platforms of the Portal de Periódicos CAPES and Scielo using the following terms: lycophytes and ferns Amazonia,

lycophytes, and ferns Cerrado, lycophytes and ferns, Cerrado. Only works published between 2018 and 2022 were included. We chose papers about surveys of ferns and lycophytes in the Amazonia or Cerrado biomes with a minimum of 10 species. We used these works cited in Table 1 for comparison with our study because they already use the most recent concept about the recorded taxa in our sampled area, thus facilitating the analysis. Data were compared using the Jaccard similarity index and a mean association cluster analysis (UPGMA), with internal support calculated through 5000 bootstrap simulations, using the software Paleontological Statistics– PAST [29].

Table 1. Data used to construct the floristic similarity analysis.

Study Area	Biome	State	Species number	Reference
Immediate Geographic Region of São Luís (IGR)	Amazonia/Cerrado	Maranhão	63	This study
Serra dos Carajás (SC)	Amazonia	Pará	186	Salino et al. 2018 [25]
Amazonian remnants in Maranhão (ARM)	Amazonia	Maranhão	64	Silva Junior et al. 2020 [5]
Parque Nacional da Amazônia (PNA)	Amazonia	Pará	83	Menezes and Labiak 2020 [30]
Baixo Tapajós (BT)	Amazonia	Pará	151	Oliveira et al. 2021 [31]
Carambeí (C)	Cerrado/Atlantic Forest	Paraná	129	Michelon et al. 2018 [32]
Parque Estadual Monte Alegre (PEMA)	Amazonia/Cerrado	Pará	20	Della et al. 2019 [33]
Parque Estadual do Cerrado (PEC)	Cerrado/Atlantic Forest	Paraná	112	Nunes and Labiak 2021 [34]
Parque Nacional da Chapada das Mesas e arredores (PNCM)	Cerrado	Maranhão	86	Fernandes et al. 2022 [4]

3. RESULTS AND DISCUSSION

We identified 63 taxa (Table 2): 60 fern species in 18 families and 37 genera, and three lycophyte species in one family (Lycopodiaceae) and two genera. There was a predominance of individuals in the families Pteridaceae and Polypodiaceae, with 17 and 9 species, respectively, while the most abundant genera were *Adiantum* L. (5 spp.) and *Lindsaea* Dryand. ex sm. (4 spp.).

Only two species occurred exclusively in the Cerrado portion of the state, *Actinostachys pennula* (Sw.) Hook. and *Schizaea elegans* (Vahl) Sw., which are in the family Schizaeaceae. *Hemionitis rufa* (L.) Sw and *Pecluma plumula* (Willd.) M.G. Price were collected in the transition zone between the Amazonia and Cerrado; they do not occur in other areas of the Cerrado but do grow in the Amazonia portion. For these species, we observed the phenomenon of poikiloidry, which was also seen in *Microgramma percussa* (Cav.) de la Sota during the dry period. The three species of lycophytes occurred in marshy areas and *veredas*, which are sunny and humid places throughout the year, in addition to occasionally growing along roadsides. However, it was noted that *Pseudolycopodiella meridionalis* (Underw. & Loyd) Holub is less frequent than the other lycophytes. It only occurs in *veredas*, where the soil is partially wet, unlike *Palhinhaea camporum* (B. Øllg. & P.G. Windisch) Holub and *Palhinhaea cernua* (L.) Franco & Vasc. that were observed in dry and humid environments. *Acrostichum aureum* L. was the only species that tolerated the salinity of coastal vegetation areas, and generally occurs on mangrove edges, in contrast to *Acrostichum danaeifolium* Langsd. & Fisch. that was observed only in areas further inland and is mainly associated with swamps.

Table 2. Species collected in the study area, with information for life forms, environment, municipalities where the species were found and vouchers. SLUI = Herbário Rosa Mochel.

Group/Family/Species	Life form	Environment of occurrence	Municipality	Voucher
Lycophytes				
Lycopodiaceae				
<i>Palhinhaea camporum</i> (B. Øllg. & P.G. Windisch) Holub	Terrestrial	Swamp, Capoeira	Morros, Presidente Juscelino, Rosário, São Luís	SLUI 6850; 6852; 6887; 6907
<i>Palhinhaea cernua</i> (L.) Franco & Vasc.	Terrestrial	Swamp, Capoeira	Morros, Presidente Juscelino, Rosário, São Luís	SLUI 6853; 6888; 6889; 6899
<i>Pseudolycopodiella meridionalis</i> (Underw. & Loyd) Holub	Terrestrial	Swamp, Capoeira	Cachoeira Grande, Morros	SLUI 6580; 6590
Ferns				
Aspleniaceae				
<i>Asplenium serratum</i> L.	Epiphyte	Gallery Forest	Axixá, Cachoeira Grande	SLUI 6873; 6874
Blechnaceae				
<i>Telmatoblechnum serrulatum</i> (Rich.) Perrie, D.J. Ohlsen & Brownsey	Terrestrial	Swamp	Axixá, Bacabeira, Cachoeira Grande, Icatu, Morros, Presidente Juscelino, Raposa, Rosário, São Luís	SLUI 6592; 6840; 6841; 6843; 6844; 6856; 6857; 6894; 6897; 6910
Cyatheaceae				
<i>Cyathea delgadoi</i> Pohl.	Terrestrial	Gallery Forest	Cachoeira Grande	SLUI 6836
<i>Cyathea microdonta</i> (Desv.) Domin	Terrestrial	Gallery Forest	Alcântara, Axixá, Cachoeira Grande	SLUI 6596; 6597; 6598; 6828; 6916
Dennstaedtiaceae				
<i>Pteridium esculentum</i> var. <i>harpianum</i> Schwartsb. & A. Yanez	Terrestrial	Capoeira	Cachoeira Grande, Morros	SLUI 6546; 6561; 6591
Dryopteridaceae				
<i>Cyclodium meniscioides</i> (Willd.) C. Presl var. <i>meniscioides</i>	Terrestrial	Gallery Forest	Axixá, Morros	SLUI 6562; 6579; 6832
Hymenophyllaceae				
<i>Didymoglossum punctatum</i> (Poir.) Desv.	Epiphyte	Gallery Forest	Axixá, Cachoeira Grande	SLUI 6583
<i>Didymoglossum nummularium</i> Bosch	Epiphyte	Gallery Forest	Axixá, Cachoeira Grande	SLUI 6582; 6584
<i>Trichomanes hostmannianum</i> (Klotzsch) Kunze	Terrestrial	Gallery Forest	Axixá, Icatu, Morros	SLUI 6555; 6595; 6817; 6868
<i>Trichomanes pinnatum</i> Hedw.	Terrestrial	Terra Firme Forest	Axixá	SLUI 6848

Lindsaeaceae				
<i>Lindsaea divaricata</i> Klotzsch	Terrestrial	Terra Firme Forest	Axixá	SLUI 6571
<i>Lindsaea falcata</i> Dryand.	Terrestrial	Gallery Forest	Morros	SLUI 6563
<i>Lindsaea guianensis</i> Aubl. var. <i>guianensis</i>	Terrestrial	Gallery Forest	Icatu	SLUI 6551; 6552
<i>Lindsaea pallida</i> Klotzsch	Terrestrial	Gallery Forest	Icatu	SLUI 6556
Lygodiaceae				
<i>Lygodium venustum</i> Sw.	Hemiepiphyte	Urban Environment, Capoeira	Alcântara, Axixá, Bacabeira, Cachoeira Grande, Icatu, Morros, Paço do Lumiar, Presidente Juscelino, Raposa, Rosário, Santa Rita, São José de Ribamar, São Luís	SLUI 6814; 6863; 6864; 6903; 6909; 6918; 6919
<i>Lygodium volubile</i> Sw.	Hemiepiphyte	Capoeira, Terra Firme Forest	Cachoeira Grande, Raposa, São José de Ribamar, São Luís	SLUI 6829; 6830
Marsileaceae				
<i>Marsilea polycarpa</i> Hook. & Grev.	Aquatic	Urban Environment	Paço do Lumiar, São José de Ribamar	SLUI 6913; 6914
Metaxyaceae				
<i>Metaxya parkeri</i> (Hook. & Grev.) J. Sm.	Terrestrial	Gallery Forest	Morros	SLUI 6566
Nephrolepidaceae				
<i>Nephrolepis biserrata</i> (Sw.) Schott	Epiphyte, Terrestrial	Urban Environment, Swamp, Capoeira, Terra Firme Forest	Alcântara, Axixá, Bacabeira, Cachoeira Grande, Icatu, Morros, Paço do Lumiar, Presidente Juscelino, Raposa, Rosário, Santa Rita, São José de Ribamar, São Luís	SLUI 6820; 6821; 6823; 6824; 6846; 6847; 6855; 6858; 6865; 6866; 6878; 6879; 6880; 6890; 6896; 6901; 6902
<i>Nephrolepis brownii</i> (Desv.) Hovenkamp & Miyam.	Terrestrial	Swamp, Terra Firme Forest	Cachoeira Grande, São Luís	SLUI 6904; 6905
Polypodiaceae				
<i>Campyloneurum brevifolium</i> (Link) Link	Epiphyte	Gallery Forest	Axixá	SLUI 6569
<i>Campyloneurum phyllitidis</i> (L.) C. Presl	Epiphyte	Terra Firme Forest	Cachoeira Grande	SLUI 6895
<i>Microgramma lycopodioides</i> (L.) Copel.	Epiphyte	Gallery Forest	Rosário	SLUI 6831
<i>Microgramma percussa</i> (Cav.) de la Sota	Epiphyte	Terra Firme Forest	Axixá, Bacabeira	SLUI 6553; 6560; 6842
<i>Microgramma persicariifolia</i> (Schrad.) C. Presl	Epiphyte, Rupicolous, Terrestrial	Terra Firme Forest	Axixá, Cachoeira Grande	SLUI 6837; 6839
<i>Pecluma plumula</i> (Willd.) M.G. Price	Epiphyte	Gallery Forest	Cachoeira Grande	SLUI 6544; 6545

<i>Phlebodium aureum</i> (L.) J. Sm.	Epiphyte	Urban Environment, Terra Firme Forest	Alcântara, Axixá, Bacabeira, Cachoeira Grande, Icatu, Morros, Paço do Lumiar, Presidente Juscelino, Raposa, Rosário, Santa Rita, São José de Ribamar, São Luís	SLUI 6849; 6854; 6875; 6876; 6877; 6912
<i>Phlebodium decumanum</i> (Willd.) J. Sm.	Epiphyte	Urban Environment, Terra Firme Forest	Alcântara, Axixá, Bacabeira, Cachoeira Grande, Icatu, Morros, Paço do Lumiar, Presidente Juscelino, Raposa, Rosário, Santa Rita, São José de Ribamar, São Luís	SLUI 6833; 6834; 6859; 6860; 6861; 6862; 6891; 6892
<i>Serpocaulon triseriale</i> (Sw.) A.R. Sm.	Epiphyte	Terra Firme Forest	Axixá	SLUI 6548; 6570
Psilotaceae				
<i>Psilotum nudum</i> (L.) P. Beauv.	Rupicolous	Urban Environment	São Luís	SLUI 6921
Pteridaceae				
<i>Acrostichum danaeifolium</i> Langsd. & Fisch.	Terrestrial	Swamp	Axixá, Morros, São José de Ribamar	SLUI 6883; 6884; 6885
<i>Acrostichum aureum</i> L.	Terrestrial	Swamp	Axixá	SLUI 6886
<i>Adiantum deflectens</i> Mart.	Rupicolous, Terrestrial	Urban Environment	Alcântara, São José de Ribamar	SLUI 6920
<i>Adiantum dolosum</i> Kunze	Terrestrial	Terra Firme Forest	Axixá	SLUI 6549
<i>Adiantum latifolium</i> Lam.	Terrestrial	Terra Firme Forest	Axixá, Cachoeira Grande, Rosário, Santa Rita	SLUI 6550; 6565; 6585 6851; 6872
<i>Adiantum pulverulentum</i> L.	Terrestrial	Terra Firme Forest	Axixá	SLUI 6576
<i>Adiantum terminatum</i> Kunze ex Miq.	Terrestrial	Terra firme Forest	Axixá, Cachoeira Grande	SLUI 6593; 6594; 6908
<i>Ananthacorus angustifolius</i> (Sw.) Underw. & Maxon	Epiphyte	Terra Firme Forest	Axixá	SLUI 6819
<i>Ceratopteris thalictroides</i> (L.) Brongn.	Aquatic	Urban Environment, Gallery Forest	Cachoeira Grande, São José de Ribamar	SLUI 6870; 6871
<i>Hemionitis rufa</i> (L.) Sw.	Rupicolous, Terrestrial	Terra Firme Forest, Gallery Forest	Axixá, Cachoeira Grande	SLUI 6564; 6838
<i>Pityrogramma calomelanos</i> (L.) Link	Rupicolous, Terrestrial	Urban Environment, Swamp, Gallery Forest	Alcântara, Axixá, Cachoeira Grande, Paço do Lumiar, São José de Ribamar, São Luís	SLUI 6815; 6816; 6881; 6882; 6906; 6917
<i>Polytaenium citrifolium</i> (L.) Schuettp.	Epiphyte	Gallery Forest	Cachoeira Grande	SLUI 6558
<i>Polytaenium guayanense</i> (Hieron.) Alston	Epiphyte	Gallery Forest	Cachoeira Grande	SLUI 6572
<i>Pteris ensiformis</i> Burm.f.	Rupicolous	Urban Environment, Gallery Forest	Presidente Juscelino, São Luís	SLUI 6867; 6893
<i>Pteris tripartita</i> Sw.	Terrestrial	Urban Environment, Swamp	Cachoeira Grande, São José de Ribamar	SLUI 6869
<i>Pteris vittata</i> L.	Rupicolous	Urban Environment	São Luís	SLUI 6911

<i>Vittaria lineata</i> (L.) Sm.	Epiphyte	Terra firme Forest	Axixá, Bacabeira, Cachoeira Grande, São Luís	SLUI 6586; 6845; 6898; 6900
Salviniaceae				
<i>Salvinia auriculata</i> Aubl.	Aquatic	Floating	São José de Ribamar	SLUI 6557
<i>Salvinia radula</i> Baker	Aquatic	Floating	Alcântara, Santa Rita	SLUI 6588; 6915
Schizaeaceae				
<i>Actinostachys pennula</i> (Sw.) Hook.	Terrestrial	Capoeira	Icatu, Morros	SLUI 6581; 6818
<i>Schizaea elegans</i> (Vahl) Sw.	Terrestrial	Terra Firme Forest	Morros	SLUI 6589
Tectariaceae				
<i>Tectaria incisa</i> Cav.	Terrestrial	Terra Firme Forest, Creek, Gallery Forest	Axixá	SLUI 6577
<i>Triplophyllum funestum</i> (Kunze) Holttum	Terrestrial	Gallery Forest	Axixá	SLUI 6559; 6575
Thelypteridaceae				
<i>Christella hispidula</i> (Decne) Holttum	Terrestrial	Gallery Forest	São Luís	SLUI 6567
<i>Cyclosorus interruptus</i> (Willd.) H. Ito	Terrestrial	Capoeira	Axixá	SLUI 6587; 6835
<i>Goniopteris poiteana</i> (Bory) Ching	Terrestrial	Terra Firme Forest	Axixá	SLUI 6573
<i>Goniopteris tristis</i> (Kunze) Brade	Terrestrial	Terra Firme Forest	Axixá	SLUI 6547; 6574
<i>Macrothelypteris torresiana</i> (Gaud.) Ching	Terrestrial	Gallery Forest	São Luís	SLUI 6568
<i>Meniscium hostmannii</i> (Klotzsch) R.S. Fern. & Salino	Terrestrial	Swamp	Cachoeira Grande	SLUI 6822
<i>Meniscium serratum</i> Cav.	Terrestrial	Swamp	Axixá, Cachoeira Grande, Icatu	SLUI 6825, 6826; 6827

Pteridaceae and Polypodiaceae commonly stand out as the most diverse families in studies carried out in the Amazonia and Cerrado biomes in other Brazilian states [23, 30, 32] and Maranhão [4, 5]. These families have wide geographic distributions in Brazil, individuals that occupy different habitats, and are highly morphologically variable [3].

Among the life forms observed, terrestrial stands out, with 34 species, followed by epiphytic with 15 species, aquatic with four species, rupicolous with three species, and hemiepiphytic with two species. Four species were observed with two life forms (terrestrial/rupicolous and epiphytic/terrestrial) and one species had three life forms (epiphytic, terrestrial, and rupicolous) (Table 2).

The similarity analysis (cophenetic correlation: 0.98) had two major clusters (1 and 2) and several subgroups in group 1 (Figure 2). Group 1 comprises mostly areas that are predominantly Amazonian vegetation and some areas transitioning to Cerrado vegetation, while group 2 comprises areas where Cerrado vegetation is dominant and there is little influence of Atlantic Forest vegetation. Within group 1, subgroup A stands out and is represented by Chapada das Mesas National Park and its surroundings, which have Cerrado vegetation. However, although this area is predominantly Cerrado, due to its proximity to the Amazonia biome in Maranhão it shares species in common between the two biomes.

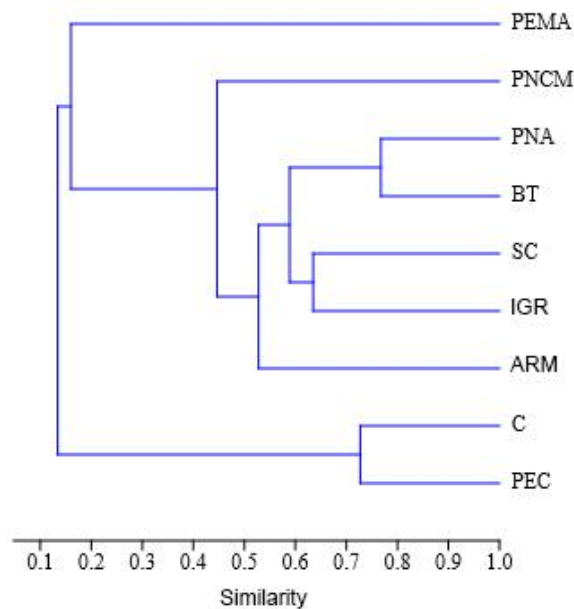


Figure 2. Dendrogram of relationships between areas used in the floristic similarity analysis. PEMA – Parque Estadual Monte Alegre, PNCM – Parque Nacional Chapada das Mesas and its surroundings, PNA – Parque Nacional da Amazônia, BT – Baixo Tapajós, SC – Serra dos Carajás, IGR – Immediate Geographic Region of São Luís, ARM – Remnants of the Amazônia Maranhense, C – Carambeí, PEC – Parque Estadual do Cerrado. 1 and 2 are major groups, and A, B, C, D, E, and F are subgroups.

Group 1 also has subgroup B, which contains studies carried out in areas of the Amazonia, subgroup C (ARM) stands out in relation to the other subgroups in this part of the dendrogram. Although the study (ARM) was carried out in areas of the Amazonia in Maranhão, it lists a smaller number of species compared to the other works of subgroup B, except for the survey of the present study (IGR).

Subgroup E has two studies that were carried out in large areas with vegetation typical of the Amazonia. This subgroup formed because a study by Oliveira et al. (2021) [31] included a large area of the Tapajós River Basin, which contains Amazon National Park, as well as the study area of Menezes and Labiak (2020) [30]. These study areas mainly have Campinaranas, upland

forests, partially flooded forests (such as floodplains and igapós), and secondary forests, which are suitable environments for ferns and lycophytes.

Subgroup F includes a study by Salino et al. (2018) [25] that was carried out in Serra dos Carajás. Of the studies used in the floristic similarity analysis, this study by Salino et al. [25] has the most species. Despite that it was carried out in a mountainous region, 70% of the recorded species were found in forested areas. This subgroup also includes data from the Immediate Geographic Region of São Luís (IGR). Although this is a transition region between the Amazonia and Cerrado biomes, its vegetation type comprises species found more frequently in the Amazonia biome. The two study areas do not have similar vegetation formations because in Serra dos Carajás (SC) there is more high-altitude vegetation and rocky places [35], and in the IGR there is Terra Firme Forest, marshes, riparian forest, and gallery forest. Despite the topographical differences, the similarity between SC and IGR species seems to be linked to greater water availability throughout the year, which favors the life cycle of ferns and lycophytes.

4. CONCLUSION

This is the first floristic similarity study that emphasizes ferns and lycophytes in Maranhão, state. However, the scarcity of floristic surveys in Maranhão and other ecotonal areas in Brazil made more complex analyses of floristic similarity and threats of the species difficult. Even with recent efforts that resulted in publications of floristic surveys of these plants in areas of the Amazonia and Cerrado in Maranhão, additional data are needed. Floristic similarity studies can contribute to more precisely delimiting the distributions of the most species-rich areas of biomes and determining which transition areas between biomes are the most relevant to preserve and conserving species. In this similarity study, the species found were mostly Amazonia. The prevalence of Amazonia species is probably because ferns and lycophytes need water for the gametophytic phase to complete the reproductive cycle of the alternation of generations. In the Cerrado, the effect of the dry season is more noticeable than in the Amazonia, which makes it difficult for ferns and lycophytes to reproduce. Even in Cerrado areas in Maranhão, most species occur in gallery forests, which have a more humid environment throughout the year.

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