

Research article

Checklist and conservation of the flora in an ecotonal area in the Bico do Papagaio microregion, Tocantins state, Brazil

Lista y conservación de la flora en un área ecotonal de la microregión del Bico do Papagaio, estado de Tocantins, Brasil

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Received: 19th October 2024. Revised: 19th May 2025. Accepted: 11th July 2025

Associate Editor: Magdi T. Abdelhamid

Citation/ citar este artículo como: Silva, A. O., Amorim, I. F. F., Feitosa, V. R., Pereira, A. V. S., Thomas, W. W. and Almeida Jr. E. B. (2025). Checklist and conservation of the flora in an ecotonal area in the Bico do Papagaio microregion, Tocantins state, Brazil. *Acta Biol. Colomb.* 30(3), 46-54. <https://doi.org/10.15446/abc.v30n3.117127>

ABSTRACT

The Amazon and Cerrado biomes form a wide and complex savanna-forest ecotone, particularly in northern Brazil. The Bico do Papagaio micro-region is an important area of biodiversity due to its floristic diversity. This study aimed to provide a species list of Angiosperm Flora of Bico do Papagaio micro-region, Tocantins state, Brazil. The species list was compiled from Brazilian and international herbaria, in collections available in Reflora Herbario Virtual and SpeciesLink. A total of 928 species, distributed in 475 genera and 117 families were reported to Bico do Papagaio micro region. The families with the greatest number of species were Fabaceae (148 species), Poaceae (63), Euphorbiaceae (38), Myrtaceae (26), Bignoniaceae (22), Malvaceae (24), Melastomataceae (26), Cyperaceae (29), Convolvulaceae (24) and Apocynaceae (23). The families were highlighted due to ecotonal characteristics of the studied area, since those are plants easily found on these biomes, as well as diverse phytogeographic domains, since they easily adapt to diverse environments, like Cerrado and Amazon. This study indicates the importance of specific data species compilation from herbaria collections to comprehend the already historical record of species in the region and which are no longer collected, be it for low data collection effort or the extinction of these species.

Keywords: Amazon, biodiversity, Cerrado, ecotone, floristic.

RESUMEN

Los biomas Amazonia y Cerrado forman un ecotono sabana-bosque amplio y complejo, especialmente en el norte de Brasil. La micro región del Bico do Papagaio es una importante área de biodiversidad debido a las peculiaridades de su diversidad florística. Así, el presente estudio objetivó proporcionar una lista de especies de la flora de angiospermas de la región del Bico do Papagaio, Tocantins, Brasil. Los datos de la lista fueron compilados de herbarios de Brasil e internacionales, en colecciones disponibles en Reflora Herbario Virtual y SpeciesLink. Fueron reportadas 928 especies, distribuidas en 475 géneros y 117 familias para la región del Bico do Papagaio. Las familias más significativas en número de especies fueron Fabaceae (148 especies), Poaceae (63), Euphorbiaceae (38), Myrtaceae (26), Bignoniaceae (22), Malvaceae (24), Melastomataceae (26), Cyperaceae (29), Convolvulaceae (24) y Apocynaceae (23). Las familias se destacan debido a características del área estudiada, ya que esas plantas son fácilmente encontradas en estos biomas,

así como en dominios fitogeográficos diversos, ya que ellas se adaptan fácilmente a distintos ambientes, tales como Cerrado y Amazonia. Ese estudio indica la importancia de las compilaciones de datos puntuales acerca de las especies en colecciones de herbarios, para comprender la historia de esas especies en la región y otras que no son más colectadas, sea por poco esfuerzo de colecta o por extinción de esas especies.

Palabras clave: Amazonía, biodiversidad, Cerrado, ecotono, florística.

INTRODUCTION

The Amazonia-Cerrado ecotonal zone forms one of Brazil's largest transition areas between phytogeographical domains in Pará, Mato Grosso, Maranhão, and Tocantins states. This transition zone has diverse vegetation formations, such as typical cerrado, *cerradão*, and semi-deciduous seasonal forests (Ratter *et al.*, 2003; Marimon-Junior and Haridasan, 2005; Marimon *et al.*, 2014). This zone has ecological diversity, which serves as a habitat for numerous species (Britto, 2021). Between these phytogeographical domains, there is a large ecotonal region characterized by a unique complexity of species from both communities, highlighting the importance of conserving biodiversity in these areas (Marques *et al.*, 2020). Ecotones between the Amazon and Cerrado biomes are naturally rich in biodiversity because they harbor species from both biomes, creating areas of overlap. However, these ecotonal regions are located within the Deforestation Arc, which threatens their unique diversity. This overlap of ecosystems is valuable but at risk, raising concerns about the potential loss of species in these transitional areas.

The Deforestation Arc extends from the southern limit of Amazonia, in Pará and Maranhão, to the western limit in Acre (Fearnside *et al.*, 2009). It is an agricultural and timber frontier zone and in the Amazonia-Cerrado ecotone there is the highest concentration of deciduous and semi deciduous forests in Brazil, which has experienced around 60% deforestation and/or burning (Santos, 2024). According to data from the National Institute for Space Research (INPE), 278,299 wildfire hotspots were recorded in Brazil in 2024, representing a 46.5% increase compared to the previous year, which registered 189,901 occurrences (INPE, 2025). Therefore, because of fires in Cerrado areas, combined with livestock farming, agriculture and illegal logging, many species, especially flora, may disappear before being recorded or described by science (Cardille and Foley, 2003; Gullison *et al.*, 2007; Rivero *et al.*, 2009).

Due to increasing deforestation, correctly identifying and georeferencing species threatened with extinction has become important to direct research and policies related to the conservation of the region or ecosystem (Sambuichi *et al.*, 2008). Governmental and non-governmental organizations have relied on these red lists to define priorities, influence legislation, and guide investments related to conservation (Hoffmann *et al.*, 2008). Thus, including the conservation status on lists of species can guide public conservation policies for priority areas at the local, regional, or global scale (Rodrigues *et al.*, 2006).

This reinforces the urgent need for studies that expand records and knowledge of the flora, in Tocantins there are only six integral conservation units and these occupy only 5.45% of the state. Sustainable use conservation units occupy 9.27% of the state (Silva *et al.*, 2017) and are completely or partially in the Bico do Papagaio microregion (Britto, 2021).

Within this context, the Bico do Papagaio microregion, whose phanerogamic flora is poorly known, needs to be considered a priority area for biodiversity conservation. Thus, the present study aims to research about the composition of the Angiosperm flora of the Bico do Papagaio microregion. The data provided can contribute to policy proposals for the protection and conservation of the flora in order to minimize losses from excessive exploitation and environmental degradation.

MATERIAL AND METHODS

Characterization of the study area

The state of Tocantins covers 277,621 km² (IBGE 2023) and (IBGE 2023) and the Bico do Papagaio microregion, in the extreme north of the state (Fig. 1), is 15,203.63 km². This microregion lies within the Amazon Arc of Deforestation, reinforcing the urgency of conservation efforts in this transitional zone between the Cerrado and Amazonia (Silva *et al.*, 2019) and is located between the Tocantins and Araguaia rivers (Oliveira, 2016; Nascimento, 2021). The Bico do Papagaio microregion covers 25 municipalities, from Darcinópolis in the south to São Sebastião do Tocantins in the extreme north (Rodrigues *et al.*, 2020). The data collected in this study was limited to the geographical coverage of the municipalities cited (Table 1).

In the southernmost part of the microregion lies the Apinajé Indigenous Land, which has an area of 1,420 km² and covers the municipalities of Itaguatins, Maurilândia do Tocantins, Cachoeirinha, São Bento do Tocantins, and Tocantinópolis (Britto, 2021). All this Indigenous land is in the Cerrado phytogeographic region (Torres and Costa, 2020). The Bico do Papagaio microregion contains three sustainable-conservation units, located wholly or partially within it (Britto, 2021). This are: Área de Proteção Ambiental Lago de Santa Isabel, created in 2002 with an estimated area of 18,608 ha; Área de Proteção Ambiental do Rio Taquari, which was also created in 2002 and is 26,152 ha; and Reserva Extrativista Extremo Norte do Tocantins, which was created in 1992 and is 9,125 ha of

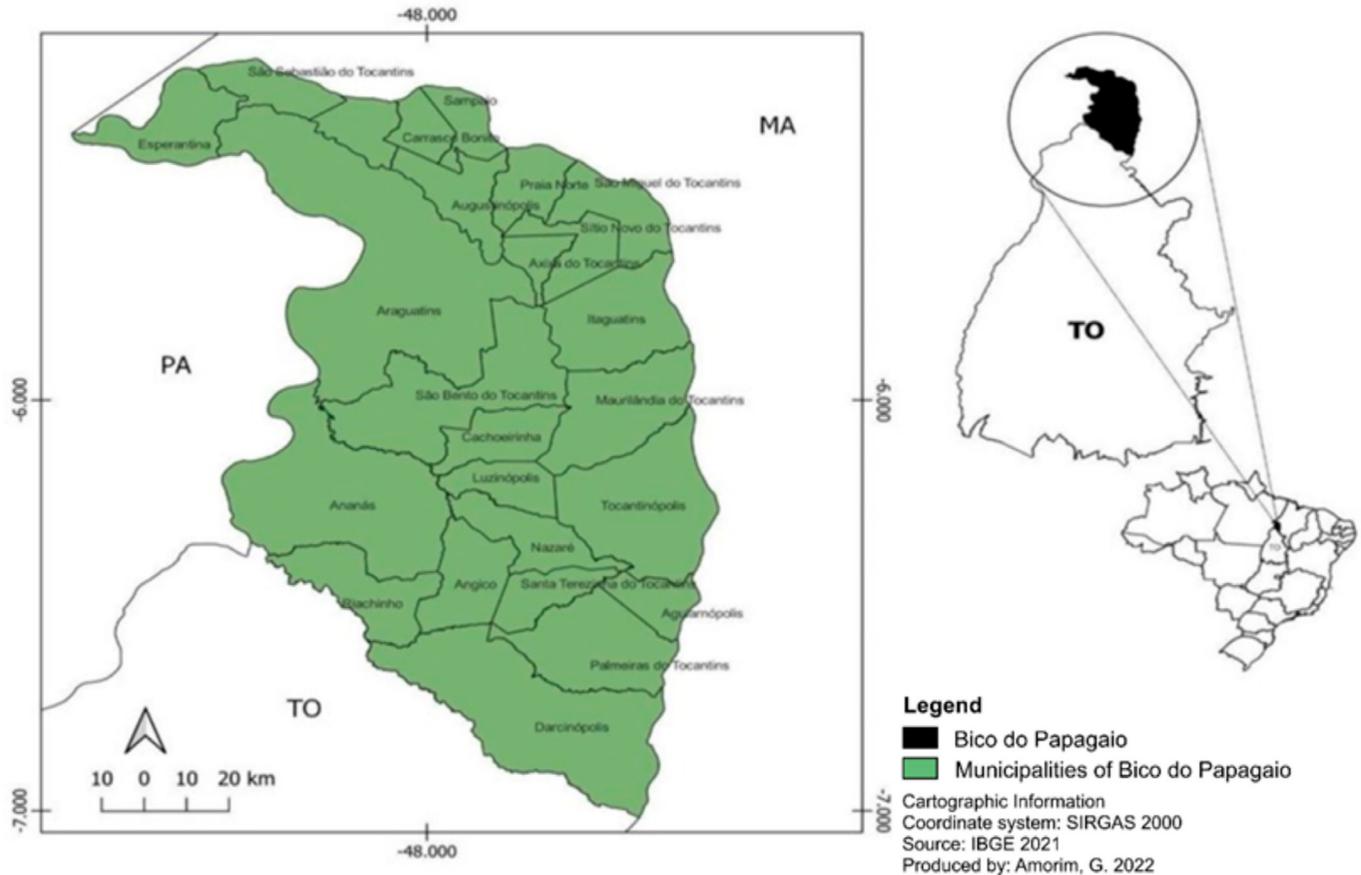


Figure 1. Geographic location of the Bico do Papagaio microregion in Tocantins, Brazil.

babaçu, with the aim of insuring the extraction of babaçu coconuts by “coconut breakers” (*quebradeiras de coco*) and other traditional communities (Britto, 2021). According to Köppen classification (Kottek et al., 2006; Roldão and Ferreira, 2019), the predominant climate in the Bico do Papagaio microregion is Aw (Araújo et al., 2017) with two well-defined periods, a dry season (April to September) and a rainy season (October to March) (Carneiro et al., 2019). The mean annual temperature is 26°C and the mean annual precipitation is 1,200 mm (Haidar, 2013).

Collecting and analyzing the data

The data about the flora of Bico do Papagaio were obtained from national and international herbarium records indexed in SpeciesLink (<https://specieslink.net>) and Herbário Virtual REFLORA (<https://reflora.jbrj.gov.br/reflora/herbarioVirtual/>) platforms. Filters were applied to searches to select species that occur in the Bico do Papagaio microregion, using the following inclusion criteria: collection location, geographic coordinates and verification of the collection location recorded in the exsiccata. All plants considered up to December 2023 were considered as the time frame.

After the initial listing, records without vouchers were excluded. Records that did not have an image of the specimen were only considered if identification had been confirmed by a specialist taxonomist. The species names were then checked on the Flora e Funga do Brasil website to verify spelling, synonyms and their nomenclatural validity.

Data on growth habit were obtained by searching for the species name in the Flora e Funga do Brasil (<http://floradobrasil.jbrj.gov.br>) database; terrestrial and aquatic phanerogams were considered. Data such as origin and type of biome were not included in our dataset because they were not recorded in the exsiccata or in a reliable database. The species names and their respective authors were verified on the Flora e Funga do Brasil database. Families were classified according to APG IV (2016). The conservation status data were verified using the IUCN (<https://www.iucnredlist.org>) and CNCFlora (<http://cncflora.jbrj.gov.br>) databases. The Venn diagram (Gotelli and Ellison, 2016) was constructed to assess species sharing between the Amazon and Cerrado biomes.

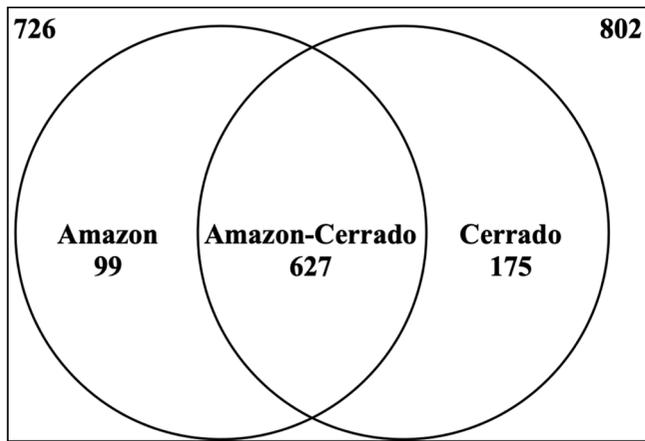


Figure 2. Venn diagram of the floristic composition of the Bico do Papagaio microregion, Tocantins, Brazil.

RESULTS

A total of 928 species, 475 genera, and 117 families were recorded. The families with the greatest number of species were Bignoniaceae (22 spp.), Asteraceae (17 spp.), Malvaceae (24 spp.), Convolvulaceae (23 spp.), Apocynaceae (23 spp.), Melastomataceae (26 spp.), Myrtaceae (26 spp.), Cyperaceae (29 spp.), Euphorbiaceae (38 spp.), Rubiaceae (51 spp.), Poaceae (63 spp.), Fabaceae (146 spp.). These families together accounted for 52.58% of the species recorded (Supplementary table 1, Fig. 2). The most representative genera were *Paspalum* (18 spp.), *Eugenia* (14 spp.), *Miconia* (13 spp.), *Ipomoea*, *Chamaecrista*, *Erythroxylum*, *Bauhinia* (11 spp., each), *Cyperus* (10 spp.), *Passiflora* (nine spp.), *Croton*, *Centrosema*, *Manihot*, *Axonopus* (eight spp., each) and *Senna* (seven spp.). Together, these genera accounted for 15.84% of the total.

In terms of growth habit 336 species were classified as shrubs (35.20%), 271 as herbs (29.20%), 229 as trees (25.10%), 85 as lianas (9.05%), and 14 as palms (1.40%). Of the total species recorded, 853 (91.91%) lack conservation assessment. The remaining species fall into the following categories: 6.93% as least concern (LC); 0.42% as vulnerable (VU); 0.21% as data deficient (DD); 0.21% as critically endangered (CR); 0.10% as endangered (EN); and 0.10% as near threatened (NT). Of the 928 inventoried species, 99 spp. (10.66%) occur in the Cerrado biome, 175 spp. (18.5%) occur in the Amazônia biome, and 627 spp. (67.56%) are present in both.

DISCUSSION

The present study provides a comprehensive understanding of the floristic composition and ecological structure of the Bico do Papagaio microregion, emphasizing its significance as a transitional zone between the Amazon and Cerrado biomes. The predominance of Fabaceae, Poaceae, and Euphorbiaceae, as revealed in the inventories, directly

supports the study's central objective of characterizing the adaptive mechanisms that sustain plant diversity in ecotonal systems. These families, widely recognized for their ecological plasticity, nitrogen-fixing capacity, and tolerance to edaphic variation, are fundamental in maintaining soil fertility and ecosystem stability in areas subject to hydric stress and climatic fluctuations. Such dominance is consistent with previous findings from Miguel *et al.* (2016) and Aguiar *et al.* (2018, 2021), who documented similar floristic patterns in ecotonal environments across central Brazil, confirming their functional importance in mixed phytogeographic mosaics.

In alignment with these patterns, the observed composition of life forms - predominantly arbustive and arboreal - reflects the structural complexity and adaptive responses of vegetation to environmental gradients. Soil texture, drainage, and precipitation were identified as key drivers of species distribution, reinforcing the premise proposed by Andrade *et al.* (2019) that edaphic heterogeneity acts as a determining factor in floristic differentiation. The Inselberg formation, which concentrated the highest species richness, illustrates how microtopography and substrate variation foster niche diversification, contributing to the persistence of unique plant assemblages. These findings converge with Albuquerque *et al.* (2017), who emphasized the ecological relevance of rocky outcrops as microhabitats promoting diversification and resilience in transitional ecosystems.

Furthermore, the presence of threatened and endemic species - such as *Gomphrena hillii* (EN), *Cedrela fissilis* (VU), and *Apuleia leiocarpa* (VU) - highlights the ecological vulnerability of the microregion amid intensifying anthropogenic disturbances, including deforestation and fire recurrence. These results correspond with national assessments (CNCFlora, 2022; Flora do Brasil, 2020) and echo concerns raised by Miguel *et al.* (2016) regarding the conservation challenges faced by ecotonal floras. The identification of *Ruellia asperula* as a new record for Tocantins and the North region of Brazil exemplifies the potential of underexplored ecotones to reveal novel biodiversity patterns, while also evidencing the persistence of taxonomic and distributional knowledge gaps. Together, these findings confirm the hypothesis that the Bico do Papagaio microregion functions as both a biogeographic corridor and a reservoir of biodiversity, underscoring the need for intensified research and immediate conservation action.

CONCLUSIONS

This integrative floristic assessment confirms that the Bico do Papagaio microregion, located within the Amazon-Cerrado ecotone, harbors exceptional botanical diversity, encompassing 928 species distributed across 117 families. The dominance of Fabaceae, Poaceae, and Euphorbiaceae reaffirms their adaptive prominence in structurally and climatically heterogeneous environments, directly linking their ecological roles to the study's objectives

Table 1. Municipalities of the Bico do Papagaio microregion with their respective number of plant records in herbaria and territorial area.

Municipalities	Number of collection records per municipality	Area in km ²
Aguiarnópolis	112	236,8
Ananás	229	1.581,1
Angico	27	447,5
Araguatins	140	2.633,3
Augustinópolis	36	388,8
Axixá do Tocantins	19	153,5
Buriti do Tocantins	27	252,7
Cachoeirinha	4	351,5
Carrasco Bonito	20	190,4
Darcinópolis	390	1.641,8
Esperantina	41	506,2
Itaguatins	3	730,2
Luzinópolis	1	281,5
Maurilândia do Tocantins	0	736,3
Nazaré	171	376,0
Palmeiras do Tocantins	174	743,4
Praia Norte	15	301,0
Riachinho	3	512,2
Sampaio	26	222,4
Santa Terezinha do Tocantins	1	274,1
São Bento do Tocantins	19	1.099,6
São Miguel do Tocantins	15	407,0
São Sebastião do Tocantins	23	289,6
Sítio Novo do Tocantins	27	307,1
Tocantinópolis	390	1.083,6
Total area	1.913	15.747,524

of understanding species resilience and community composition in transitional systems. These results not only consolidate the hypothesis of ecotonal adaptability but also contribute to broader discussions on the functional ecology of tropical vegetation.

When compared with previous studies, including Miguel *et al.* (2016), Aguiar *et al.* (2018), Aguiar *et al.* (2021), Andrade *et al.* (2019), and Albuquerque *et al.* (2017), the results demonstrate strong convergence regarding the structural and ecological importance of these dominant families in maintaining stability and biodiversity in frontier ecosystems. However, this research advances the current understanding by revealing substantial data gaps in northern Tocantins and documenting new occurrences such as *Ruellia asperula*, expanding the biogeographical scope of the species and highlighting the urgency of continuous botanical exploration.

From a conservation and management perspective, the results underscore the importance of floristic inventories as essential tools for environmental planning, biodiversity governance, and habitat restoration. The evidence supports

the creation and strengthening of protected areas, ecological corridors, and restoration programs that maintain connectivity between the Amazon and Cerrado biomes. In this context, the Bico do Papagaio microregion emerges as a strategic area for implementing long-term conservation strategies aimed at preserving the genetic, ecological, and functional diversity of its flora.

Ultimately, the study advances understanding of how ecotonal dynamics shape plant diversity and ecosystem resilience. By integrating ecological patterns with conservation priorities, it reinforces the necessity of bridging scientific research, policy-making, and local community engagement. The preservation of the Bico do Papagaio microregion thus represents not only a regional commitment but also a national and global imperative for safeguarding biodiversity in one of Brazil's most critical transitional frontiers. Future research should deepen taxonomic, phylogenetic, and socio-environmental analyses to strengthen conservation strategies and ensure the sustainability of this unique ecotonal ecosystem.

ACKNOWLEDGEMENTS

We thank Instituto Federal do Tocantins - IFTO, campus Araguatins, for the student scholarship. The Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for the productivity grant of the last author (grant 316031/2021-6 to EBAJ). The Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - CAPES (finance code 001). The Fundação de Amparo à Pesquisa e ao Desenvolvimento Científico e Tecnológico do Maranhão - FAPEMA for supporting and financing projects. The Herbário IFTO, and the Herbário MAR, for infrastructure and field logistics.

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SUPPLEMENTARY MATERIAL

Supplementary table 1.

List of phanerogamic species occurring in the microregion of the extreme north of Tocantins state, Bico do Papagaio, Brazil.

Available at: <https://doi.org/10.5281/zenodo.17981659>