dos Santos *et al.*
Journal of Ethnobiology and Ethnomedicine (2025) 21:12
https://doi.org/10.1186/s13002-025-00769-1

Journal of Ethnobiology and Ethnomedicine

REVIEW

Open Access

The traditional knowledge about the biodiversity of edible Brazilian fruits and their pollinators: an integrative review

Luan Victor Brandão dos Santos[1*], Daniel Pereira Monteiro[2], André Luiz Borba do Nascimento[3] and Roseli Farias Melo de Barros[1]

Abstract

Brazilian fruit trees are vital for food security, and their pollination is crucial. This study aimed to build a database of edible fruit trees and their pollinators in Brazil, integrating ethnobotanical and pollination ecology research. The database was built from an integrative review of ethnobotanical records of edible fruit plants and pollination biology research in Brazil. The data were then statistically treated with the Wilcoxon test to understand the influence of the origin factors (native and exotic) on species richness associated between the groups. In total, 175 ethnobotanical scientific articles were collected, and these cited the food consumption of 557 species of fruit trees. A total of 557 fruit tree species were identified, with only 29.4% having recorded pollinators. Exotic pollinators tend to prefer exotic plants, while native pollinators show greater versatility. Hymenoptera, especially bees, are the most important pollinators. A significant knowledge gap remains regarding the diversity of pollinators and their interactions with fruit trees. Increased research is needed to address this and ensure the conservation of these important food plants. The data presented in this study can provide a solid foundation for future research focused on pollination ecology and the conservation of important food plants in Brazil.

Keywords Apidae, Food sovereignty, Species richness, Traditional knowledge

Introduction

Edible plants generally encompass all vegetables used by humans to compose their diet [1]. This group includes all plants that, in some way, are part of the diet of rural or urban communities, even if they are not consumed daily by most of the population, and whether they participate or not in the national production chain of a region or country [2].

These plants are crucial for the subsistence of traditional communities in Brazil facing food insecurity, given that they provide essential nutrients during times of extreme hunger and financial scarcity [3].

Of all plant-derived resources, fruits are the primary dietary component for Brazilians, consumed both raw and processed into various culinary preparations such as juices, sweets, cooked dishes, among others. [4, 5].

The term "edible fruit-bearing plant", used in this research, refers to all plants that produce edible fruits cited by Brazilian human communities, whether these are true fruits, pseudofruits, or if the consumption is in the form of by-products (oils) or parts (aril, mesocarp) that are consumed. For this list, there was no discrimination

*Correspondence:
Luan Victor Brandão dos Santos
luanbrandao2@outlook.com
[1] Programa de Pós-Graduação em Desenvolvimento e Meio Ambiente, Universidade Federal do Piauí, Campus Ministro Petrônio Portela, Teresina, Piauí, Brazil
[2] Programa de Pós-Graduação em Ecologia, Universidade Federal do Pará, Belém, Pará, Brazil
[3] Coordenação de Ciências Naturais/Biologia, Universidade Federal do Maranhão, Campus Centro de Ciências de Bacabal, Bacabal, Brazil

regarding the origin of the plant, or whether it participates in agricultural production chain processes.

Most fruiting plants require external factors for pollination. This essential ecosystem service can be accomplished by non-living factors like wind or by living organisms, primarily animals. Those are the most important pollinators and encompass the most well-known plant species in this system, with plants being more or less dependent on their activity [6, 7]. In extreme cases of codependency, reproduction only occurs in the presence of a specific pollinator species, as seen in some species of *Ficus* and Agaonidae wasps [8–10].

Insects are the primary group of modern pollinators, particularly bees, beetles, flies, and moths. However, they are not the only animals to perform this task; some plant families have adapted to attract birds, mammals, and other arthropods [11–13].

The coevolutionary process between these groups has led to the development of specialized floral structures designed to attract pollinators through visual cues (e.g., color, shape), olfactory (e.g., scent), and by offering rewards such as nectar, pollen, and resin [7, 14]. These factors have shaped highly specialized mutualistic relationships, particularly among native species of agricultural importance [15, 18].

The growing demand in the agricultural and food markets has led to an expansion of exotic plant crops in Brazil, with pollination services primarily provided by generalist native species [18, 19]. In the context of pollination, the introduction of *Apis mellifera* L. and the expansion of exotic crops in Brazil provide an opportunity to investigate the mechanisms shaping new plant–pollinator interaction networks, as well as the ecological and evolutionary impacts of these interactions [15–17]. Moreover, the capacity of *A. mellifera* to effectively pollinate native plants remains controversial for certain domestic cultivars [19].

Pollinator populations are facing a severe decline globally [20, 21], with Brazil being particularly affected, where the central-western, southeastern, and southern regions show the worst population reduction metrics. These areas are most affected by intensive agriculture, indiscriminate use of natural resources, and pesticide dumping [22].

The intensification of industrial agriculture, with its reliance on monocultures and pesticides, has been identified as a primary driver of habitat loss and landscape fragmentation, directly impacting pollinator populations. Environmental changes, climate change, land use, and water regimes also contribute to the decline of native species in the country [22, 23].

A direct consequence of declining pollinator populations is a decrease in the local productivity of agricultural areas that depend on this ecosystem service, directly and indirectly affecting food availability and prices. Furthermore, in Brazil, the COVID-19 pandemic has pushed the country back into the hunger map, which may lead to increased pressure on natural systems as people seek alternative sources of food and income [24, 25].

Fruits, as the primary consumed parts of plants, play a fundamental role in sustaining traditional communities and ensuring food security [26, 27]. Therefore, studying the fruit-bearing plants used by predominantly marginalized communities in Brazil also involves recognizing the ecosystem services provided by pollinators (both native and exotic) that contribute to the production of food used locally to achieve food security and generate income.

Based on these premises, the following research questions guided this study: (1) What are the edible fruit species used by communities in Brazil and their pollinators? (2) Is there an effect of fruit plant origin on pollinator richness? And (3) What is the effect of pollinator origin on the richness of visited fruit species? The hypotheses tested for the second question were: (1) native plants have higher total pollinator richness than exotic plants; (2) native plants have a higher richness of native pollinators; (3) exotic plants have higher richness of exotic pollinators The hypotheses for the third question were: (4) exotic pollinators visit a greater number of fruit species than native pollinators; (5) even without considering *Apis mellifera* L., exotic pollinators still visit a greater number of fruit species than native pollinators.

The objective of this study was to compile a database on the utilization of fruit-bearing plants in the diets of Brazilian rural, traditional and urban communities, including information on their pollinators, to highlight the significance of ecological interactions for food production. This database was used to: (1) demonstrate the importance of recognizing ecosystem services supporting Brazilian food production; (2) assess the impact of these resources on the food security of rural Brazilian communities; and (3) determine estimates of pollinator species richness per plant and plant species richness per pollinator.

Materials and methods

Data collection

The first step of the research was the creation of a database containing information about food plants consumed by the Brazilian population. A systematic literature review was conducted using the PRISMA 2020 protocol [28] to identify ethnobotanical studies that reported on the food uses of plants. The search was conducted on the following indexing platforms: Web of Science, Scopus, SciELO, and Google Scholar between October 13th, 2023, and December 9th, 2023.

The following descriptors were used in the search: ("Food Plants" AND "Brazil"; PANCs AND Brazil; "Wild food Plants" AND Brazil; "Unconventional Food Plants" AND Brazil). These search terms were translated into Portuguese, English, and Spanish.

The inclusion criteria were: (1) articles published up to 2023 that focused on the ethnobotanical use of fruit-bearing plants in the human diet, covering all regions and communities of Brazil; (2) articles written in Portuguese, English, or Spanish; (3) the study should have addressed primary data on the use of plants in the diet and provided a complete list of food plants, properly identified at the species level; those species identified only at the genus level were excluded from the analysis of this review.

Studies were excluded from the analysis if they failed to at least one of the inclusion criteria outlined above, or if they contained duplicate data on plant species, that is, when a single data source was used in multiple scientific articles.

The screening process began with the identification and removal of duplicate records using the Mendeley reference management software. Subsequently, titles, abstracts, and keywords were examined, and articles that did not meet the inclusion criteria were excluded. Finally, the full texts of the remaining articles were analyzed to extract the necessary data for this review.

To supplement the published data on this topic, additional publications were identified through cross-referencing among the previously selected articles, following the same inclusion and exclusion criteria outlined above. Given the exploratory nature of this review, which sought to comprehensively gather information on Brazilian food plants, a formal risk of bias assessment was not performed.

The second stage involved searching for pollinator data of the plant species mentioned in the selected studies. An initial search was conducted utilizing the Thematic Report on Pollination, Pollinators, and Food Production in Brazil, a comprehensive resource compiled by the Brazilian Platform on Biodiversity and Ecosystem Services [12], which provides information on pollinators of Brazilian food crops.

For plant species not found in the report, individual searches were carried out in Web of Science, Scopus, SciELO, and Google Scholar, using the following descriptors: ("Species Name" AND "pollin*") in both Portuguese and English.

Inclusion criteria for this second phase were: publication and indexing in one of the searched databases; being either an article or other academic publications (such as undergraduate, master's, or doctoral theses, books, scientific notes, etc.); providing primary data on pollination between animals and the target plant species; and being conducted in Brazil Similar to the ethnobotanical article inclusion criteria, there was no publication period limit or bias assessment. Only the animals identified in the studies as pollinators were included in the database for each plant investigated.

Publications that did not address the topic, relied on secondary pollination data, lacked proper identification of animal or plant species, were conducted outside of Brazil, or failed to explicitly identify the pollinator species within the text were excluded from the dataset.

For each selected ethnobotanical study, information on the research period, collection site, participating community, and inventoried plant species (family, species, common name, part consumed, and form of use) was extracted. From the pollinator studies, faunal information on the species identified by the research was extracted.

The scientific names and author abbreviations were carefully verified and updated based on the most recent information available from the Flora of Brazil [29], Global Biodiversity Information Facility [30], and Catalog of Taxonomic Fauna of Brazil [29] portals. Additionally, the Brazilian origin and growth habit of each plant species were confirmed, if not explicitly stated in the original studies. For this study, we employed a binary classification for plants, considering them either native or exotic to Brazil. The 'exotic' category encompasses both species introduced for cultivation and those that have established themselves spontaneously in the environment. Data from the selected studies were extracted, compiled, and processed in Excel spreadsheets for descriptive analysis.

To assess the effect of plant origin (native or exotic) on pollinator richness, we calculated the total richness (Sit), native pollinator richness (Sin), and exotic pollinator richness (Sie) for each plant species. Richness was defined as the total number of distinct pollinator species visiting each fruit species. To test hypothesis 1 (native plants have higher Sit than exotic plants), we used the Wilcoxon signed-rank test to compare Sit between the groups of native and exotic fruit plants. The same test was applied to hypotheses 2 (native plants have higher Sin) and 3 (exotic plants have higher Sie), comparing Sin and Sie, respectively, between the native and exotic plant groups. The dataset was filtered to include only interactions where the pollinator origin was known (native or exotic) and identified at least to the subgenus level.

To understand the effect of pollinator origin (native or exotic) on the richness of fruit plants visited, we calculated fruit plant richness (Sf), defined as the number of distinct plant species visited by each pollinator. A Wilcoxon signed-rank test was used to compare Sf between native and exotic insects. Due to the high number of species visited by *Apis mellifera* L., we conducted two separate analyses.

The first analysis included *A. mellifera*, testing hypothesis 4 (exotic pollinators visit higher Sf than native pollinators). In the second analysis, we excluded this species and assessed the remaining exotic species to test hypothesis 5 (excluding *A. mellifera*, exotic pollinators also visit higher Sf than native pollinators). This exclusion was necessary because the high frequency of *A. mellifera* in the pollination records skewed the mean Sf of exotic pollinators, underestimating the visitation potential of other exotic species. By excluding *A. mellifera*, we aimed to isolate the contribution of the remaining exotic species and infer the specific contribution of *A. mellifera* to Sf. Furthermore, permutation tests were performed to confirm the marginal significance of the results.

All analyses were performed using R statistical software, version 4.3.0 [31]. The car package [32] was employed to assess the assumption of homoscedasticity, while the coin package [33] was used for permutation tests Spatial distribution maps were generated in software QGIS 3.32.3 using modified geographic data obtained from the Brazilian Institute of Geography and Statistics [34].

The present research is conducted in accordance with Brazilian legislation that safeguards traditional knowledge associated, Law No. 13.123/15, and is duly registered in the National System for the Management of Genetic Heritage and Associated Traditional Knowledge (SISGen) under registration number A32DDC6. The definition and recognition of the types of the Brazilian traditional communities followed the predefinition of Decree No. 8.750/2016.

Bibliometric results

The initial database search produced a corpus of 2169 records. After screening and selection, 96 articles meeting the inclusion criteria were retained. Subsequently, cross-referencing among these articles yielded an additional 79 articles. Therefore, a total of 175 articles were selected for this study (Fig. 1).

Results

The oldest article in this database was published in 1977 by Anderson, investigated the names and uses of native palm trees among the Yanomami people (Additional file 1). While the topic was relatively unexplored in Brazil during the following decades, it saw a significant increase in research interest from the early 2000s, culminating in a peak of publications in the 2010s, which accounted for 74.28% of the total output analyzed in this review (Fig. 2).

The geographical distribution of ethnobotanical research on the dietary use of plants in Brazil shows a significant concentration in the northern and northeastern

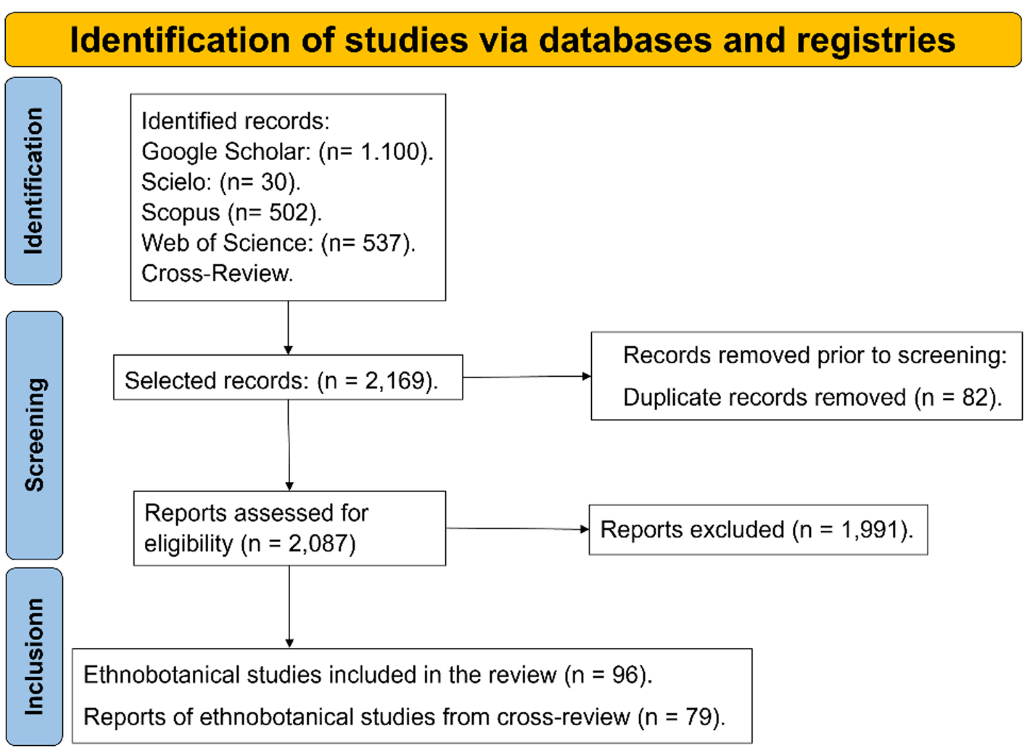


Fig. 1 Flowchart detailing the selection and inclusion process of scientific articles focused on food ethnobotany that were published in Brazil

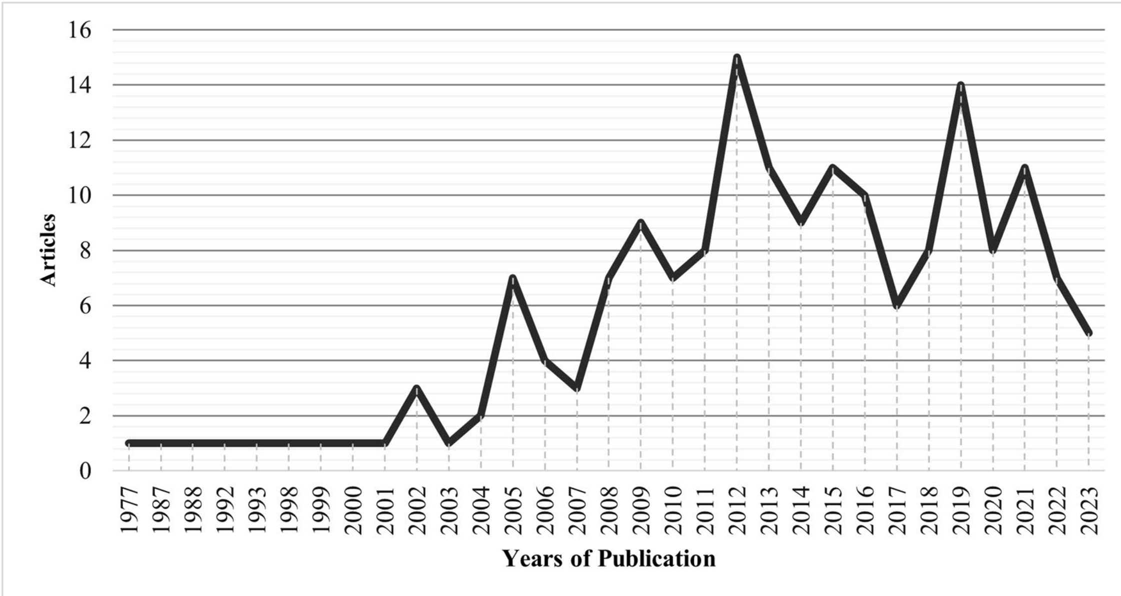


Fig. 2 Temporal distribution of scientific publications on food ethnobotany in Brazil

regions, which account for approximately 53% of the scientific output in this field. The participating communities, mostly (78.3%), are in rural areas, encompassing settlements, rural communities, agricultural producer groups, and traditional communities (Fig. 3).

A knowledge gap is observed in the production of knowledge about the consumption of food plants in the central-western and southern regions of the country, which harbor a rich biodiversity and unique phytogeographic domains, such as the flooded plains of the Pantanal wetlands and the plains and grasslands of the Pampas.

Non-traditional rural communities were the most frequently targeted for ethnobotanical research, particularly in the north and northeast regions. Studies conducted in urban areas are associated with research on the flora and social structure of home gardens as maintainers of common vegetables.

Of the 11 types of traditional communities inventoried, Quilombolas (or Maroons) were the most frequently studied, representing 28.8% of all articles in this database focusing on traditional communities. These studies spanned all Brazilian regions except the south. Conversely, ethnobotanical research on Indigenous and riverine communities concentrated primarily in the north, particularly the Amazon, reflecting the region's high biodiversity and rich cultural heritage.

A significant knowledge gap exists regarding the food practices of Indigenous communities in Brazil, as only 13 ethnicities have had their dietary habits documented. Furthermore, except for the Pankararé, all documented ethnicities reside in the Amazon Forest region or transitional areas between it and other biomes. This concentration of studies underscores a lack of information on the food practices of indigenous groups in the rest of the country. Moreover, the same situation occurs with other smaller groups of traditional communities, such as the Azoreans, Caboclos, Geraizeiros, Rubber tappers, and Seasonal farmers.

Records of edible fruit trees in Brazil

The literature reviewed reported a total of 557 fruit species utilized in Brazil Native species exhibited higher richness than exotic species, accounting for 448 species (80.4%) and 109 species (19.6%), respectively (Additional file 2). The phytogeographic domains of the Atlantic Forest, Amazon, and Cerrado were the primary focus of these studies (Fig. 4).

The geographic distribution of fruit consumption in Brazil reveals distinct patterns based on the species' origin. The northern states of Amazonas and Pará, along with the central-western state of Mato Grosso, concentrate a higher proportion of native fruit species. Conversely, the southeastern states of São Paulo and Minas Gerais, as well as the northeastern state of Bahia, exhibit a higher concentration of exotic fruit species (Fig. 5).

Among the botanical families, Myrtaceae (81 spp./14.5%) stands out as the most represented, followed by Arecaceae (72 spp./12.9%), Fabaceae (33 spp./5.9%), and Solanaceae (26 spp./4.6%). The genera *Eugenia* L. and

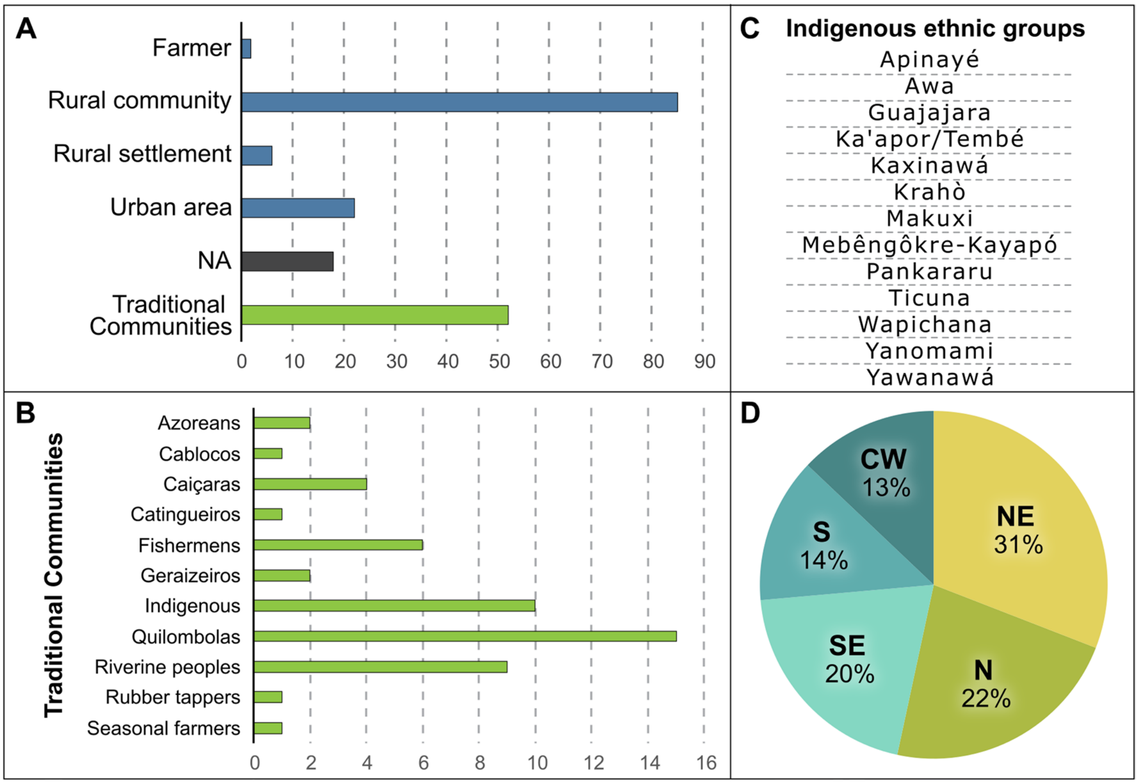


Fig. 3 Overview of the participation of Brazilian communities in ethnobotanical research on food plants, addressing their distribution by groups, ethnicities, and geographical regions. **A** Distribution of research among the main community groups. **B** Information on the traditional community groups involved in the research. **C** Indigenous ethnicities with recorded knowledge about food customs. **D** Representation of the distribution of studies in Brazilian geographical areas: NE (northeast), N (north), SE (southeast), S (south), and CW (center-west)

Annona L. are particularly rich in edible species, accounting for 4.4% and 3.4% of the total, respectively.

Shrubs and trees were the most frequently reported fruit sources *Anacardium occidentale* L. (15.9%) (Cashew), *Eugenia uniflora* L. (Pitanga) and *Psidium guajava* L. (15.3% each) (Guava), *Carica papaya* L. (14.7%) (Papaya), *Mangifera indica* L. (13.0%) (Mango), and *Cocos nucifera* L. (11.9%) (Coconut) were the most frequently mentioned species. Notably, three species from the sampled dataset were listed as endangered in both the Brazilian Ministry of Environment's (MMA, 2022) and Red List and the IUCN Red List (2024): *Butia eriospatha* (Mart. ex Drude) Becc., *Campomanesia hirsuta* Gardner, and *Inga maritima* Benth.

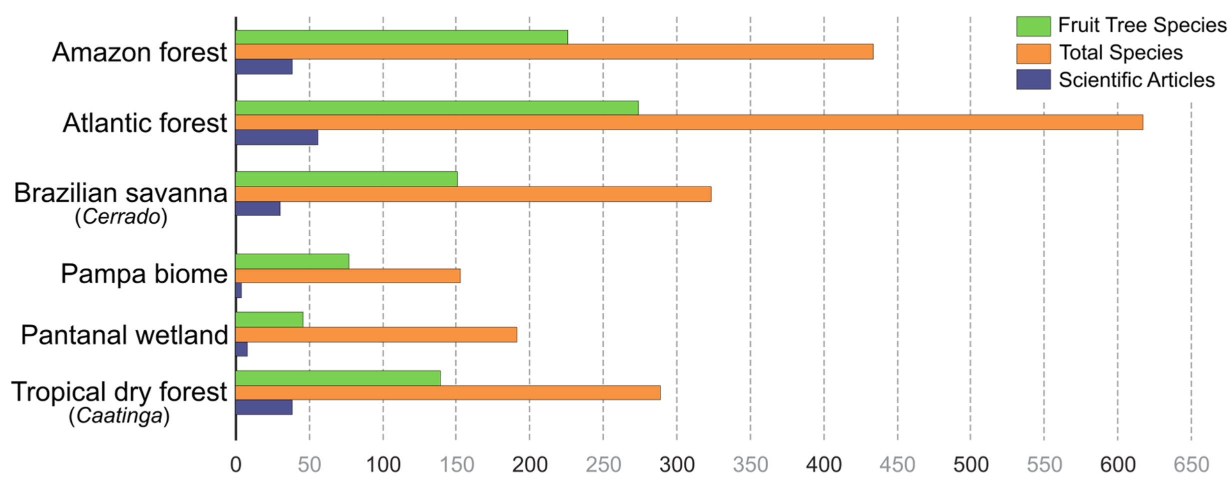
Pollinators species

Pollinator data were available for only 29.4% of the fruit trees species. These animals were distributed across 24 orders, 164 families, 351 genera, and 527 species of effective, occasional, or secondary pollinators. Of these, 24 were exotic, 441 were native, and 62 had undetermined origins, meaning there was insufficient information to determine the species' origin (Additional file 3).

Most pollinators identified in this study were classified within the Class Insecta or other arthropods. Hymenoptera is the largest order with 324 cited species (61.4%), followed by Lepidoptera (11.1%), Coleoptera (11.0%), and Diptera (4.3%). Vertebrate pollinators were concentrated in Aves (Apodiformes, Passeriformes, Psittaciformes, and Piciformes), which were the most cited, totaling 84% of the quantity, and Mammals were represented by bats (Phyllostomidae—12.5%) and small marsupials (Didelphidae, *Caluromys* spp.—3.5%) (Fig. 6).

Pollinator–fruit tree relationships

Regarding the relationship between insect pollinators and plants, *Apis mellifera* L. was the most cited pollinator of Brazilian fruit trees. Moreover, it exhibited the broadest range of species visited, being associated with 85 fruit trees in 30 families. Figure 7 illustrates the interaction network, constructed from the species data collected in the review, between fruit tree species and animal pollinators. This network visually demonstrates the impact of the presence of *A. mellifera* and the extent to which it is cited as a pollinator of food species in Brazil.



	Amazon forest	Atlantic forest	Brazilian savanna (*Cerrado*)	Pampa biome	Pantanal wetland	Tropical dry forest (*Caatinga*)
Fruit Tree Species	226	274	151	77	46	139
Total Species	434	617	323	153	191	289
Scientific Articles	38	56	30	4	8	38

Fig. 4 Spatial distributions of scientific articles on food plants, including fruit-bearing species, across Brazilian phytogeographic domains from 1970 to 2023

The most cited native pollinator species belong to the family Apidae: *Trigona (Trigona) spinipes* (Fabricius, 1793) (associated with 53 botanical species), *Tetragonisca angustula* (Latreille, 1811) (31), *Bombus (Thoracobombus) morio* (Swederus, 1787) (23), and *Xylocopa (Neoxylocopa) frontalis* (Olivier, 1789) (17). The genus *Centris* (Apidae), native to Brazil, holds the greatest species richness (30), but appears to be less sampled and have a smaller distribution than those mentioned above (Fig. 8).

Our dataset consisted of a paired list of 557 fruit tree species reported for Brazil and 527 pollinator species, as well as data on genus, family, origin (native and exotic), consumed parts, use form, and vernacular names. Records of plants with missing pollinator data, such as origin, were excluded from all statistical analyses.

The overall richness of pollinators did not differ significantly between native and exotic plants ($W = 2608.5$, $p = 0.898$). Similarly, the richness of native pollinators did not differ significantly between the two plant groups ($W = 1902.5$, $p = 0.127$). However, the richness of exotic pollinators was significantly higher in exotic plants compared to native ones ($W = 3208.5$, $p < 0.001$). On average, exotic plants hosted approximately 68% more exotic pollinators than native plants (Table 1, Fig. 9).

The violin plots below provide a visual representation of the distribution of richness data, while the box plots summarize the central tendency (median) and variability (quartiles). Letters above the boxes indicate significant differences in comparisons (Wilcoxon test), where groups with the same letter do not differ significantly.

There was no significant statistical difference in the relationship between the diversity of plants visited and the origin of pollinators ($W = 3.3265$, $p = 0.051$; $Z = 1.684$, $p = 0.093$). However, when *Apis mellifera* L. was excluded from the analysis, a significant statistical difference was observed in the number of plants visited by native and exotic pollinators ($W = 2.9785$, $p = 0.016$).

On average, native insects visited twice as many plant species (110.26%), then exotic insects when the factor *A. mellifera* was excluded from the clusters (Table 2, Fig. 10). For this analysis, richness was measured by the number of fruit species visited by pollinators and is presented in the graph as log (richness + 05) to normalize the data and improve visualization.

Our results supported only hypothesis 3, showing that exotic fruit species host more exotic pollinators than native species. The collected dataset suggests a similar richness of pollinators between the two plant groups analyzed (exotic and native). Additionally, exotic plants tend to host a higher richness of exotic pollinators than native plants. However, the same pattern was not observed when analyzing the relationship between native plant and animal data, refuting hypotheses 1 and 2. The exclusion

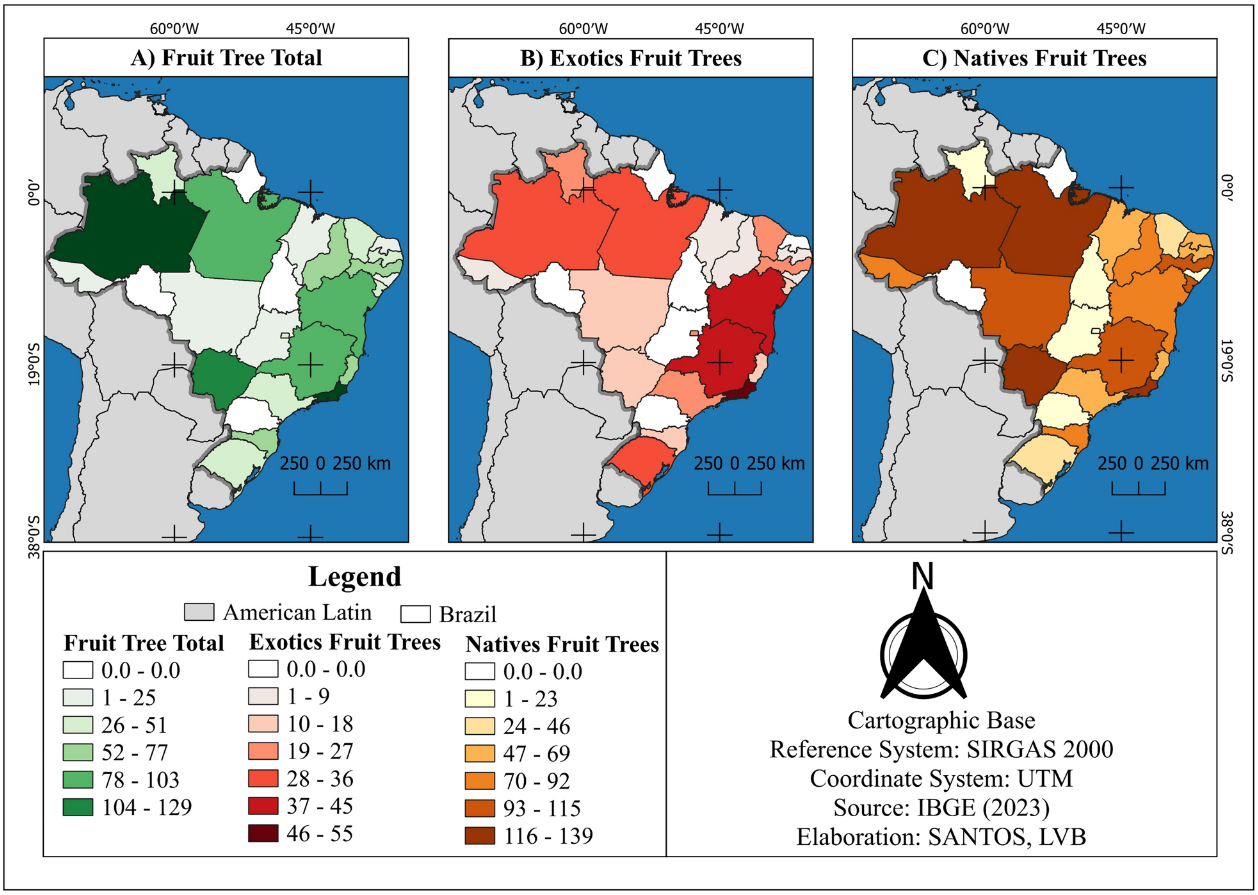


Fig. 5 Comparative distribution maps of fruit species in Brazil: **A** total fruit species; **B** exotic edible fruit species; **C** native edible fruit species

of *Apis mellifera* revealed the significant influence of this species on the observed patterns, highlighting the pollination potential of both native species and *A. mellifera* and negating hypotheses 4 and 5.

Discussion

The database for this review was constructed with information on the dietary use of 557 species of Brazilian fruit trees, consumed in both rural and urban areas. Data on pollinators of approximately 1/3 of these plants (29.3%) were found, totaling 527 species, with most species native to Brazil associated with the class Insecta, order Hymenoptera, and family Apidae. This data analysis allows us to identify ecological patterns and trends in the richness of the pollinator–plant interaction network and the use of these plants for food.

The current understanding of pollinator interactions with economically important species is still limited, hindering the development of effective conservation strategies and the assessment of ecosystem services crucial for sustaining agricultural and extractive industries [35]. This research underscores a notable knowledge gap in pollination mechanisms, as 70.7% of the species investigated lack documented information on their pollinators and pollination syndromes.

Regarding the hypotheses tested, only the third was supported, namely, exotic plants have greater diversity of exotic pollinators compared to native plants. The other hypotheses about the relationships between species origin and pollinator richness (1—native plants have a higher total pollinator richness than exotic plants and 2—native plants have a higher richness of native pollinators) were not supported by the data.

It is important to highlight the limitations of this research. Firstly, the data on plants were collected only from scientific articles, which limits the scope of knowledge accessed in other forms of publications. There is an irregular geographical distribution of studies in the country, with some areas much more known than others, in addition to the lack of data in the literature regarding pollinators of the food plants investigated.

Apis mellifera L. has proven to be a key pollinator of native and introduced fruit species in Brazil, including star fruit (*Averrhoa carambola* L.), coffee (*Coffea arabica*

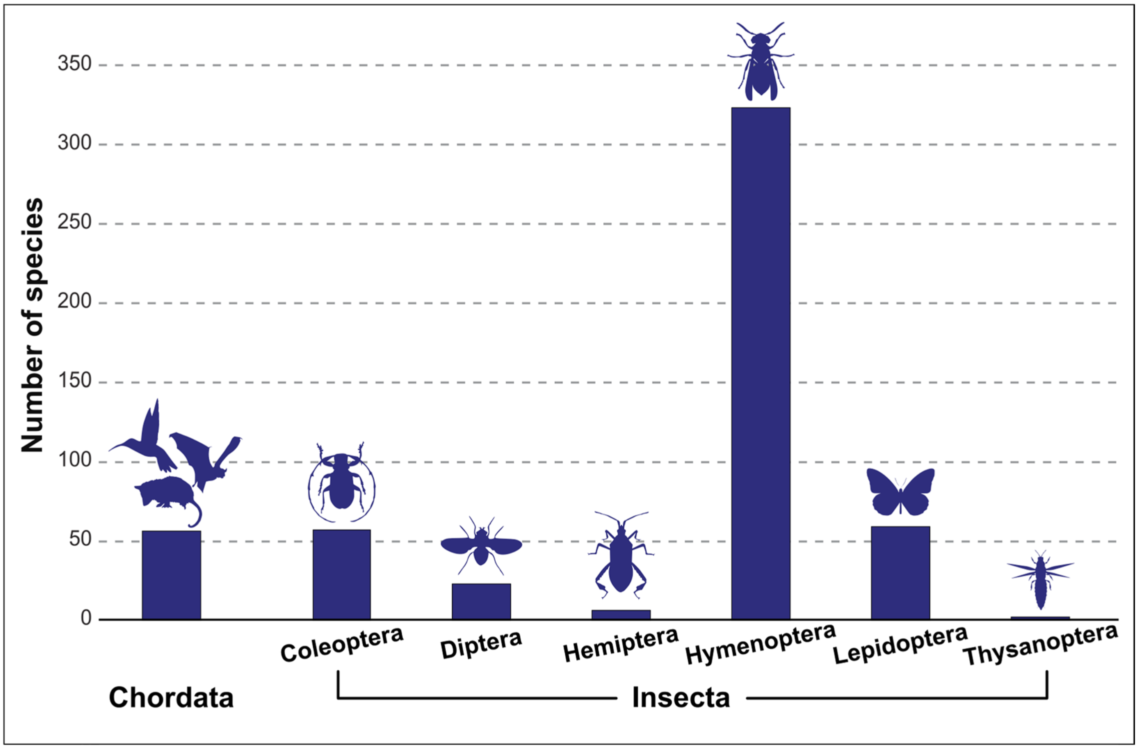


Fig. 6 Distribution of identified species from the two main classes of animal pollinators of Brazilian fruit trees

L.), and lemon (*Citrus limon* (L.) Osbeck). Its activity appears to fulfill the pollination needs of a large proportion of Brazilian cultivars and wild plants, especially in agricultural areas [35, 36], thus becoming a central pollinator in Brazil.

This species was introduced to Brazil in the 1950s to increase honey production and other beekeeping resources [37]. Subsequent swarm escapes, coupled with its high adaptability to the Brazilian environment and associated economic value, were the elements that promoted its national conservation [37].

It is crucial to highlight that, despite its significance, *A. mellifera* can negatively impact plant–pollinator networks and pollinator richness in the field [38]. Studies have shown that this species exhibits dominant social behavior over pollen resources near their nests, hindering other bees from accessing these resources, leading to population decline and even the complete replacement of native bees in areas near *A. mellifera* nests [39, 40]. In extreme cases, its ecological replacement is the only way to meet the pollination demands of plants due to the decline of native insects [39, 40].

In anthropic environments such as agricultural areas, the abundant and generalized supply of floral resources seems to favor the activity of generalist pollinators. Species like *Trigona spinipes* (Fabricius, 1793) and *A. mellifera* are examples of generalist pollinators that actively exploit these environments, competing for resources with other pollinators, both native and exotic. This ecological behavior likely explains the high richness observed in the quantitative data collected in this study.

This result contradicts hypotheses 4 and 5, which attribute to exotic pollinators a superiority in terms of visitation richness and pollination breadth. The wide distribution and generalist behavior of *A. mellifera* virtually increase the contribution of other pollinator groups, both native and exotic, to Brazilian pollination.

(See figure on next page.)

Fig. 7 Plant–pollinator network containing information on the association of 557 fruit species and 527 pollinators. **A** Interaction network between native (green) and exotic (purple) Apidae bee species and native (light green) and exotic (blue) fruit species, indicating the four most important species; **B** Interaction network between the others animals' pollinators, indicating the groups found and native (green) and exotic (blue) fruit tree species. Line thickness corresponds to the number of species visited by a particular animal or the number of animal visitors to a specific fruit species

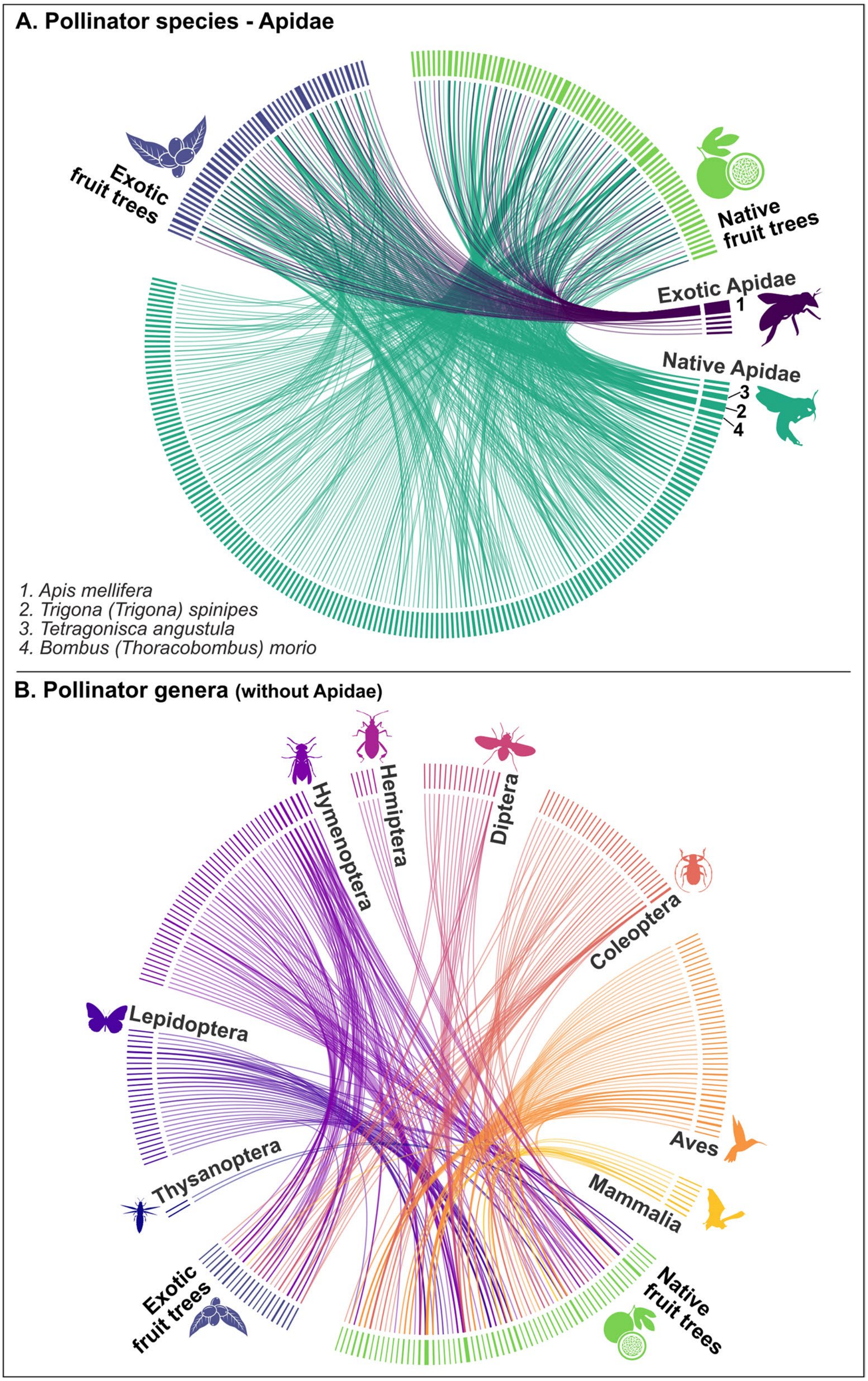


Fig. 7 (See legend on previous page.)

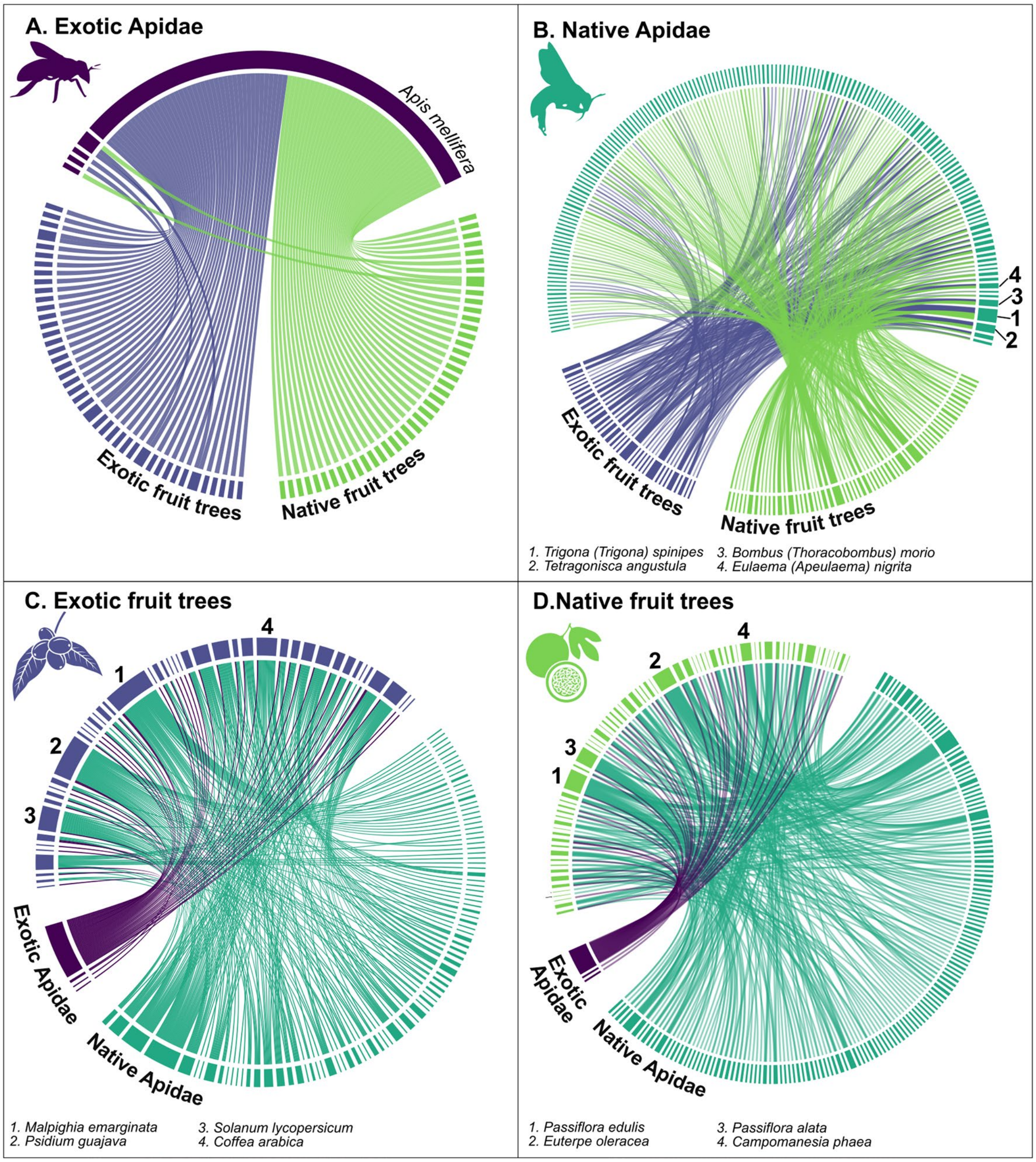


Fig. 8 Pollinator–plant interaction network highlighting the main Apidae bees and Brazilian fruit trees. **A** Interaction between exotic bees (purple) and native (green) and exotic (blue) fruit trees. **B** Interaction between native bees (green) and fruit trees. **C** Interaction network between exotic fruit trees and native and exotic bees. **D** Interaction network between native fruit trees and native and exotic bees

Table 1 Descriptive statistics of exotic pollinator richness visiting native and exotic fruit plants ($W = 3.2085$, $p < 0.001$) n = number of observations (n) of fruit plant richness for each pollinator origin group

Origin of the fruit tree	Mean	Median	Standard deviation	*n*
Exotic	1.080	1	0.571	49
Native	0.641	0	0.944	92

Both *Apis* and non-*Apis* bees plays a crucial role in enhancing fruit production in Brazilian crops, with similar increases in productivity observed in plantings visited by both groups [19, 41]. Among native pollinators, stingless bees (non-*Apis*) are the most diverse group of species in Brazilian pollination (81 spp.). The highest concentration of these bees is in the Neotropical region, where approximately 47% of all species are described in Brazil, further justifying their relevance in local pollination [42, 43]. Asteraceae, Fabaceae, Lamiaceae, and Malvaceae are

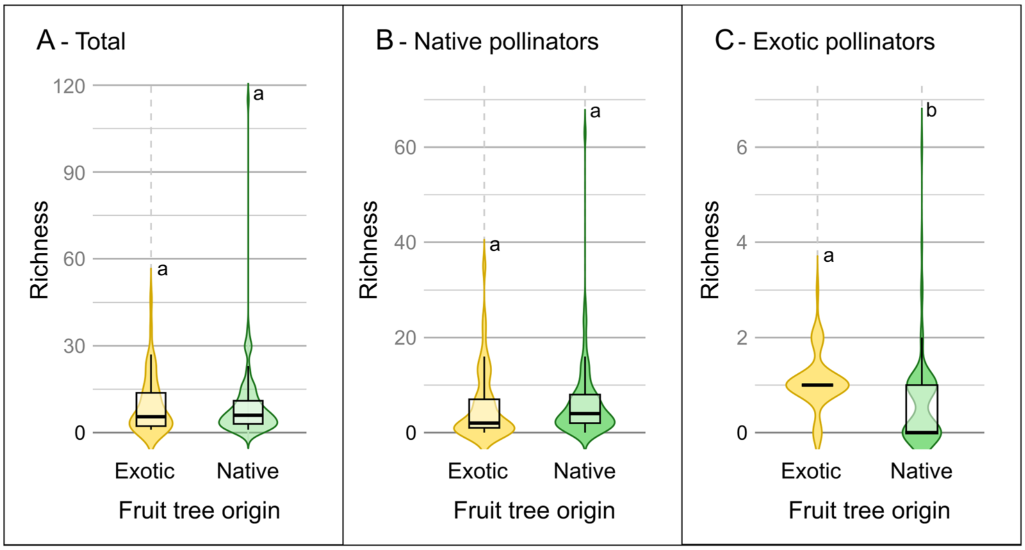


Fig. 9 Pollinator richness **A** total, **B** native, and **C** exotic associated with native and exotic fruit plants in Brazil

Table 2 Descriptive statistics of fruit plant richness visited by native and exotic pollinators in a scenario without *Apis mellifera* ($W = 3.2085$, $p < 0.001$) n = number of observations (n) of fruit plant richness for each pollinator origin group

Origin of the fruit tree	Mean	Median	Standard deviation	*n*
Exotic	1.170	1	0.230	23
Native	2.460	1	4.650	348

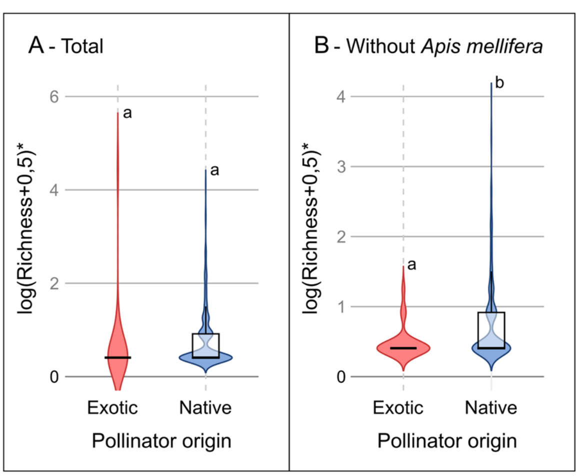


Fig. 10 Richness of fruit plants visited by exotic and native pollinators in Brazil, considering **A** the total number of pollinators and **B** a scenario without *Apis mellifera*

the botanical families most frequently visited by stingless bees, with *Trigona* and *Melipona* being the most diverse and important genera [43].

The functional diversity of pollinators is crucial for maximizing agricultural yields. Although bees are the primary pollinators, recent studies [44–46] have demonstrated the significance of other pollinator groups, such as beetles, flies, wasps, butterflies, and moths. These groups, which visit 25–50% of cultivated plant species worldwide, can significantly increase agricultural production by promoting a higher frequency of floral visits, even if they are less efficient than bees in this role. The synergy between different pollinator groups can enhance fruit production, leading to increased plant productivity or larger fruit size, highlighting the importance of conserving and promoting pollinator diversity in agroecosystems [45, 46].

Insect populations, including pollinators, have experienced significant declines in recent decades, impacting major orders like Coleoptera, Lepidoptera, Hymenoptera, and Diptera. These declines are widely attributed to anthropogenic activities, as documented in numerous countries, particularly the United Kingdom [47, 48].

Our understanding of the effects of human activities on insect diversity in tropical regions, which currently harbor the largest extent of deforestation for agriculture and extensive livestock farming, remains limited. This scenario is concerning, given that the greatest diversity of animals and plants on the planet is in the tropics yet, have been comparatively less studied than other regions

[47, 48]. This lack of knowledge not only hinders our ability to accurately assess species diversity in the tropics but also prevents us from quantifying the impact of environmental pressures induced by human activities on local species.

Beyond heightened competition for plant resources, various factors contribute to the systematic decline of pollinator insect populations. Synthetic pesticides are implicated in the decimation of entomofauna diversity in agricultural landscapes. These pesticides can induce colony collapse disorder in social bees, contaminate water bodies, and kill larval stages, among other indirect effects on insects [49, 50].

Furthermore, the findings of this review highlight the abundance of food-producing fruit trees utilized by Brazilian communities. These species are accessed both through agricultural production and direct extraction from natural environments.

This situation highlights the need to seek wild food sources to supplement daily meals [51]. Rural communities have been the most studied in published articles, especially those in the northern and northeastern regions, which have the highest concentration of people with low monthly incomes and a higher predisposition to food insecurity in the country.

Additionally, Brazilian ethnobotanical research tends to prioritize the exploration of traditional knowledge and use of plants in rural environments [2, 52, 53], and preferentially in traditional communities (indigenous, quilombola, fishermen, riverine people, etc.). Furthermore, research on the use of food plants predominantly focuses on communities situated within the phytogeographic zones of the Atlantic Forest and Amazon biomes. This emphasis neglects the knowledge generated in urban areas of the country, where, when such research is conducted, it concentrates on the topic of urban home gardens. Consequently, this focus exacerbates the information gap concerning this fundamental portion of the nation.

Quilombola communities have been a focal point in ethnobotanical research. These communities, formed by descendants of enslaved Africans who escaped during Brazil's slavery era, have historically relied on surrounding natural resources for sustenance and food [54, 55]. However, there remains a significant gap in our understanding of food plant consumption in Brazil.

This is particularly concerning given the country's rich diversity of 305 indigenous ethnicities [56], of which only 13 (4.26%) have been included in ethnobotanical studies. Given the uneven geographical distribution of ethnobotanical studies within the country, with some areas being considerably more extensively researched than others, there is a lack of data in the literature concerning the pollinators of the food plants under investigation.

For traditional communities such as quilombolas and indigenous peoples in rural areas, food security is intrinsically linked to the availability of wild resources. Food insecurity increased in Brazil from the second half of the 2010s, due to the convergence of several factors, including the economic crisis, the discontinuation of public policies promoting food security in vulnerable populations, the disruption of food transfers to low-income populations, and the health crisis exacerbated by the COVID-19 pandemic in 2020 [24, 25, 57, 58], leading to increased pressure on wild resources.

This literature review highlights the importance of fruit trees in the Brazilian diet, given their high biodiversity found in Brazilian hotspot areas, such as the Amazon Rainforest, the Atlantic Forest, and the Cerrado, as a crucial factor for the food security of these communities.

Natural areas play a fundamental role in ensuring food security for both rural communities, which depend directly on natural resources for their subsistence, and urban communities, which benefit from agricultural production and the supply of food from these areas [35, 36]. Traditional communities, in turn, are crucial agents in promoting environmental conservation in these regions [53], being essential for the dissemination of good practices in land use with sustainable family agricultural production that respects the limits of the environment.

Our results align with those found on literature who indicate a consistent preference for certain plant families among traditional Brazilian communities [27]. As in their study, the Anacardiaceae, Arecaceae, Fabaceae, Myrtaceae, Passifloraceae, and Solanaceae families were the most frequently cited in our analysis, evidencing a consistent pattern in the choice of food forest resources.

The relevance of insects as pollinators is confirmed by the expressive diversity of species found in this research, corroborating previous studies [15, 35, 36]. These results reaffirm the importance of insects in the pollination of modern plants and highlight their crucial role in maintaining biodiversity and the food production chain, essential for food maintenance and the promotion of food security in rural and urban communities.

Conclusion

The recovery of traditional knowledge about the food use of plants is fundamental for biodiversity conservation and food security. In Brazil, ethnobotanical research has primarily focused on traditional communities in rural areas of the northern and northeastern regions, revealing a rich knowledge about the use of plants, with a highlight on those from the Anacardiaceae, Arecaceae, Fabaceae, Myrtaceae, Passifloraceae, and Solanaceae families. However, there is a need to expand these studies to other regions, like south and center-west poorly study, and social groups like indigenous ethnics, to build a more complete picture of the diversity of food plants used in the country and to guarantee the valorization of this ancestral knowledge.

This research compiled the largest amount of published ethnobotanical data on edible fruits in communities and their respective pollinators in Brazil. These plants play a fundamental role in the food security of Brazilian communities, as is evident from the richness of fruits recovered in this review, with 557 species, 80% of which are native.

The Brazilian pollinator is generally characterized as a small to medium-sized arthropod of the order Hymenoptera from the family Apidae, since this group is associated with the pollination of a quarter of the total fruit species studied.

Based on these data, we can estimate that *Apis mellifera* Linnaeus, 1758, *Bombus* (*Thoracobombus*) *morio* (Swederus, 1787), *Tetragonisca angustula* (Latreille, 1811), *Trigona* (*Trigona*) *spinipes* (Fabricius, 1793), and *Xylocopa* (*Neoxylocopa*) *frontalis* (Olivier, 1789) are the pollinator species with the greatest richness of associated fruit species.

The results of this review corroborate the hypothesis that exotic pollinators tend to visit exotic plants. Native pollinators have demonstrated a greater ability to pollinate a wider variety of botanical species, both native and exotic, underlining their importance for maintaining biodiversity and food security.

Despite the advances, scientific knowledge on the subject in Brazil is still incipient, given that there is no information on the pollinators of 393 fruit species, one-third of the total investigated, which highlights the need for more research in this area.

The data about the pollinator groups associated with these plants are essential for the conservation of endangered species, such as *Butia eriospatha, Campomanesia hirsuta* and *Inga maritima*. Understanding the interactions between plants and pollinators is fundamental for developing effective conservation strategies and ensuring the sustainability of ecosystems. Therefore, it is imperative to deepen knowledge on the subject, focusing mainly on those plants that have not yet been studied, using the evidence of this research as a basis for future research choices of groups or local of study.

Abbreviations

PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
Sie	Exotic pollinator richness
Sin	Native pollinator richness
Sit	Total richness

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13002-025-00769-1.

Additional file 1.

Additional file 2.

Additional file 3.

Acknowledgements

We would like to express our gratitude to the Coordination for the Improvement of Higher Education Personnel (CAPES) for providing open access to selected journal databases, to FAPEPI, CNPq, and CAPES for the scholarship granted, and to the Federal University of Piauí for the infrastructure and support.

Author contributions

LVBS was involved in conceptualization, methodology, data gathering and writing; DPM helped in conceptualization, methodology and formal analysis; RFMB and ALBN contributed to conceptualization and writing—review and editing.

Funding

This research was funded by the Fundação de Amparo à Pesquisa do Estado do Piauí (FAPEPI), the Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the scholarship granted to Santos, LVB, and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ) for Research Productivity Grant (PQ-1) to Barros, RFM.

Availability of data and materials

All data generated or analyzed during this study were included in this published article (along with the supplementary files).

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

We, the authors, grant permission for the publication of our article, "The biodiversity of edible Brazilian fruits and their pollinators: An integrative review" in Journal of Ethnobiology and Ethnomedicine. We confirm that this work is original and does not violate any copyrights. We agree to the journal's terms and conditions.

Competing interests

The authors declare that they have no competing interests.

Received: 30 December 2024 Accepted: 15 February 2025
Published online: 03 March 2025

References

1. Kinupp VF, Lorenzi H, Cavalleiro ADS, Souza VC, Brochini V. Plantas alimentícias não convencionais (PANC) no Brasil: guia de identificação, aspectos nutricionais e receitas ilustradas. 1ed. Instituto Plantarum de Estudos da Flora. 2021.
2. Jacob MCM, Albuquerque UP. Biodiverse food plants: which gaps do we need to address to promote sustainable diets? Ethnobiol Conserv. 2020. https://doi.org/10.15451/ec2020-04-9.09-1-6.
3. Borelli T, Hunter D, Powell B, Ulian T, Mattana E, Termote Pawera L, Beltrame D, Penafiel D, Tan A, Taylor M, Engels J. Born to eat wild: an integrated conservation approach to secure wild food plants for food security and nutrition. Plants. 2020. https://doi.org/10.3390/plants9101299.

4. Kinupp VF, de Barros IBI. Riqueza de plantas alimentícias não-convencionais na região metropolitana de Porto Alegre, Rio Grande do Sul. Revista Brasileira de Biociências. 2007;5:S1.
5. Chaves EMF, Siqueira JIA, Morais RF, Barros RFM. Conocimiento y uso de plantas alimenticias silvestres en comunidades campesinas del Semiárido de Piauí, Noreste de Brasil. Ethnobot Res Appl. 2019. https://doi.org/10.32859/era.18.33.1-20.
6. Ollerton J, Winfree R, Tarrant S. How many flowering plants are pollinated by animals? Oikos. 2011. https://doi.org/10.1111/j.1600-0706.2010.18644.x.
7. Rech AR, Avila Jr, RD, Schlindwein C. Síndromes de polinização: especialização e generalização. In: Rech AR, Avila Jr, RD, Schlindwein C, editors. Síndromes de polinização: especialização e generalização. Biologia da polinização, 2014. p. 171–181.
8. Waser NM, Chittka L, Price MV, Williams NM, Ollerton J. Generalization in pollination systems, and why it matters. Ecology. 1996. https://doi.org/10.2307/2265575.
9. Cook JM, Rasplus JY. Mutualists with attitude: coevolving fig wasps and figs. Trends Ecol Evol. 2003. https://doi.org/10.1016/S0169-5347(03)00062-4.
10. Eisikowitch D, Ghara M. An overview on *Ficus* pollination with some notes on *Ficus carica*. Italus Hortus. 2015;22:3.
11. Pauw A. A bird's-eye view of pollination: biotic interactions as drivers of adaptation and community change. Annu Rev Ecol Evol Syst. 2019. https://doi.org/10.1146/annurev-ecolsys-110218-024845.
12. Wolowski M, Agostini K, Rech A, Varassin I, Maués M, Freitas L, et al. Relatório Temático Sobre Polinização. Polinizadores e Produção de Alimentos No Brasil. São Carlos, SP: Editora Cubo. 2019.
13. Domingos-Melo A, Albuquerque-Lima S, Diniz UM, Lopes AV, Machado IC. Bat pollination in the Caatinga: a review of studies and peculiarities of the system in the new world's largest and most diverse seasonally dry tropical forest. Flora. 2023. https://doi.org/10.1016/j.flora.2023.152332.
14. Zariman NA, Omar NA, Huda AN. Plant attractants and rewards for pollinators: their significant to successful crop pollination. Int J Life Sci Biotechnol. 2022. https://doi.org/10.38001/ijlsb.1069254.
15. Oliveira W, Colares LF, Porto RG, Viana BF, Tabarelli M, Lopes AV. Food plants in Brazil: origin, economic value of pollination and pollinator shortage risk. Sci Total Environ. 2024. https://doi.org/10.1016/j.scitotenv.2023.169147.
16. Tomchinsky B, Ming LC. As plantas comestíveis no Brasil dos séculos XVI e XVII segundo relatos de época. Rodriguésia. 2019. https://doi.org/10.1590/2175-7860201970040.
17. Dean W. A botânica e a política imperial: a introdução e a domesticação de plantas no Brasil. Revista Estudos Históricos. 1991;4:8.
18. Giannini TC, Alves DA, Alves R, Cordeiro GD, Campbell AJ, Awade M, Bento JMS, Saraiva AM, Imperatriz-Fonseca VL. Unveiling the contribution of bee pollinators to Brazilian crops with implications for bee management. Apidologie. 2020. https://doi.org/10.1007/s13592-019-00727-3.
19. Junqueira CN, Pereira RAS, da Silva RC, Kobal ROAC, Araújo TN, Prato A, et al. Do Apis and non-Apis bees provide a similar contribution to crop production with different levels of pollination dependency? A review using meta-analysis. Ecol Entomol. 2022. https://doi.org/10.1111/een.13092.
20. Halsch CA, Shapiro AM, Fordyce JA, Nice CC, Thorne JH, Waetjen DP, Forister ML. Insects and recent climate change. Proc Natl Acad Sci. 2021. https://doi.org/10.1073/pnas.2002543117.
21. Wagner DL, Grames EM, Forister ML, Berenbaum MR, Stopak D. Insects decline in the anthropocene: death by a thousand cuts. Proc Natl Acad Sci. 2021. https://doi.org/10.1073/pnas.2023989118.
22. Giannini TC, Costa WF, Cordeiro GD, Imperatriz-Fonseca VL, Saraiva AM, Biesmeijer J, Garibaldi LA. Projected climate change threatens pollinators and crop production in Brazil. PLoS ONE. 2017. https://doi.org/10.1371/journal.pone.0182274.
23. Vasiliev D, Greenwood S. The role of climate change in pollinator decline across the Northern Hemisphere is underestimated. Sci Total Environ. 2021. https://doi.org/10.1016/j.scitotenv.2021.145788.
24. Manfrinato CV, Marino A, Condé VF, Franco MCP, Stedefeldt E, Tomita LY. High prevalence of food insecurity, the adverse impact of COVID-19 in Brazilian favela. Public Health Nutr. 2021. https://doi.org/10.1017/S1368980020005261.
25. Pérez-Escamilla R, Salles-Costa R, Segall-Corrêa AM. Food insecurity experience-based scales and food security governance: a case study from Brazil. Glob Food Secur. 2024. https://doi.org/10.1016/j.gfs.2024.100766.
26. Jacob MCM, Medeiros MFA, Albuquerque UP. Biodiverse food plants in the semiarid region of Brazil have unknown potential: a systematic review. PLoS ONE. 2020. https://doi.org/10.1371/journal.pone.0230936.
27. Gomes LCA, de Medeiros PM, Prata APN. Wild food plants of Brazil: a theoretical approach to non-random selection. J Ethnobiol Ethnomed. 2023. https://doi.org/10.1186/s13002-023-00603-6.
28. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. A declaração PRISMA 2020: diretriz atualizada para relatar revisões sistemáticas. Rev Panam Salud Publica. 2020. https://doi.org/10.26633/RPSP.2022.112.
29. Flora e Funga do Brasil. 2023. Jardim Botânico do Rio de Janeiro. Available at: http://floradobrasil.jbrj.gov.br/. Accessed 13 Jun 2024.
30. GBIF.org. GBIF Home Page. 2024. Available from: https://www.gbif.org. Accessed 13 Jun 2024.
31. R Core TEAM. RA language and environment for statistical computing, R Foundation for Statistical. Computing, 2020.
32. Fox J, Weisberg S, Adler D, Bates D, Baud-Bovy G, Ellison S, Firth D, Friendly M, Gorjanc G, Graves S. Package 'car'. Vienna: R Foundation for Statistical Computing, 2012; 16:332.
33. Hothorn T, Hornik K, Van De Wiel MA, Zeileis A. Implementing a class of permutation tests: the coin package. Journal of statistical software. 2008; 28(8).
34. IBGE. Malha Municipal. Available from: https://www.ibge.gov.br/geociencias/organizacao-do-territorio/malhas-territoriais/15774-malhas.html?=&t=downloads. Accessed 13 Sep 2023.
35. Giannini TC, Cordeiro GD, Freitas BM, Saraiva AM, Imperatriz-Fonseca VL. The dependence of crops for pollinators and the economic value of pollination in Brazil. J Econ Entomol. 2015. https://doi.org/10.1093/jee/tov093.
36. Giannini TC, Boff S, Cordeiro GD, Cartolano EA, Veiga AK, Imperatriz-Fonseca VL, Saraiva AM. Crop pollinators in Brazil: a review of reported interactions. Apidologie. 2015. https://doi.org/10.1007/s13592-014-0316-z.
37. Michener CD. The Brazilian bee problem. Annu Rev Entomol. 1975. https://doi.org/10.1146/annurev.en.20.010175.002151.
38. Mallinger RE, Gaines-Day HR, Gratton C. Do managed bees have negative effects on wild bees? A systematic review of the literature. PLoS ONE. 2017. https://doi.org/10.1371/journal.pone.0189268.
39. Santos GMM, Aguiar CM, Genini J, Martins CF, Zanella FC, Mello MA. Invasive Africanized honeybees change the structure of native pollination networks in Brazil. Biol Invasions. 2012. https://doi.org/10.1007/s10530-012-0235-8.
40. Kovács-Hostyánszki A, Földesi R, Báldi A, Endrédi A, Jordán F. The vulnerability of plant-pollinator communities to honeybee decline: a comparative network analysis in different habitat types. Ecol Ind. 2019. https://doi.org/10.1016/j.ecolind.2018.09.047.
41. Esquivel IL, Parys KA, Brewer MJ. Pollination by non-*Apis* bees and potential benefits in self-pollinating crops. Ann Entomol Soc Am. 2021;114(2):257–66. https://doi.org/10.1093/aesa/saaa059.
42. Pedro SR. The stingless bee fauna in Brazil (Hymenoptera: Apidae). Sociobiology. 2014. https://doi.org/10.13102/sociobiology.v61i4.348-354.
43. Bueno FGB, Kendall L, Alves DA, Tamara ML, Heard T, Latty T, Gloag R. Stingless bee floral visitation in the global tropics and subtropics. Glob Ecol Conserv. 2023. https://doi.org/10.1016/j.gecco.2023.e02454.
44. Garibaldi LA, Steffan-Dewenter I, Winfree R, Aizen MA, Bommarco R, et al. Wild pollinators enhance fruit set of crops regardless of honeybee abundance. Science. 2013;339:6127.
45. Rader R, Bartomeus I, Garibaldi LA, Garratt MP, Howlett BG, Winfree R, et al. Non-bee insects are important contributors to global crop pollination. Proc Natl Acad Sci. 2016. https://doi.org/10.1073/pnas.1517092112.
46. Requier F, Pérez-Méndez N, Andersson GK, Blareau E, Merle I, Garibaldi LA. Bee and non-bee pollinator importance for local food security. Trends Ecol Evol. 2023. https://doi.org/10.1016/j.tree.2022.10.006.
47. Biesmeijer JC, Roberts SP, Reemer M, Ohlemuller R, Edwards M, Peeters T, Schaffers AP, Potts SG, Kleukers R, Thomas CD, Settele J, Kunin WE. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. Science. 2006;313:351–4.

48. Oliveira CM, Auad AM, Mendes SM, Frizzas MR. Crop losses and the economic impact of insect pests on Brazilian agriculture. Crop Prot. 2014. https://doi.org/10.1016/j.cropro.2013.10.022.
49. Van der Sluijs JP, Vaage NS. Pollinators and global food security: the need for holistic global stewardship. Food Ethics. 2016. https://doi.org/10.1007/s41055-016-0003-z.
50. Murphy JT, Breeze TD, Willcox B, Kavanagh S, Stout JC. Globalisation and pollinators: pollinator declines are an economic threat to global food systems. People Nat. 2022. https://doi.org/10.1002/pan3.10314.
51. Marzulo EP, Heck MA, Filippi EE. Desigualdades socioeconômicas no Brasil: dinâmicas territoriais no urbano e no rural. DRd-Desenvolvimento Regional em debate. 2020. https://doi.org/10.24302/drd.v10i0.3191.
52. Campos LZO, Albuquerque UP, Peroni N, Araujo EL. Do socioeconomic characteristics explain the knowledge and use of native food plants in semiarid environments in Northeastern Brazil? J Arid Environ. 2015. https://doi.org/10.1016/j.jaridenv.2015.01.002.
53. Medeiros PM, Dos Santos GMC, Barbosa DM, Gomes LCA, Santos EMDC, da Silva RRV. Local knowledge as a tool for prospecting wild food plants: experiences in northeastern Brazil. Sci Rep. 2021. https://doi.org/10.1038/s41598-020-79835-5.
54. Santos DM, Lima SO. Movimento Quilombola do Piauí: participação e organização para além da terra. Revista Espacialidades. 2013;6:5.
55. Pereira ADS, Magalhães L. A vida no quilombo: trabalho, afeto e cuidado nas palavras e imagens de mulheres quilombolas. Interface-Comunicação, Saúde, Educação. 2022; https://doi.org/10.1590/interface.210788.
56. IBGE. Indígenas. Available from: https://indigenas.ibge.gov.br/estudos-especiais-3/o-brasil-indigena/povos-etnias. Accessed 29 Jan 2025.
57. Ribeiro-Silva RDC, Pereira M, Campello T, Aragão É, Guimarães JMDM, Ferreira AJ, Barreto ML, Santos SMCD. Implicações da pandemia COVID-19 para a segurança alimentar e nutricional no Brasil. Cien Saude Colet. 2020. https://doi.org/10.1590/1413-81232020259.22152020.
58. Galindo E, Teixeira MA, De Araújo M, Motta R, Pessoa M, Mendes L, Rennó L. "Efeitos da pandemia na alimentação e na situação da segurança alimentar no Brasil." Food for Justice Working Paper Series, no. 4. Berlin: Food for Justice: Power, Politics, and Food Inequalities in a Bioeconomy. https://doi.org/10.17169/refubium-29554.2.

Publisher's Note