Agroforestry systems and meliponiculture in western Pará, Brazil: contributions to conservation, income, and ecosystem services

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Abstract

Integration of agroforestry systems (AFSs) with meliponiculture constitutes a promising strategy for combining environmental conservation, income generation in rural communities, and provision of ecosystem services, particularly in areas with high biodiversity, such as western Pará, Brazil. A systematic literature review was carried out to investigate this interaction, following the methodological criteria established by the PRISMA statement. The databases consulted included Science Direct, SciELO, Google Scholar, and the CAPES Journals portal, covering the period from 2014 to 2024. A total of 53 articles were selected, which were classified according to thematic lines related to interfaces between meliponiculture and AFSs. In the state of Pará, nine genera of stingless bees were identified, comprising 30 species, with prominence of the genera *Melipona*and *Trigona*. These genera are widely found in natural environments and in managed agroforestry arrangements. Pollination stood out as the key ecosystem service, exerting a direct effect on increased agroforestry yield, in situ maintenance of plant species of socioeconomic interest, and added value for honey from native bee species. Results also showed the strategic role of AFSs as drivers of ecological restoration on a landscape scale, contributing to carbon sequestration, climate resilience, and diversification of local economies, with direct effects on strengthening sustainable production chains.

Introduction

Agroforestry systems (AFSs) are consolidated practices that integrate agricultural management with forest species and native vegetation, promoting sustainable use of the land, biodiversity conservation, and improvement of the quality of life in rural areas (Schembergue et al. 2017; Lobo et al. 2021). As AFSs promote environments with greater biological diversity and offer production alternatives in harmony with natural ecosystems, AFSs have become a reference in policies of sustainability and recovery of degraded areas, especially in the Brazilian Amazon (Costa et al. 2022).

The association between AFSs and meliponiculture represents a synergistic strategy with potential for generating positive impacts in three fundamental dimensions: ecological, economic, and social. This integration, as Gemim and Silva (2017) highlight, contributes to increased agricultural production, crop pollination, and conservation of native flora. In addition, it strengthens family farming and generation of income through the commercialization of honey and other products of sociobiodiversity.

Native stingless bees, belonging to the tribe Meliponini, play an essential role in maintaining tropical ecosystems, both by their pollination efficiency and their connection with ancestral cultural practices (Barbiéri and Francoy 2020; Gonzales et al. 2021). However, as Silva and Ferrarezi Junior (2022) warn, anthropogenic pressures such as deforestation, indiscriminate use of agricultural chemicals, and climate change have caused an alarming decline in these populations, negatively affecting agricultural production and biodiversity.

Meliponiculture, or managed rearing of native stingless bees, is an ancient practice, recorded prior to European colonization of the Americas. Paulo Nogueira Neto coined the term in 1953, significantly contributing to scientific systematization of the activity in Brazil. Currently, this management practice is widespread among indigenous peoples, riverine communities, and family farmers, especially in the North and Northeast regions of Brazil (Castro et al. 2022). In western Pará, the activity has intensified through research, training, and transfer of technologies aimed at valuing traditional knowledge and encouragement of regional bioeconomies (Oliveira et al. 2022).

The adoption of sustainable production techniques, such as AFSs and meliponiculture, directly addresses contemporary challenges related to food security, environmental conservation, and the climate crisis. The diversity of melliferous plants in agroforestry systems, for example, increases the resilience of apiaries in periods of climate instability and improves colony productivity (Paray et al. 2021; Santos et al. 2023). This diversity also promotes in situ conservation of native species and ecosystem services fundamental for agroecosystems.

The Agricultural Census of 2017 indicates the existence of approximately 5 million properties with some type of AFS in Brazil, and more than 4.9 million include forest species associated with crop cultivation or animal raising (IBGE 2017). These figures show the potential of these systems in integrating conservation and production, particularly in Amazon territories.

In this context, meliponiculture plays a strategic role in integrating the production chains of Amazon sociobiodiversity, with considerable potential in contributing to the Sustainable Development Goals (SDGs), especially those related to zero hunger (SDG 2), responsible consumption and production (SDG 12), and action against global climate change (SDG 13) (Imperatriz-Fonseca et al. 2024).

The growing body of scientific research directed toward integration of meliponiculture and AFSs reflects the maturation of this field and the search for nature-based solutions. Identifying the trends, progress, and gaps in this research requires robust methodological approaches. A systematic review of the literature with state of the art (SOTA) analysis allows critical understanding of the development of this topic over time, considering evidence, impacts, and future directions (Santos et al. 2020; Da Costa and Silva et al. 2024).

To ensure transparency and scientific reproducibility, this study adopts the recommendations of the PRISMA statement, an internationally recognized protocol for conducting and reporting systematic reviews. The PRISMA statement and its extensions are a set of evidence-based recommendations aimed at complete and transparent performance and reporting of systematic reviews (Sarkis-Onofre et al. 2021).

In this context, the SOTA study emerges as a methodological approach with specific development and elaboration criteria that goes beyond mere descriptive mapping of academic production. It is an in-depth bibliographical analysis that identifies progress, gaps, and trends in knowledge (Santos et al. 2020).

Thus, the aim of the present study is to conduct a systematic review of the literature published from 2014 to 2024 on the integration between agroforestry systems and meliponiculture in the Amazon region, with an emphasis on evidence from research, innovation, and technology transfer applicable to the reality of western Pará, Brazil.

Methodology

This study adopted an integrative systematic literature review method, with the aim of mapping, analyzing, and synthesizing scientific evidence published from 2014 to 2024 regarding the integration of agroforestry systems (AFSs) and meliponiculture in the Brazilian Amazon, with an emphasis on the ecological, economic, and social contributions of these sustainable production arrangements in western Pará.

Integrative review was chosen because of its ability to bring together different methodological approaches (quantitative and qualitative), allowing a comprehensive analysis of the experiences, gaps, and scientific advances on this topic (Souza and Silva, Carvalho 2019). The analysis protocol followed the updated guidelines of PRISMA 2020 – Preferred Reporting Items for Systematic Reviews and Meta-Analyses, recommended by high-impact journals to ensure clarity, rigor, and methodological transparency (Galvão et al. 2020).

Searches were carried out between October 2024 and February 2025 in the following electronic databases: ScienceDirect, SciELO, Google Scholar, and the CAPES Journals portal. The time frame (2014–2024) was defined based on the intensification of scientific debates on ecosystem services, environmental restoration, sociobiodiversity, and bioeconomies in the Amazon region. Portuguese language descriptors and Boolean operators were used to enhance the precision of the results.

The following search terms were used: “espécies florestais melíferas Amazônia” (“Amazon meliferous forest species”); "sistemas agroflorestais melitófilos" (“melitophilous agroforestry systems”); "sistemas agroflorestais restauração OR ambiental “abelhas sem ferrão”" (agroforestry systems restoration OR environmental “stingless bees”"); "Oeste do Pará agricultura OR familiar “abelhas sem ferrão”" (western Pará agriculture OR family “stingless bees”"); "criação racional de abelhas nativas “Oeste do Pará”" (“managed rearing of native bees “western Pará”"); "abelhas sem ferrão Oeste OR do OR Pará “restauração ambiental”" (“stingless bees western OR of OR Pará “environmental restoration”"); and "abelhas sem ferrão Amazônia OR Pará “restauração ambiental”" (“stingless bees Amazon OR Pará “environmental restoration”").

The inclusion criteria were original peer-reviewed articles published between 2014 and 2024; studies developed in the context of the Brazilian Amazon, preferentially with data or analyses related to western Pará; studies that directly or indirectly addressed the integration between AFSs and meliponiculture; and studies focusing on ecosystem services, social reproduction, bioeconomics, ecological restoration, family farming, or pollinator conservation.

The exclusion criteria included duplicate studies, non-peer-reviewed trials, gray literature (theses, dissertations, technical reports, and conference proceedings); publications without empirical data or without relationship to the Amazon territory; and studies exclusively focused on exotic species or on non-integrated conventional production systems.

The selection process followed the four steps of the PRISMA protocol (identification, screening, eligibility, and inclusion), as illustrated in Fig. 1.

At the end of the screening process, 53 scientific articles that met the established criteria were included. These studies were organized by thematic categories (ecology, production, sociocultural studies, and economics) and analyzed based on the geographic region of coverage, the AFS model adopted, the bee species involved, and the strategies of appreciation of biodiversity and local knowledge.

The guiding question of the review was framed as follows:

Does the scientific literature published between 2014 and 2024 provide evidence regarding integrated adoption of agroforestry systems and meliponiculture in the Amazon region, particularly in western Pará, as a sustainable development strategy aiming at conservation of biodiversity, the strengthening of family farming, and the mitigation of climate crises?

Considering the Amazon context, and especially the territorial and environmental dynamics of western Pará, it has become ever more important to identify production arrangements that promote sustainable land use, the increased presence of pollinators, appreciation for native species, and income generation for traditional communities. Recent studies caution that changes in land use and cover, driven by anthropogenic pressures, are changing climate dynamics and accelerating processes of forest degradation, with direct impacts on tree diversity and the social reproduction of rural populations (Freitas et al. 2024; Castro et al. 2022).

Therefore, this review seeks to systematize the main findings and trends of scientific production over the past decade, contributing to the development of sustainable strategies based on evidence, the transfer of social technologies, and coordination among science, territory, and local communities.

Figure 1 presents the flow diagram of the process of identification, screening, eligibility, and inclusion of the selected studies, according to the guidelines of the PRISMA 2020 protocol; and the process carried out to classify the studies found within the scope of the research can be observed.

Results and discussion

The systematic search in the selected databases resulted in initial identification of 2667 publications related to meliponiculture in the Legal Amazon (Amazon administrative region) from 2014 to 2024. After title screening, abstract reading, removal of duplicates, and application of the inclusion and exclusion criteria, 53 articles were considered eligible for final analysis.

The state of Pará accounted for the largest number of publications, particularly studies conducted in western Pará, showing a growing body of scientific research addressing integration of meliponiculture, biodiversity, and sustainable land-use practices. This regional pattern reflects the academic interest for areas where the relationship between traditional communities, forests, and production systems is more evident and coordinated.

The articles were organized into six major thematic axes, namely:

- Quality of honey and by-products – studies addressing physicochemical, microbiological, and nutritional aspects of honey from native bees;
- Sustainable development – focused on integration of production, environmental conservation, and food security;
- Environmental education – highlighting activities of training communities and schools in managing stingless bees;
- Pollination – addressing the ecological role of bees and their contribution to agricultural productivity;
- Biodiversity – studies on species conservation, melliferous flora, and associated fauna;
- Agroforestry systems (AFSs) – especially those that combine agroecological practices and ecological restoration.

Thematic categorization reinforces the interdisciplinary nature of meliponiculture, showing its relevance in the fields of applied ecology, agroecology, bioeconomics, and environmental education. In addition, the diversity of focus areas found in these publications suggests theoretical and methodological maturation in research developed in the region.

According to the IBGE (2017), the territorial extension of the Legal Amazon area is 5,015,146.008 km², representing approximately 58.93% of Brazilian territory. This region comprises 772 municipalities/counties across nine states: Rondônia, Acre, Amazonas, Roraima, Pará, Amapá, Tocantins, Mato Grosso, and part of Maranhão. The geographic and ecological extent of the Legal Amazon, combined with the sociocultural diversity of the populations that inhabit it, explains the volume of studies concentrated in territories where traditional meliponiculture is maintained as an ancestral and sustainable practice.

Table 1 presents the distribution of articles per Brazilian state, considering the locations specified in the studies. Studies classified as “not specified” refer to bibliographical reviews or general studies that deal with meliponiculture in the Amazon as a whole, without defined territorial delimitation. This classification allowed differentiation of the studies with a clear geographic location from those with a broader approach.

Table 1
Number of studies found for each state of the Legal Amazon

State	No. of studies (n)
Acre	3
Amapá	1
Amazonas	13
Maranhão	2
Mato Grosso	2
Pará	21
Rondônia	1
Roraima	-
Tocantins	2
Not specified	8
TOTAL	**53**

Source: Prepared by the authors (2025), based on systematic review of the literature (2014–2024).

In the Legal Amazon, a significant milestone for scientific development of meliponiculture was the arrival of the researcher Dr. Warwick E. Kerr at the Federal University of Maranhão (Universidade Federal do Maranhão - UFMA) after his retirement from the University of São Paulo (USP). His activity contributed decisively to promote scientific study, training of new researchers, and integration of academic and traditional knowledge in the region (Imperatriz-Fonseca et al. 2024).

Bees, recognized as key pollination agents, play a fundamental ecological role in tropical ecosystems. During foraging, bees collect nectar and pollen, promoting not only maintenance and survival of the colonies but also fertilization of flowers, ensuring perpetuation of plant species. This interaction improves seed and fruit quality and significantly contributes to an increase in agricultural productivity, especially in agroecologically based systems (Severino, Reis, Ortiz 2024).

Analysis of the 53 selected articles revealed considerable thematic diversity, showing the interdisciplinary and complex nature of meliponiculture in the Amazon. Publications were grouped into 15 main thematic categories, as shown in Table 2. The most frequent themes are listed below.

Table 2
Grouping of the selected studies by macro-thematic axes in state of the art analysis of meliponiculture and agroforestry systems in the Legal Amazon

Thematic axis	**Thematic category**	**No. of studies**
Hive quality and products	**Quality of honey and by-products**	**13**
	Sensory analysis	2
	Product use	1
Sustainability and education	**Sustainable development**	**9**
	Sustainable development / Environmental education	3
	Environmental education	1
Ecological functions	**Pollination**	**5**
	Biodiversity	**5**
	Thermoregulation	2
Integrated production systems	Agroforestry systems	3
	Agroforestry systems / Sustainable development	1
	Agroforestry homegardens	2
Knowledge and biology of the species	Traditional knowledge	2
	Traditional knowledge / Sustainable development	2
	Nesting	2
	Total	**53**

Source: Prepared by the authors (2025), based on a systematic review of the literature (2014–2024).

As shown in Table 2, most studies focus on the physicochemical aspects of honey and its by-products (13 publications), showing a predominantly technological approach. In contrast, themes such as product use and environmental education are still incipient, with only one study each, indicating potential areas for future investigations.

This classification allows for an understanding of the thematic scope of scientific production over the past decade, reflecting growing academic interest in sustainable practices that integrate ecology, culture, technology, and local economies. Table 3 presents the quantitative synthesis of the identified categories.

Table 3

– Distribution of the selected studies by thematic focus in construction of the state of the art on meliponiculture and agroforestry systems in the Legal Amazon (2014–2024)

	Thematic focus (macrotheme)	**Thematic sub-category**	**No. of studies**	**Authors**	**States**	**Type of study**
1	Technology and Quality	Honey quality	13	Mendonça Neto et al (2021); Oliveira et al (2023); Castro et al (2022); Picanço et al (2018); Menezes, Mattietto, Lourenço (2018); Fernandes, Dias, Barreto (2022); Aguiar et al (2016); Pires et al (2020b); Ciríaco et al (2021); Freitas et al (2022); Pinto et al (2022); Amud et al (2022); Tenório, Sousa, Carvalho Neta (2020)	PA, AM, AC, MA	Field / Laboratory
		Sensory analysis	2	Pires et al (2020); Pires et al (2021)	PA	Field / Laboratory
		Product use	1	Galvão et al (2018)	PA	Laboratory
2	Sustainability	Sustainable development	9	Gama et al (2024); Souza and Chalco (2017); Soares (2014); Gama and Brasileiro (2024); Cipriano Neto, Araújo, Louzada (2024); Souza et al (2018b); Costanti and Nogueira (2018); Silva et al (2023); Meireles et al (2018)	PA, AM, AP	Case study / Field
		Sustainability / Environmental education	3	Neu et al (2016); Fernandes et al (2018); Azambuja et al (2018)	AM, PA	Extension / Project

	Thematic focus (macrotheme)	Thematic sub-category	No. of studies	Authors	States	Type of study
		Environmental education	1	Moura et al. (2022)	PA	Extension / Project
3	Ecological functions	Pollination	5	Maia-Silva et al (2024); Souza et al (2018); Pimentel et al (2020); Rocha et al (2022); Correia et al (2020)	PA, AM, AC, MT	Field
		Biodiversity	5	Fonseca et al (2020); Costa-Neto et al (2016); Machado et al (2024; Freitas and Novais (2014; Correia, Pires, Peruquetti (2020)	PA, TO, AC	Field / Database
		Thermoregulation	2	Pires et al (2017a); Caldas et al (2024)	PA, MA	Field
4	Production systems	Agroforestry systems	3	Gemim and Silva (2017); Viana et al (2021); Araújo and Sousa (2022)	PA, AM	Field / Production arrangements / Database
		Agroforestry systems / Sustainable development	1	Abreu and Watanabe (2016)	RO	Field / Production arrangements / Database
		Agroforestry homegardens	2	Maia et al (2020); Francisco et al (2016)	PA	Field / Production arrangements / Database
5	Knowledge and biology of the species	Traditional knowledge	2	Apodonepa and Barreto, (2015); Araújo, Andrade, Nogueira (2023)	MT	Field / Database
		Traditional knowledge / Sustainable development	2	Costa et al (2021); Oliveira and Cruz (2018)	AM,	Field
		Nesting	2	Pires et al (2019); Barbosa et al (2024)	PA, TO	Field

Source: Prepared by the authors (2025), based on a systematic review of the literature (2014–2024).

Analysis of the relationship between meliponiculture and sustainable development enables understanding of how this activity can promote local development while respecting the sociocultural and ecological characteristics of each territory. Particularly in the Legal Amazon, this integration contributes to conservation of biodiversity, food security, quality of life, and mitigation of climate change – topics that have been widely discussed in recent decades. Most of the selected studies are concentrated in the states of Pará and Amazonas.

The role of stingless bees in pollination has been widely recognized as essential for maintaining biodiversity and increasing agricultural yield, generating positive impacts on food security and sustainable development of local communities (Constanti and Nogueira 2018; Neu et al. 2016; Abreu and Watanabe 2016; Machado et al. 2024). In contrast, habitat degradation and indiscriminate use of agricultural chemicals have been identified as direct threats to colonies.

For the sustainability of meliponiculture, balance between extraction of natural resources and residue generation is of prominent importance. Local imbalances between production and conservation may lead to loss of quality of life, food insecurity, and ecosystem collapse (Neu et al. 2016). In this respect, the studies analyzed reinforce the importance of promoting public policies that consider traditional communities, such as riverine, indigenous, *quilombola*, and agroextractivist communities, as well residents of agriculture-based villages, recognizing their knowledge and practices as essential elements for social reproduction and environmental conservation.

Meliponiculture also stands out as a tool for education and appreciation of traditional knowledge. Studies recommend that this activity be incorporated into environmental education practices, particularly in schools within the Amazon region, contributing to the training of future professionals committed to the conservation of sociobiodiversity (Moura et al. 2022; Costa et al. 2021).

Management of native bee populations is particularly important given the risks associated with climate change. From an environmental perspective, it contributes to the conservation of pollinator fauna, forest regeneration, and maintenance of plant diversity (Meireles et al. 2018; Lehmen 2025). Additionally, the quality of the honey produced by native species has come to be recognized. The composition of the honey varies according to the genetics of the species, the flower sources available, and management practices (Castro et al. 2022). Although specific national regulations have not yet been applied, researchers have proposed quality control parameters for honey from stingless bees (Bonagura et al. 2024).

In Pará, the ordinance ADEPARÁ no. 7554/2021 establishes criteria for the identity and quality of native bee honey, while the resolution COEMA no. 184/2024 regulates environmental licensing of meliponiculture. At the national level, the ordinance MAPA no. 665/2021 established the National Catalogue of Native Stingless Bees, and the resolution CONAMA no. 496/2020 defines standards for the use and management of these species, revoking resolution no. 346/2004.

Physicochemical analyses of the honeys showed variations according to species, the climate, and management practices, highlighting the importance of specific regulations for meliponiculture. The honeys from *Melipona flavolineata* and *M. fasciculata*, for example, had higher moisture and acidity and lower pH compared to honeys from *Apis mellifera*, which affects honey shelf life and requires additional care during harvesting and processing (Castro et al. 2022; Oliveira et al. 2023; Menezes et al. 2018). Furthermore, fermented honeys, such as *samburá*, are typical products of cultural and nutritional value in Amazon communities (Mendonça Neto et al. 2021).

Although the term “agroforestry systems” is not present in all studies, most of them recognize the forest component as essential for the success of managed meliponiculture (Araújo and Sousa 2022; Gemim and Silva 2017; Viana et al. 2021). The association of native bees with crops such as açai palm (*Euterpe oleracea*) has proven to be promising for both environmental restoration and income generation, as the visits of bees to açaí flowers increase their yield and encourage ecological handicrafts (Souza et al. 2018; Neu et al. 2016).

The InfoBee platform, developed by Embrapa, has supported those who work with meliponiculture through a digital calendar of flowering periods, indicating botanical species that are most visited by bees in different regions of the Amazon (Lima 2023). For example, *Melipona* (*Michmelia) paraensis* Ducke exhibits wide pollen diversity, and species of the family Fabaceae predominate (Castro et al. 2022).

Even species less suitable for honey production, such as *Trigona truculenta*, are important for the ecosystem service of pollination, especially in areas with agroforestry systems (Pires et al. 2019). Understanding the bee-flower relationship is key for conservation actions and for guiding species selection in AFS projects.

Other studies highlighted the importance of thermoregulation in colonies, which can be compromised by temperature extremes, as observed in *Melipona interrupta* hives. The ideal temperature ranges from 34°C to 36°C, but specific studies in the Amazon are still necessary to understand regional microclimate variations (Pires et al. 2017; Cunha et al. 2025).

Sensory analysis of native honeys is also being used to assess product acceptability, considering color, fluidity, aroma, crystallization, and flavor (Pires et al. 2020, 2021). Moreover, water activity and moisture content, especially in samples from *Scaptotrigona sp.*, affect honey shelf life and stability (Picanço et al. 2018).

Finally, the use of by-products from meliponiculture is also significant. An example is the use of geopropolis from *Melipona melanoventer* for the surface treatment of eggshells, with potential for agroindustrial applications (Galvão et al. 2018). Furthermore, the inadequacy of current legislation regarding pollen from meliponine bees confirms the need for specific regulations, as these products are collected and stored differently than those from bees of the genus *Apis* (Oliveira et al. 2023).

Table 4
Bee species reported in studies conducted in the state of Pará, Brazil.

	Scientific name	Common name	Reference	Location
1	*Frieseomelitta longipes* (Smith, 1854)	Cacho de uva	Fonseca et al (2020); Viana et al (2021)	Santarém, Belterra
2	*Frieseomelitta sp.*	Moça branca	Souza et al (2017)	Resex Tapajós Arapiuns
3	*Melipona (Michmelia) paraensis* (Ducke, 1916)	Jandaíra	Castro et al (2022)	Mojuí dos Campos
4	*Melipona compressipes* (Smith, 1854)	Jupará, Jandaíra-Preta	Gemim and Silva (2017); Pires et al (2019)	Belterra
5	*Melipona fasciculata* (Smith, 1854)	Tiúba, Uruçu-Cinzenta	Gemim and Silva (2017); Menezes et al (2018); Oliveira et al (2023); Meireles et al (2018)	Tracuateua no Nordeste Paraense, Castanhal, Ilha do Mosqueiro, Baião, Mocajuba
6	*Melipona flavolineata* (Friese, 1900)	Uruçu amarela	Menezes et al (2018); Viana et al (2021); Machado et al (2024); Neu et al (2016); Oliveira et al (2023); Meireles et al (2018)	Tracuateua no Nordeste Paraense, Belterra, PAE Ilha das Onças, Belém, Castanhal, Ilha do Mosqueiro, Baião, Mocajuba
7	*Melipona fulva* (Lepeletier, 1836)	Uruçu-amarela	Souza et al (2018)	Ilha do Combu, Belém
8	*Melipona interrupta* (Latreille, 1811)	Jandaíra, jandaíra-preta-da-amazônia, jupará	Mendonça Neto et al (2021); Moura et al (2022); Fonseca et al (2020); Pires et al (2019); Pires et al (2020); Viana et al (2021); Pires et al (2017)	Rio Arapiuns, Santarém, Belterra
9	*Melipona melanoventer* (Schwarz, 1932)	Uruçu da bunda-preta	Galvão et al (2018); Meireles et al (2018)	Santarém, Baião, Mocajuba
10	*Melipona ponclicoliis*	Unspecified	Souza et al (2018)	Ilha do Combu, Belém
11	*Melipona seminigra* (Friese, 1903)	Uruçu-Boca-de-Renda	Souza et al (2018); Fonseca et al (2020); Gemim and Silva (2017); Pires et al (2020); Viana et al (2021)	Ilha do Combu, Belém, Santarém, Belterra

	Scientific name	Common name	Reference	Location
12	*Melipona sp*	Uruçu, jandaira- -da-Amazônia	Mendonça Neto et al (2021); Maia et al (2020); Souza et al (2017); Pires et al (2020); Viana et al (2021); Freitas et al (2022)	Rio Arapiuns, Santarém, Belterra, Mojuí dos Campos, Resex Tapajós Arapiuns, Cachoeira do Arari
13	*Melipona subnitida* (Ducke, 1910)	Jandaíra	Maia et al (2020)	Santarém, Belterra, Mojuí dos Campos
14	*Oxytrigona mellicolor* (Packard, 1869)	Abelha-de-fogo ou tataíra	Souza et al (2018)	Ilha do Combu, Belém
15	*Partamona aequitoriana*	Não especificado		
16	*Partamona epiphytophila* (Pedro & Camargo, 2003)	Cupira		
17	*Plebeia mínima* (Gribodo, 1893)	Jataí mirim” or “mosquito	Viana et al (2021)	Belterra
18	*Plebeia sp.*	Mirim	Souza et al (2018)	Ilha do Combu, Belém
19	*Scaptotrigona aff. Xanthotricha* (Moure, 1950)	Canudo amarela, mandaguari-amarela	Fonseca et al (2020); Pires et al (2020a); Pires et al (2020b); Viana et al (2021)	Santarém, Belterra
20	*Scaptotrigona polystica* (Moure, 1950)	Pinto caído	Mendonça Neto et al (2021); Pires et al (2020)	Rio Arapiuns, Santarém, Belterra
21	*Scaptotrigona sp*	Canudo	Mendonça Neto et al (2021); Moura et al (2022); Gemim and Silva (2017); Maia et al (2020); Souza et al (2017); Picanço et al (2018)	Rio Arapiuns, Santarém, Belterra, Mojuí dos Campos, Resex Tapajós Arapiuns
22	*Tetragona clavipes* (Fabricius, 1804)	Serena, borá	Pires et al (2021)	Belterra
23	*Tetragonisca angustula* (Latreille, 1811)	Jataí	Fonseca et al (2020); Pires et al (2019); Maia et al (2020); Pires et al (2021); Viana et al (2021)	Santarém, Belterra, Mojuí dos Campos

	Scientific name	Common name	Reference	Location
24	*Trigona amalthea* (Olivier, 1789)	Jandaíra-preta	Souza et al (2018)	Ilha do Combu, Belém
25	*Trigona amazonensis* (Ducke, 1916)	Guaxupé, xupé-grande or corta-cabelo	Araújo et al (2023)	Unspecified
26	*Trigona fulviventris* (Guérin, 1835)	Abelha-cachorro	Souza et al (2018)	Ilha do Combu, Belém
27	*Trigona seminigra* (Friese, 1903)	Uruçu-boca-de-renda, jandaíra-alaranjada-de-manaus		
28	*Trigona silvestriana* (Vachal, 1908)	Abelha-sanharó, sanharão		
29	*Trigona spinipes* (Fabricius, 1793)	Irapuá		
30	*Trigona truculenta* (Almeida, 1984)	Sanharão	Pires et al (2019)	Belterra

Source: Prepared by the authors (2025), based on a systematic review of the literature (2014–2024).

The state of Pará stood out among the studies analyzed, with the largest number of records regarding meliponiculture. Nine genera and 30 species of native bees were identified, with the most recurrent genera being *Melipona* (11 species) and *Trigona* (7 species). The most cited species included *Melipona interrupta* (8 times), *Melipona sp.* (6), *Melipona flavolineata* (6), *Scaptotrigona sp.* (6), *Melipona seminigra* (5), and *Tetragonisca angustula* (5), among others (Table 4).

With the growth in the market for stingless bee honey, physicochemical studies of these products in Pará have gained relevance, both for characterization and for comparison with honey from *Apis mellifera* (Menezes et al. 2018). Nevertheless, other approaches have also been noteworthy in the region.

In Santarém, Moura et al. (2022) developed an educational project with adolescents regarding the origin of honey and the importance of pollination, and the honey from native bees obtained good acceptability. In the riverine community of Anã, in the Resex Tapajós-Arapiuns reserve, Gama and Brasileiro (2024) and Gama et al (2024) described meliponiculture as an innovative socio-productive chain, associated with combating climate change and the generation of local income.

In homegardens in the Santarém metropolitan region, a study examines the rearing of easily managed species, such as jandaíra (*Melipona subnitida*), jataí (*Tetragonisca angustula*), canudo (*Scaptotrigona sp.*), and uruçu (*Melipona sp.*), using plants such as cipó-mel (*Antigonon leptopus*), cupuaçu

(*Theobroma grandiflorum*), and açaí (*Euterpe oleracea*). These activities reinforce the role of meliponiculture in food provision and food security (Maia et al. 2020).

In the Resex Tapajós–Arapiuns reserve, producers manage species such as *Scaptotrigona sp.* (canudo amarelo), *Melipona sp.* (jandaíra-da-Amazônia), and *Frieseomelitta sp.* (moça branca), in which pollination is highlighted as one of the main benefits from the activity, especially for agricultural crops (Souza et al. 2017).

Adequate management of the meliponicultural pasture is essential for pollination of fruit crops; the species *Melipona fasciculata* (uruçu cinzenta), *Melipona flavolineata* (uruçu amarela), and *Melipona melanoventer* (uruçu da bunda-preta) are recognized for their role in agriculture (Meireles et al. 2018).

Nevertheless, challenges remain. In Belterra, PA, impacts from the loss of habitat and the use of agricultural chemicals in proximity to meliponaries have been observed, directly affecting development of the activity (Viana et al. 2021).

The findings of this systematic review of the literature are also consistent with more recent observations of Viana et al (2021), who highlight the importance of the structure and floristic diversity of agroforestry systems in maintaining colonies of native stingless bees. According to the authors, the continuous presence of mellitophilous plant species in the AFSs favors the provision of trophic resources throughout the year, promoting not only colony stability, but also intensification of ecosystem services, such as pollination of agricultural crops and native forest species. This study reaffirms that biodiverse and well-managed agroforestry arrangements are essential for successful integration of meliponiculture, acting as a bridge between biodiversity conservation and the economic sustainability of Amazon communities. This evidence confirms the strategic role of AFSs as a foundation for integrated public policies for sustainable rural development, environmental conservation, and food security.

Final considerations

The integration of meliponiculture with agroforestry systems constitutes a promising strategy for recovery of degraded areas and promotion of sustainable development in the Amazon region, combining environmental, economic, and social benefits. The reviewed literature highlights the central role of native stingless bees in maintaining biodiversity, in food security, and in income generation for family farmers and traditional communities.

Pollination stands out as an essential ecosystem service and directly influences both agricultural productivity and honey quality and composition, It also contributes to regeneration of productive landscapes and to regional ecological balance. The predominance of studies in the state of Pará confirms its relevance as a strategic hub for advancing meliponiculture in the Eastern Amazon.

Nevertheless, the observed panorama reveals important gaps. These include a lack of specific public policies, of adequate regulation of meliponiculture products, of continuous technical assistance, and of incentives for applied research, especially that which integrates ecological, sociocultural, and economic dimensions. The absence of specific federal standards for honey from stingless bees, for example, compromises adding value and reliable commercialization of this product on a large scale.

In this context, strengthening sociobiodiversity production chains is recommended through integrated actions among research institutions, rural extension services, public authorities, and community organizations. Meliponiculture, in combination with agroforestry systems, should be recognized as a strategic activity for meeting environmental, economic, and social goals in Amazon territories, effectively contributing to facing the challenges of climate change, to ecological restoration, and to appreciation of traditional knowledge.

Declarations

Conflict of interest: The authors declare no competing inter ests.

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Figures

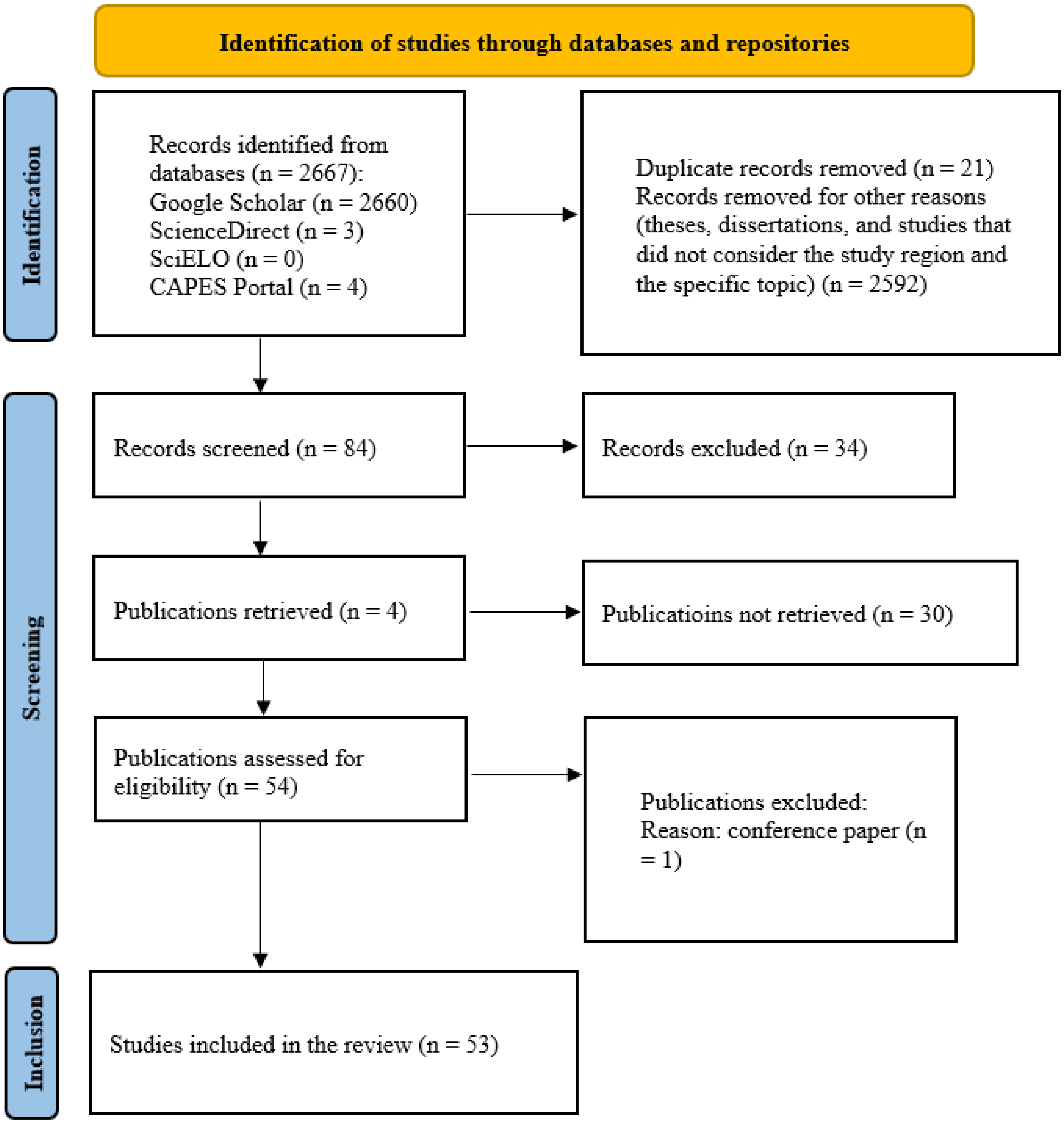

Figure 1

Flow diagram of the study selection process according to the PRISMA 2020 model, adapted for an integrative, systematic review, adapted from Galvão et al (2022). Source: prepared by the authors (2025), based on a systematic review of the literature (2014–2024).