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One biodiversity: Conservation of stingless bee bibliometrics and legal progress protecting pollinators; thus, their nest materials, microbiome, and active biomolecules

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ABSTRACT

Stingless bees (Hymenoptera, Apoidea, Meliponini) are the most biodiverse group of social bees with more than 605 formally described species inhabiting the tropics. Protecting their biodiversity sounds challenging. A team work for humans in close contact with stingless bees: Those who take care of them in meliponaries, and dedicated multidisciplinary scientists, merging the best ancestral to innovative knowledge. The Scopus database was used for the first bibliometric study on conservation of stingless bees for most productive authors, institutions, countries, and sources, since 2000. A total of 359 documents were retrieved from 141 sources, published by 1463 authors in English (348), Spanish (10), Portuguese (6), Chinese, Indonesian and Thai (1), from 58 countries, no single-authored, citing 2350 references. Most productive authors and affiliations are from Brazil, Mexico, and Argentina. With its participation in 11 and 12 documents and impacting the theme with the most globally cited document, the United States and Brazil emerged as the leading producer of scholarly works. A steady growth on scientific publications on conservation of stingless bees reached maximum of 46 documents in 2024 and 44 in 2025. Bibliometrix was used to visualize our dataset in graphics on most cited documents, collaborative map, cloud of authors' keywords, the most cited countries, multivariate analysis topic dendrogram plot which classified authors' keywords in four clusters on: 1. Biodiversity loss (deforestation and climate change), 2. Stingless bee and honey, plant diversity for melissopalynology, distribution, pollen, and *Heterotrigona itama*, 3. Bee diversity, and 4. Pollination and pollinators' ecological service needed to maintain biodiversity, including the most biodiverse stingless bee genus *Melipona*. Our review underscores policy advances and prospects for sustainably harnessing stingless bees, their active biomaterials, and microbiomes alongside the legal frameworks that support their conservation in Bolivia, Brazil, Costa Rica, Ecuador, El Salvador, Guatemala, the Philippines, and Tanzania.

Keywords active metabolites, bibliometrics, biodiversity, conservation, microbiome, stingless bees

1. Introduction

Bees are one of the most diverse groups, as more than 20,700 bee species have been described worldwide.[1] The well-known social honey bees (genus *Apis*) account for less than ten recognized species globally. Other social bees include about 250 species of bumblebees and over 600 species of stingless bees. These bees have co-evolved with flowering plants, developing a mutualistic relationship since their appearance on earth more than 100 million years ago, becoming one of the main pollinators. Bees play a fundamental role in ecosystems, since they ensure the reproduction of numerous plants and the maintenance of biodiversity. The presence and activity of stingless bees reflect the availability of diverse foraged plant resources and microbiomes, so they are health indicators of the stingless bee colony, the habitat, and potential therapeutic materials of biotic (botanical, entomological, and microbial) origins, and less studied abiotic components limited to elements of the periodic table.

Stingless bees (Hymenoptera; Apidae; Apinae; Meliponini) host such a biodiversity among honey making bees. More than 605 global species[2] evidence admirable adaptations along their natural life. Biological communities comprise microorganisms, plants, and animals. Biodiversity has been partitioned into genetic, species, ecosystem, and functional diversity. One biodiversity could be a concept embracing the variety of life in a given ecosystem –Amazonian forest, a marine coast, the Andes, or an urban habitat– having genetic descriptors, number of species, their interactions within communities and the environment. A pool of diverse genes –genetic diversity– favor adaptations to environmental changes and resistance to diseases. Richness of species inform speciation processes were needed for survival. A wide variety of genes within a species, provides the raw material for natural selection and evolution.[3] This diversity is crucial for long-term survival and adaptability. Therefore, all ecological knowledge used to protect natural products is needed for availability of medical resources, such as the materials produced by stingless bees in their nests.

Tropical ecosystems are known to have the highest biodiversity in our planet, having warm climate, rainfall, and solar energy year-round, supporting a vast biodiversity of plants and animals. Corcovado National Park in Costa Rica, and Yasuní National Park in the Ecuadorian Amazon are known to host the higher biodiversity in the planet.[4] Threatening vegetation reduces availability of food and nesting sites, causing inbreeding and genetic loss of stingless bees. Particularly, a deforestation rate of 12.2 km^2/year is not permitted in environmental agreements to overcome climate change, as well as invasions and mining on native people lands,[5] and conversion to pasture increasing deforestation rates. Preliminary studies on the Brazilian Amazon have assessed a decline of 95 % in meliponines species for the Carajás National Forest.[6] Expansion of protected areas is recommended for Meliponines visiting 756 species of plants having economic and ecological importance in Legal Amazon, mainly concentrated along the largest rivers of the Amazon basin.[7] Biodiversity loss has a tremendous impact on humanity[8], and loosing pollinators reflects a risk in food security, because they feed populations and change landscapes for global crops.[9] Additionally, their ancestral medicinal uses can be affected if they become not available in a region.

A bibliometric review was done using the Scopus database, covering research published in the period 2000 to 2025. Top ten prominent authors, institutions, countries, sources, subject areas and financial sponsors were ranked according to the number of documents retrieved. Diverse visualizations of the dataset were selected using Bibliometrix, to show authors' keywords word cloud, tree map, topic dendrogram, most cited authors, sources, and countries, collaborative worldwide map, single or multiple country publications of corresponding author's countries, and a three-field-plot for country, source, and author. This paper presents the legal frameworks relevant to stingless bee conservation in Bolivia, Brazil, Costa Rica, Ecuador, El Salvador, Guatemala, the Philippines, and Tanzania. Policy developments and opportunities for sustainable utilization of stingless are highlighted.

Therefore, the purpose of this study is to perform the first bibliometric analysis on the conservation and sustainable use of stingless bees, aiming to identify the most productive authors, institutions, and countries in the field. The scope of the article comprises publications from 2000 to 2025 addressing stingless bee conservation, including their use in human health. Safeguarding biomaterials of phytochemical origin and biotransformations by microbiomes associated with stingless bees, as well as highlighting potential threats and protective legislation for stingless bees found in the tropics worldwide, is our call in this contribution.

2. Methodology of the bibliometric study

2.1 Scopus database

The bibliometric search was carried out in the Scopus database, in the "TITLE-ABS-KEY" field using the operator AND, on November 8, 2025.

TITLE-ABS-KEY (conservation AND stingless AND bee)

A total of 359 documents were retrieved from 2000 to 2025, 299 articles, 25 reviews, 19 book chapters, 6 conference papers, and 1 books. The documents of published research in our dataset were ranked in Scopus for authors, affiliations, countries, sources, subject areas, and funding sponsors. The absolute number of documents was exported in a CSV Excel file for the Bibliometrix statistical analysis and visualization.

2.2 Bibliometrix statistical analysis and visualization

The CSV Excel file containing the Scopus search results was downloaded in the Bibliometrix Bibliometrix R package created by Aria and Cuccurullo (2017)[10] in R Version 4.2.1 and the Biblioshiny App. We investigated correlations and classifications of authors' keywords using multivariate factorial analysis for topical dendrograms by Hierarchical Cluster Analysis (HCA). Plots and Excel files were saved in files for the selected visualizations presented here.

3. Bibliometric analysis

3.1 Annual publication trends

The annual publication trend on conservation of stingless bee research is visualized in Fig. 1. The first document was published in 2000, showing a growing pattern up to 2025 with 44 documents.

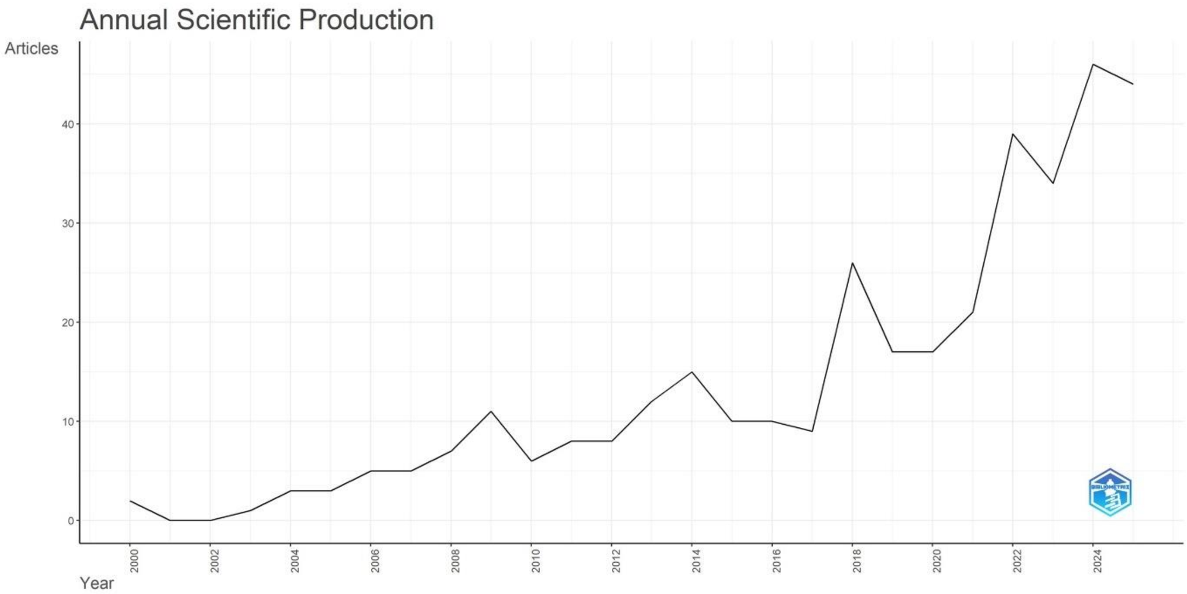

Fig. 1 Evolution of the number of documents produced every year on conservation of stingless bee research in the period 2000 to 2025

3.2 Main information of the retrieved documents

The major information of our dataset is presented in Table 1. The Scopus database retrieved 359 documents published on conservation of stingless bees from 2000 to 2025. A bibliometric study was conducted since the first article published on conservation of stingless bees the year 2000,[11] and the last two in this dataset (Campos et al., 2025; Real-Luna et al., 2025)[12,13]

The main information of bibliometric descriptors is presented in Table 1 including publications from the first retrieved document since 2000 to date in 2025, more than two decades. The 359 documents of the dataset were published in Chinese (1), English (148), Indonesian (1), Portuguese (6), Spanish (10), and Thai (1).

Table 1. Bibliometric descriptors of published conservation of stingless bee research since 2000 to date in 2025

Main information of the dataset bibliometric descriptors	**Counts of all documents**
Timespan	2000:2025
Sources (Journals, Books, etc)	141
Documents	359
Annual Growth Rate %	13.6
Document Average Age	6.23
Average Citations per Document	30.77
References	2350
Document Contents	
Keywords Plus (ID)	1541
Author's Keywords (DE)	1054
Authors	
Authors	1463
Authors of Single-Authored Documents	0
Authors Collaboration	
Single-Authored Documents	0
Multi-Authored Documents	1463
Co-Authors per Document	9.57
International Co-Authorships %	29.53
Document Types	
Article	299
Review	25

Main information of the dataset bibliometric descriptors	Counts of all documents
Book chapter	19
Conference paper	6
Note	2
Book	2
Editorial	2
Note	2
Conference review	1
Erratum	1
No. of languages	
Chinese	1
English	348
Indonesian	1
Portuguese	6
Spanish	10
Thai	1

3.3 Most productive authors

Table 2. Top-ten most productive researchers in conservation of stingless bees since 2000 with their affiliations, cities, and countries

Ranking	NP[1]	Microbiome of stingless bees and nest materials		
		Author	**Affiliation, city**	**Country**
1	18	Imperatriz-Fonseca VL	Universidade de São Paulo, São Paulo	Brazil
2	16	Quezada-Euan JJG	Autonomous University of Yucatan UADY, Merida	Mexico
3	12	Woldschmidt AM	Universidade Estadual do Sudoeste da Bahia	Brazil
4	11	Francoy TM	Universidade de São Paulo, São Paulo	Brazil
5	9	Giannini TC	Instituto Tecnológico Vale, Belem	Brazil
6	8	Blochtein B	Pontifícia Universidade Católica do Rio Grande do Sul	Brazil
7	8	Nunes LA	Faculdade Tecnologia e Ciencias, Jequie	Brazil
8	7	Arias MC	Faculdade de Tecnologia e Ciências-FTC, Jequie	Brazil
9	7	Freitas BM	Universidade Federal do Ceara, Fortaleza	Brazil
10	6	Alves DA	Universidade de São Paulo, São Paulo	Brazil

[1]NP number of publications

3.4 Most Productive Affiliations

Brazil has 8/10 of the most productive top ten affiliations ranked in Table 7. The other two are form Mexico and Argentina.

Table 3. Number of documents on conservation of stingless bee research since 2000 ranking top ten most productive institutions worldwide

Ranking	NP[1]	Institution, city	Country
1	47	Universidade de São Paulo, São Paulo	Brazil
2	23	Universidad Autonoma de Mexico, Mexico DF	Mexico
3	17	Universidade Federal de Vicosa	Brazil
4	16	Instituto Tecnologico Vale	Brazil
5	13	Empresa Brasileira de Pesquisa Agropecuária - Embrapa	Brazil
6	13	Universidade Estadual do Sudoeste da Bahia	Brazil
7	12	Universidade Federal do Ceará	Brazil
8	11	Consejo Nacional de de Investigaciones Científicas y Técnicas	Argentina
9	11	Universidade Federal do Reconcavo da Bahia	Brazil
10	11	Universidade Federal de São Carlos	Brazil

[1]NP number of publications

3.5 Most productive countries and collaborative map

The most prolific countries for conservation of stingless bee publications ranked in the Scopus database (Table 4) were Brazil (154), Mexico (52), USA (31), Malaysia (21), Germany 19), Indonesia (17), and 15 documents from Belgium, Colombia, India, and the United Kingdom. A total of 58 countries participated in our dataset, including Argentina (14), Australia (13), Spain (12), Kenya (11), Thailand and Costa Rica (9), Netherlands and Canada (8), Panama and China (6), Tanzania, Portugal, Guatemala, and France (5), Uganda, South Africa, Philippines, Bolivia and Austria (3), Vietnam, Sweden, Peru, Italy, Ghana, Ethiopia, Ecuador, Congo, Chile, qnd Bulgaria (2), and one document for Zimbabwe, Venezuela, United Arab Emirates, Turkey, Switzerland, Sri Lanka, South Korea, Singapore, Pakistan, Japan, Iran, Hong Kong, Democratic Republic Congo, Cameroon, Burundi, Burkina Faso, Brunei Darussalam, and Botswana.

Table 4. Number of documents in the ten countries most productive on conservation of stingless bee research since 2000.

Ranking	NP[1]	Country
1	154	Brazil
2	52	Mexico
3	31	United States
4	21	Malaysia
5	19	Germany
6	17	Indonesia
7	15	Belgium
8	15	Colombia
9	15	India
10	15	United Kingdom

[1]NP number of publications

The most globally ten cited countries for conservation of stingless bee in the Bibliometrix plot (Fig. 2) are Germany (5412), Brazil (1985), USA (646), Mexico (595), United Kingdom (498), Australia (189), Malaysia (122), France (106), Japan (88), and Panama (76).

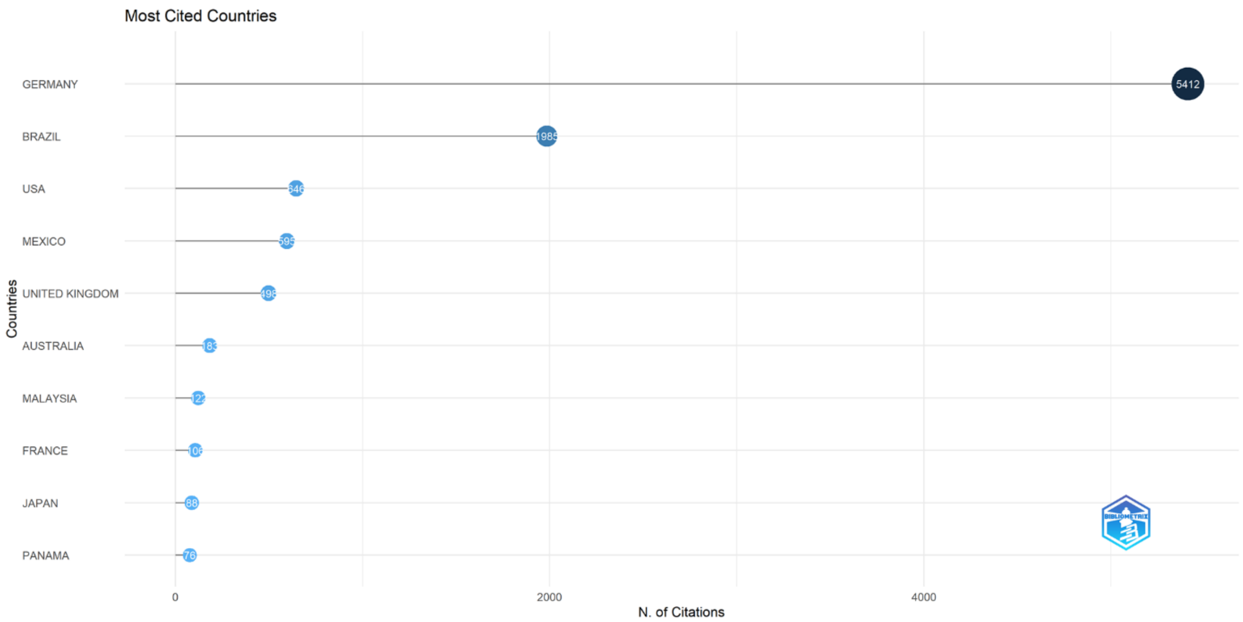

Fig. 2 Most globally cited countries on conservation of stingless bee research (2000–2025)
The bubble size is proportional to the number of documents, and the blue color shade corresponds to the total citations per year, darker blue for more citations than lighter blue.

The collaboration between countries sharing publications on conservation of stingless bee research in the period 2000 to 2025 was visualized in the country collaborative map of Fig. 3 using brown connectors in a worldwide map. The frequencies of collaboration between two countries are available in the corresponding Excel file. The highest collaborative frequency was between Brazil and USA, and for Spain and Mexico

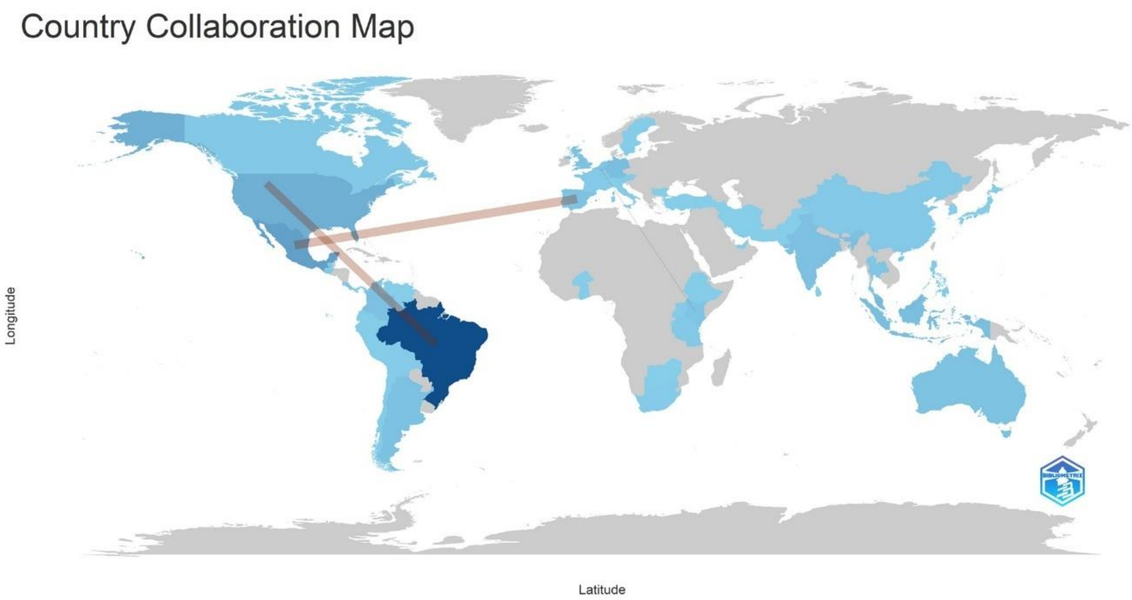

Fig. 3 Worldwide map with country collaboration for conservation of stingless bee research (2000–2025). Dark blue countries are more productive than light blue countries. Thicker collaboration brown lines were visualized between Brazil and USA and Spain and Mexico (3 or more shared documents), and between Belgium and Kenya (2 documents). Thin lines connecting many countries sharing one document were not included in the map. Connecting countries increase line thickness with most frequently shared publications

In Table 5, top ten sources were represented by nine journals and one book. The h-index range from 11 to 487 shows diverse background of the sources. The variation of Q was from Q4 to Q1. The Impact score (0.64 to 2.67) was modest.

Table 5. Most productive sources hosting research of microbiome and stingless bees since 2013.

Ranking	**Conservation of stingless bees**	
	NP[1]	**Source (h index, Quartile, impact score)**[2] **Editorial, Country**
1	115	Apidologie (h 105, Q1, 2.23) Springer-Verlag Italia s.r.l., Italy
2	92	Journal of Apicultural Research (h 81, Q1, 2.08) Taylor and Francis Ltd., United Kingdom
3	64	Sociobiology (h 44, Q4, 0.65) Universidade Estadual de Feira de Santana, Brazil
4	56	Journal of Insect Conservation (h 76, Q1, 2.46) Springer Nature, Switzerland
5	54	International Journal of Tropical Insect Science (h 35, Q2, 1.45) Springer Nature, Switzerland
6	49	Stingless Bee Nest Cerumen and Propolis Springer Nature, Switzerland
7	46	Serangga (h 11, Q3, 0.64) Penerbit Universiti Kebangsaan Malaysia, Malaysia
8	44	Insectes Sociaux (h 70, Q2, 1.18) Springer Science and Business Media Deutschland GmbH. Switzerland
9	44	Plos One (h 487, Q1, 2.67) Public Library of Science, United States
10	40	Grana (h 47, Q3, 1.02) Taylor and Francis Ltd., United Kingdom

[1]NP number of publications
[2]https://www.resurchify.com

In Table 6, documents on conservation of stingless bees were most frequently published in eight subject areas of the Scopus database, covering the following percentages: 51.8% Agricultural and Biological Sciences, 20.2% Environmental Science, 8.2% Biochemistry, Genetics and Molecular Biology, 3.8% Multidisciplinary, 3.4% Social Sciences, 2.9% Medicine, 2.7% Earth and Planetary Sciences, 2.1% Engineering, and 3.2% Others.

Table 6. Most productive Scopus subject areas on conservation and stingless bee research since 2000

Ranking	Conservation of stingless bees	
	NP[1]	**Subject area**
1	272	Agricultural and Biological Sciences
2	105	Environmental Science
3	43	Biochemistry, Genetics and Molecular Biology
4	20	Multidisciplinary
5	18	Social Sciences
6	15	Medicine
7	14	Earth and Planetary Sciences
8	11	Engineering
9	5	Pharmacology, Toxicology and Pharmaceutics
10	4	Computer Science

[1]NP number of publications

3.6 Other visualizations on conservation of stingless bee publications using Bibliometrix

3.6.1 Author's keywords

A selection of the top 25 authors' keywords used in the scientific literature on conservation of stingless bees' research (2000–2025) was done. In Fig. 4 we show a word cloud using authors' keywords, with words of higher frequencies occupying the center of the cloud with larger letters, and words with lower frequencies in the periphery or between lines with smaller letters: stingless bees (83), conservation (63), stingless bee (55), meliponini (54), meliponiculture (38), pollination (22), pollinators (21), biodiversity (17), honey (13), Apidae (11), bees (11), genetic diversity (11), melipona (11), melissopalynology (10), pollen (10), pollinator (10), diversity (9), geometric morphometrics (9), heterotrigona itama (9), microsatellites (9), climate change (8), deforestation (8), hymenoptera (8), distribution (7), and mexico (7).

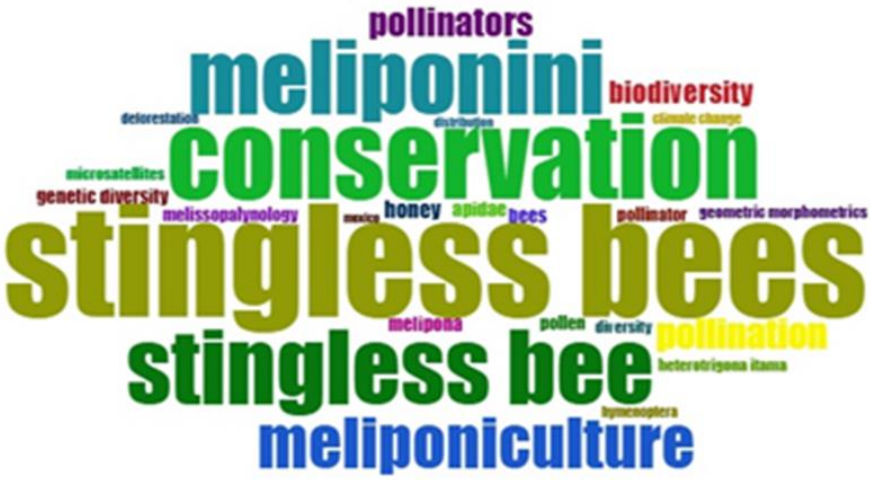

Fig. 4 Word cloud using authors' keywords in the scientific literature on conservation of stingless bees' research (2000–2025)

The word cloud is free shape but the tree map is a box arranged into contrasting colored boxes sized according to the frequence of author's keywords in descending order. The tree map in Fig. 5 shows the top 20 higher frequencies of the authors' keywords in the dataset, an informs their corresponding percentages. In the left half of the table, four words represent more than 50% frequency, stingless bee (83, 17%), conservation (63, 13%), stingless bee (55, 12%), and meliponini (54,11%). In the right side of the table, 16 words were used less frequently, meliponiculture (38, 8%), pollination (22, 5%), pollinators (21, 4%), biodiversity (17, 4%), honey (13, 3%), apidae (11, 2%), bees (11, 2%), genetic diversity (11, 2%), Melipona (11, 2%), melissopalynology (10, 2%), pollen (10, 2%), pollinator (10, 2%), diversity (9, 2%), geometric morphometrics (9, 2%), heterotrigona itama (9, 2%), microsatellites (9, 2%).

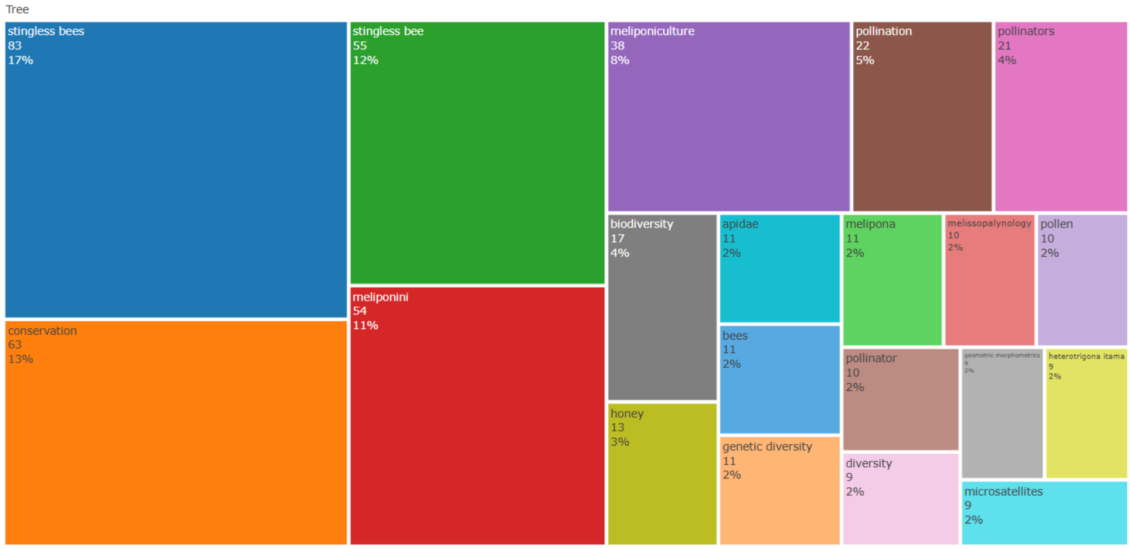

Fig. 5 Tree map on conservation of stingless bees' published research (2000–2025) using 20 authors' keywords

A dendrogram is a tree diagram showing hierarchies (order, ranks, categories, similarities and dissimilarities) in clusters (branches grouping variables to be interpreted intellectually). This plot uses the analogy of a tree with branches and a common shared root, recently represented upside down (like a fork), with the variable descriptors in the X axis, and the height (distance) in the Y axis. In Fig, 6 a topic dendrogram for authors' keywords shows four clusters for 25 terms, obtained after factorial analysis using hierarchical cluster analysis (HCA). The blue cluster consisted in two related keywords for biodiversity loss, such as deforestation and climate change. The green cluster has two subclusters, one for stingless bee and honey, the other related with plant diversity for melissopalynology, distribution, pollen, and diversity. The stingless bee *Heterotrigona itama* is also included in the green cluster. The violet cluster is related to bee diversity, with two subclusters for bees, geometric morphometrics, and hymenoptera, Apidae, microsattelites. Finally, the orange cluster has three subclusters about pollination and pollinators ecological service needed to maintain biodiversity 1. biodiversity, stingless bee, and pollinator, 2. genetic diversity, conservation, pollinators, and 3. meliponiculture, pollination, mexico, meliponini, and *Melipona*; having one country and the most biodiverse genus included here.

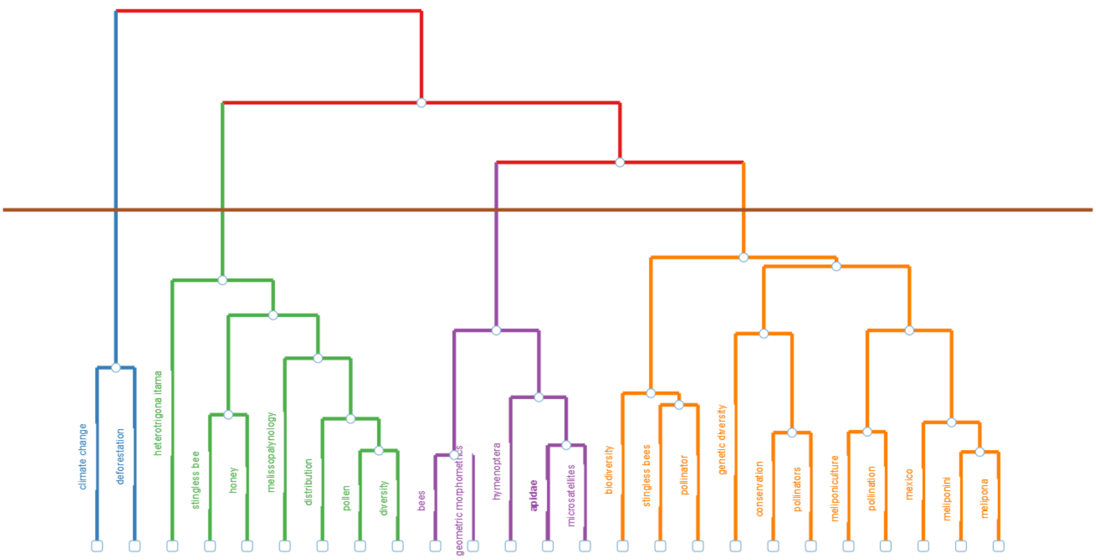

Fig. 6 Topic dendrogram by Hierarchical Cluster Analysis (HCA) of authors' keywords on conservation of stingless bees' published research (2000–2025)

3.6.2 Most globally cited documents

The plot of most globally cited documents in Fig. 7, shows the top ten documents most cited in our Scopus dataset. Klein (2007) has been cited 5284 times and the second most cited Slaa (2006) has been cited 368 times.

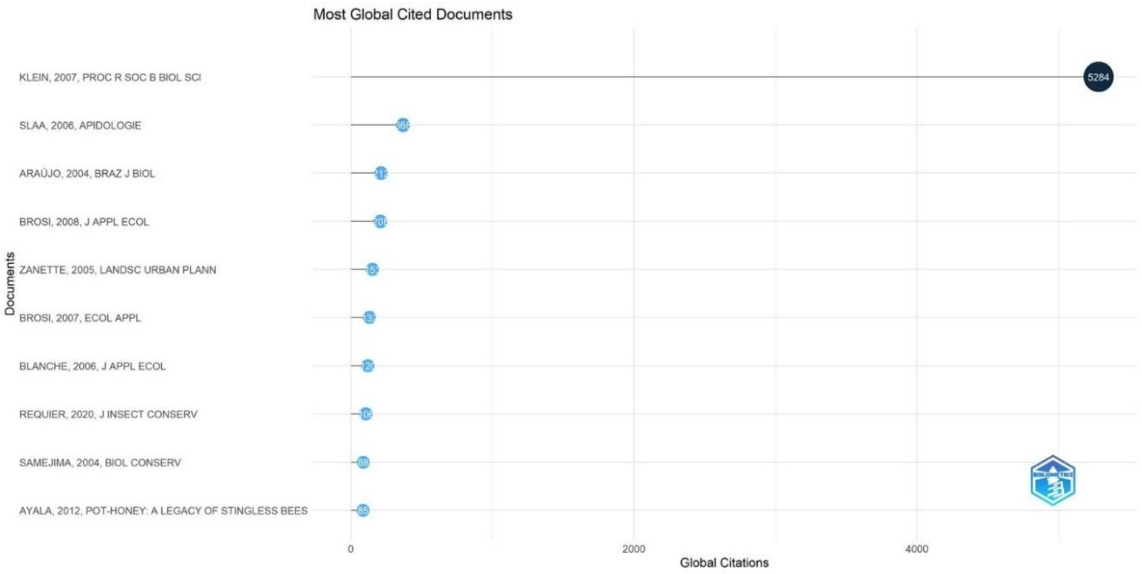

Fig. 7 Most globally cited documents on conservation of stingless bee microbiome research (2000–2025)

In Fig. 8 is visualized the composition of documents regarding the single or multiple country publications of corresponding author's countries. At a glance, Brazil, the most productive country, has devoted 4.5 times to single country publications over multiple countris. The next country, Mexico, reaches a third of the publications of Brazil, but only half of the publications are single country and the other half for multiple country, like the United States. Malaysia only published single country, as well as China and Tanzania. On the contrary, Spain, Belgium, Tanzania, and Bolivia have selected multiple country publications. Indonesia, USA, Argentina, India, Colombia, Thailand, and Australia have more single than multiple country, whereas Kenya, the United Kingdom, and Antigua have more multi country teams of authors than single country.

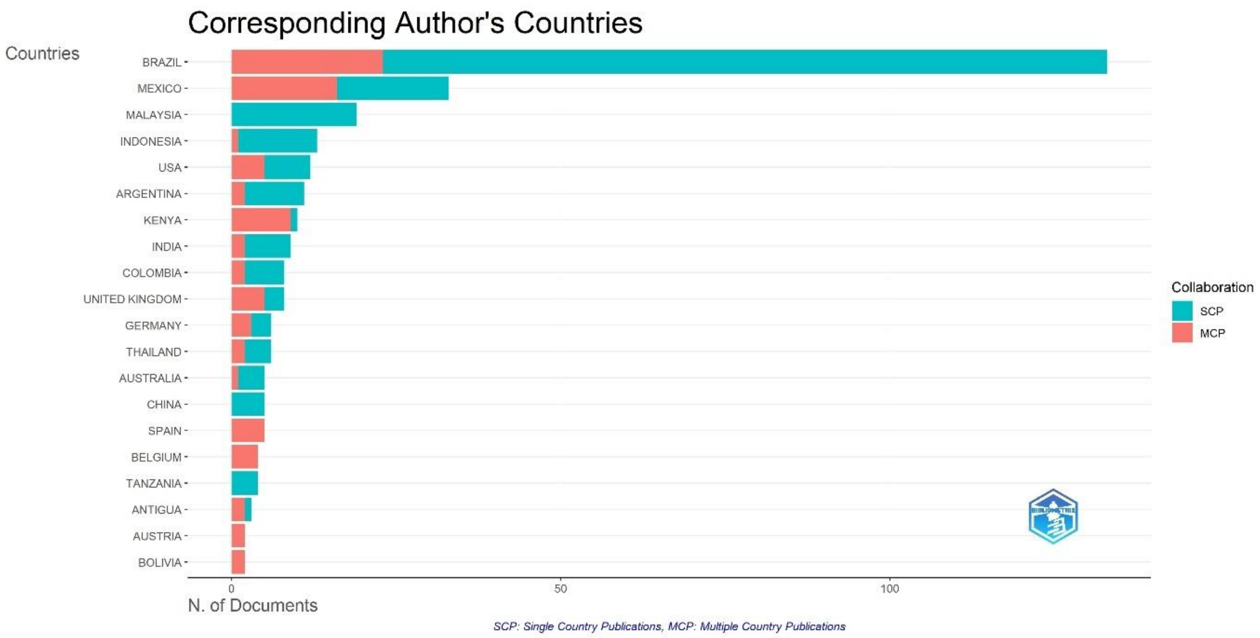

Fig. 8 Corresponding author's countries on conservation of stingless bee documents (2000–2025) Intra-country (single country publication SCP) and inter-country (multiple country publication MCP) corresponding author's collaborations.

The Sankey diagrams represent frequencies of three variables in the three-field plot of Bibliometrics R-Studio based with Biblioshiny interphase. By default, a selection of the first 20 ranked on each variable are included, but for clarity is better to select top ten. In Fig. 9 the middle variable is the source (SO) chosen by authors for the publication. The left variable is the affiliation of the first author AU_UN, and the right variable is the country of the first author, tagged (AU_CO). First authors from Brazil represent more than 50% of all authors, and published mostly in Apidologie, Journal of Apicultural Research, Sociobiology.

Journal of Insect Conservation, Insectes Sociaux, Serangga, Grana, and Plos One, from six universities and Instituto Tecnologico Vale of Brazil. Mexico, Malaysia, USA, and India are in the top five countries, after Brazil. Universidad Autónoma Yucatan from Mexico, Universiti Malaysia Terengganu, and the International Centere of Insect Physiology and Ecology.

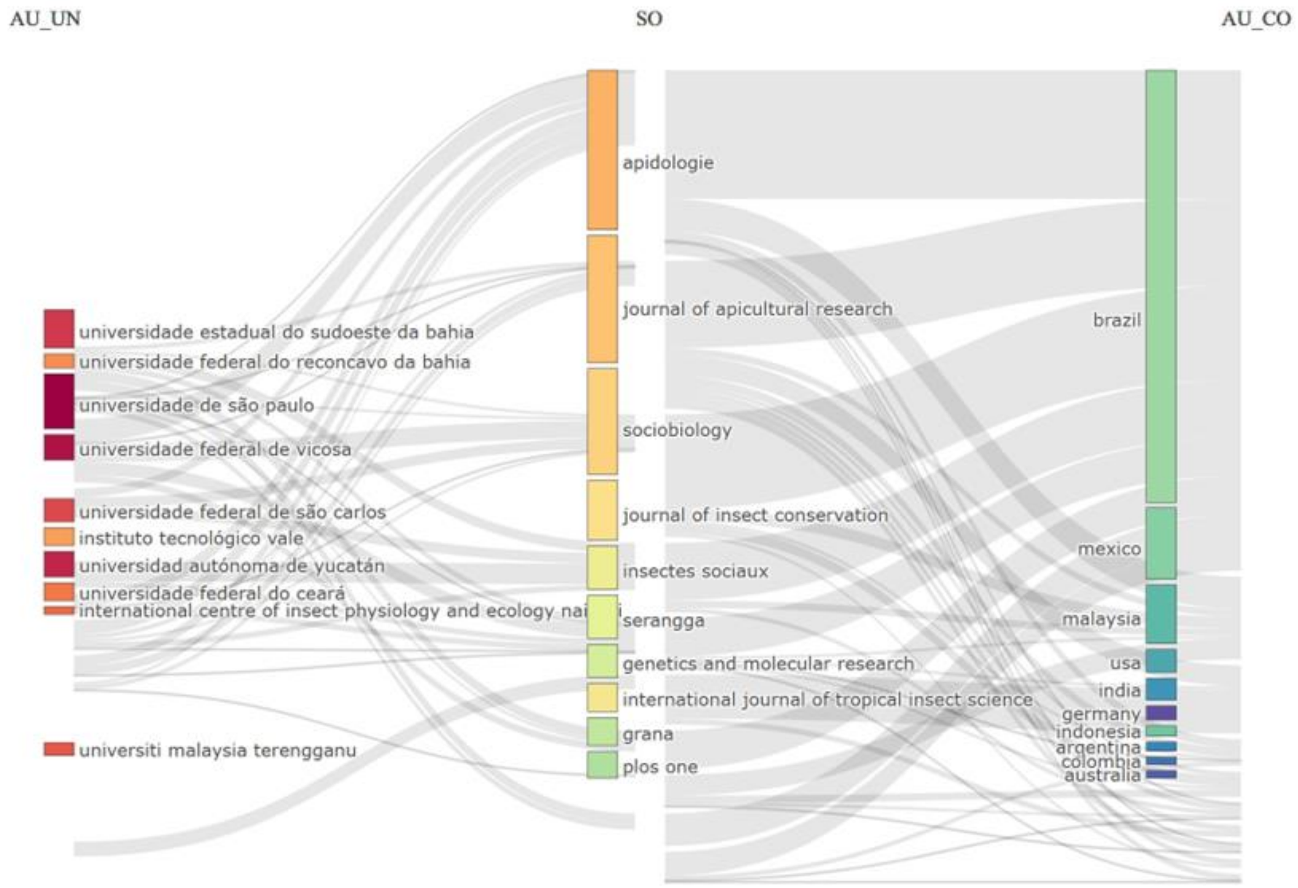

Fig. 9 Three-field plot or Sanky diagram for conservation of stingless bee documents (2000–2025) based on the affiliation of the first author (AU_UN), source (SO), and the country of authors (AU_CO).

In Fig. 10 are visualized four compartments of niche themes, motor themes, basic themes, and emerging or declining themes, showing the final stage on thematic evolution maps on publications of stingless bee conservation (2000–2025). Theme maps employ co-occurrence networks to group elements of Key Words Plus based on their relevance and development stage on publications of a theme. A theme's significance is assessed by the centrality of its clusters and its thematic status, visualized by plots on the X-axis measuring the importance of a theme, and the Y-axis measuring cluster connection density to indicate the strength of the cluster networks, to foster the evolution of a theme. According to their position on the map, the themes are classified in motor, niche, emerging or declining, and basic themes. The four types of themes: (1) motor themes in the upper right first quadrant, well-developed and important themes of a research field, (2) niche themes in the upper left second quadrant are highly developed but isolated themes of limited importance, (3) emerging or declining themes in the lower left third quadrant are marginally developed, (4) basic themes in the lower right fourth quadrant are spanning diverse research domains.

The basic theme of our dataset was represented by a unique cluster on conservation, stingless bees, and pollination; as well as the motor theme with one cluster about meliponiculture, stingless bees, and *Heterotrigona itama* –a conspicuous Malaysian stingless bee in the scientific literature, promoted to develop pot-honey for clinical use– Similarly, a unique cluster for the niche theme about well documented melissopalynology, native bees, and pollen, but somehow isolated in this analysis. Two clusters with one component on urbanization and mtdna resulted emerging themes.

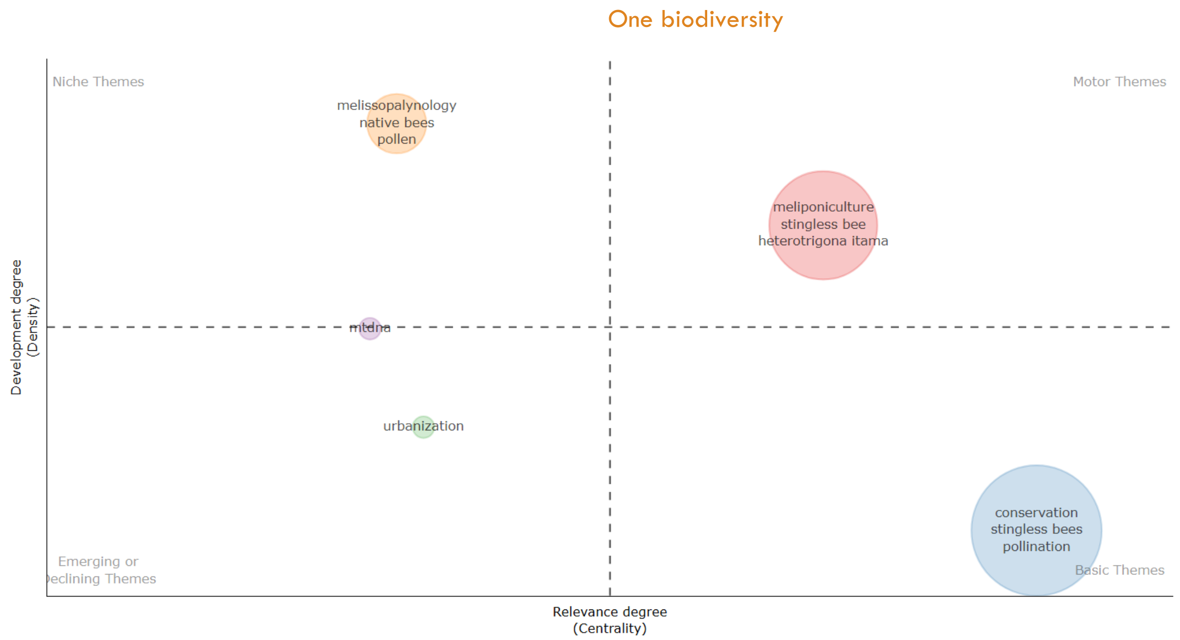

Fig. 10 Final slice for trends in thematic evolution maps on publications of stingless bee conservation (2000–2025).

Funding sponsors of research are vital for conservation of stingless bees. In Table 7 it is evident that Brazil has more funding sponsors than any other country supporting conservation of the most biodiverse country with 259 species of stingless bees, distributed in the five regions of this country: 1. North, including the Amazon (197 species), 2. Central-West (99), 3. Northeast (97), 4. Southeast (70), and 5. South (36).[14]

Table 7. Most active funding sponsors supporting research on conservation of stingless bee since 2000

Ranking	**Conservation of stingless bees**		
	NP¹	**Funding sponsor**	**Country**
1	51	Conselho Nacional de Desenvolvimento Científico e Tecnológico	Brazil
2	24	Coordenação de Aperfeiçoamento de Pessoal de Nível Superior	Brazil
3	13	Fundação de Amparo à Pesquisa do Estado de São Paulo	Brazil
4	9	Consejo Nacional de Ciencia y Tecnología	Argentina
5	8	Fundação de Amparo à Pesquisa do Estado de Minas Gerais	Brazil
6	6	Consejo Nacional de Investigaciones Científicas y Técnicas	
7	5	National Science Foundation	
8	5	Universidad Nacional de Colombia	Colombia
9	5	Universidad Nacional Autónoma de México	Mexico
10	5	Styrelsen für Internationale Ufweeklingssomarbeite	Germany

[1]NP number of publications

4. Repercussions of the environment in stingless bee nest materials

Stingless bees (*Meliponini*) exhibit profound sensitivity to environmental factors, which makes them excellent bioindicators of ecosystem health.[15,16] A thriving population reflects ecological balance, whereas their decline serves as an early warning of environmental degradation. Their vulnerability to climatic variability, habitat loss, agrochemicals, pollution, pathogens, and competition underscores the urgent need to understand and mitigate the pressures threatening their survival.

4.1 Impact of Climate and Habitat Alteration

As tropical and subtropical species, stingless bees are highly susceptible to climatic shifts. Elevated temperatures can cause brood comb melting, larval mortality, and reduced foraging activity[17,18] while extreme cold impairs brood development due to limited thermoregulation capacity.[15] Humidity extremes further destabilize colonies, either through desiccation or fungal proliferation,[19,20] Drought reduces floral resources, leading to malnutrition and decreased brood rearing,[21,22] whereas heavy rains hinder foraging and flood ground-nesting species.[15] Beyond climate, habitat loss and fragmentation represent the most critical threats worldwide.[16,22] Deforestation eliminates nesting sites, monocultures create seasonal food deserts, and urbanization reduces floral diversity while increasing pollutant exposure.[22,23]

4.2 Anthropogenic Stressors: Agrochemicals and Pollution

Stingless bees are particularly vulnerable to pesticides due to their smaller size and reduced pilosity compared to honeybees.[24] Contaminated nectar and pollen can cause direct mortality, while sublethal effects—such as impaired navigation, reduced memory, and diminished queen fecundity—undermine colony viability.[24,25] Pollution compounds these risks: air pollutants disrupt floral scent trails, impairing foraging efficiency, while soil and water contamination introduce heavy metals and toxins into nectar and pollen, generating chronic toxicity within nests.

4.3 Biotic Pressures and Invasive Species

Environmental imbalance also increases susceptibility to pathogens and parasites. Fungi such as *Aspergillus* spp. thrive in poorly ventilated nests,[19] mites like *Pyemotes* spp. kill pupae in stressed colonies,[20] and phorid flies consume brood and nest structures.[15] Additionally, stingless bees face competition from invasive species. Honey bees often outcompete them for floral resources, while Africanized honeybees may directly usurp nesting cavities.[26] Collectively, these pressures highlight the fragility of stingless bee populations and reinforce their role as sentinel species for monitoring ecosystem integrity. The significant geographical and seasonal variation in metabolite profiles are reported in studies.[27] A comprehensive understanding of both botanical and microbial origins is therefore essential for standardizing these natural products for medicinal use and for developing conservation strategies that protect the diverse ecosystems sustaining these complex chemical factories.[28] The key classes of bioactive metabolites in stingless bee nest materials and their roles are summarized and integrated in Table 8.

Table 8. Origins of bioactive metabolites in stingless bee nest materials

Source / Origin	Key Metabolite Classes	Reported Bioactivity / Role
Botanical Sources (External Environment)		
***Dalbergia* spp. (Propolis)**	Prenylated benzophenones, flavonoids	Potent antibacterial, antifungal (Campos et al., 2014).[29]
Tualang, rainforest flora (Honey)	Flavonoids, phenolic acids, galangin	Antioxidant, Antibacterial (Abdullah et al., 2025).[30]
Microbial Sources (Internal Nest Environment)		
Lactic acid bacteria (LAB) in pot-pollen	Aliphatic organic acids (acetic, lactic), bacteriocins	pH regulation, pathogen inhibition, preservative (Schwarz et al., 2023).[31]
Yeasts and fungi in fermented pot-pollen	Ethanol, bioactive peptides, enzymes	Prebiotic, nutrient enhancement (Schwarz et al., 2023).[31]

5. Secondary metabolites in stingless bee materials of the nest, microbial diversity, and medicinal applications

Stingless bees collect nectar, pollen, plant resin and oils from plants and process them into pot-honey, pot-pollen, cerumen, and propolis. Phytochemicals such as flavonoids, phenolic acids, polyphenols, and terpenoids are secondary plant metabolites affected by environmental changes.[32] Stingless bees and the materials derived from their nests have traditionally been studied in various tropical regions for their potential beneficial properties for human health. In recent years, scientific research has delved deeper into the analysis of the microbiome that resides in these bees and the materials they collect and process, such as honey, propolis, pollen, and cerumen.[33,34] This research reveals that the associated microbial richness and diversity not only contribute to the health and survival of bee communities but are also a natural source of bioactive compounds with potent antimicrobial, antioxidant, anti-inflammatory, and immunomodulatory effects, giving these products beneficial and healing properties.[35,36]

The microbiome plays a fundamental role in enriching these products with microbial secondary metabolites. When these metabolites combine with the bees' own compounds, they generate unique biochemical synergies.[37] This complexity has generated interest in the potential use of stingless bee products in integrative medicine, as well as in the development of innovative new therapeutic options capable of contributing to the fight against infectious diseases — especially those caused by multidrug-resistant pathogens — and of alleviate chronic inflammation, preventing oxidative stress and controlling metabolic dysfunctions.[38] However, these medicinal applications must be considered in the context of biodiversity preservation, since the sustainability of stingless bee populations and the integrity of their microbiome are essential for ensuring the production and quality of these natural resources.[33,38] The interplay between human health, functional microbiology, and ecological conservation is a promising interdisciplinary frontier that could improve biomedicine and environmental protection.[39]

5.1 Antimicrobial activity

The microbiome of stingless bees and the materials in their nests constitute a reservoir of beneficial microorganisms and metabolites that exhibit a wide range of antimicrobial activities against bacteria, fungi, and viruses. In vitro studies and experimental models have supported this hypothesis, reaffirming the therapeutic potential of these products in combating infections, particularly in the context of bacterial resistance.[34]

The microbiome of Meliponini bees contains bacteria such as *Lactobacillus*, *Bifidobacterium*, and *Bacillus*, which produce bacteriocins, organic acids, and enzymes that directly inhibit pathogens. These microbial communities benefit the health of the colonies and enrich the nest materials with multifunctional bioactive compounds.[41,42] The hydrogen peroxide, phenolic metabolites, and microbial enzymes found in honey from stingless bees act synergistically to inhibit both Gram-positive and Gram-negative bacteria, as well as pathogenic fungi. This spectrum includes multidrug-resistant strains, making these products important natural antimicrobial agents.[43] Similarly, propolis and cerumen, which are rich in phenolic compounds and flavonoids, exhibit significant bactericidal and fungicidal properties.[34] Their effectiveness increases when they are combined with metabolites produced by the associated microbiota, forming a biochemical complex with a multipurpose antimicrobial action.[35-37]

Recent research has highlighted the synergistic effect that occurs when honey and other bee products are associated with antibiotics. Some studies suggest that these natural products can increase the effectiveness of antibiotics, reducing the minimum inhibitory concentrations needed to eliminate resistant bacterial strains such as methicillin-resistant *Staphylococcus aureus* (MRSA) and carbapenemase-producing *Pseudomonas aeruginosa*.[44-46] This is because the compounds in honey and propolis affect different microbial targets, complementing the mechanisms of action of conventional antibiotics. For instance, honey can alter bacterial membranes and biofilms, thereby facilitating antibiotic penetration and efficacy, while its phenolic metabolites can inhibit enzymes involved in antimicrobial resistance.[41] In this context, honey and other bee products, working synergistically with antibiotics, also reduce the required dose of these drugs, which may decrease adverse effects and help contain the spread of antimicrobial resistance.[42] Therefore, the integration of products from stingless bee nests into antimicrobial therapies could optimize treatments, especially for difficult-to-treat infections caused by multidrug-resistant pathogens.[34,36,44]

It is important to note that the set of bioactive metabolites, which includes hydrogen peroxide, organic acids, flavonoids, terpenoids, and microbial enzymes, acts through various mechanisms.[36] These include perforation and destabilization of the bacterial cell membrane, inhibition of protein and nucleic acid synthesis, alteration of intracellular metabolism, and generation of oxidative stress. They also include disruption and prevention of biofilm formation.[46] These mechanisms reduce the likelihood of resistance development in pathogens and emphasize the importance of preserving microbial biodiversity in bee products to ensure and maintain these therapeutic effects.[45]

5.2 Antioxidant and anti-inflammatory potential

The bioactive factors present in the microbiome of stingless bees and their nests constitute a multifaceted source of compounds with remarkable antioxidant and anti-inflammatory properties. These mainly result from high levels of phenolic substances and flavonoids, which act as powerful free radical scavengers and protect cells against oxidative damage, a key factor in the development of various chronic diseases.[47] Recent studies have shown that the antioxidant capacity of stingless bee honey is superior to that of honey from other bee species, thanks to the symbiotic microbiome's production of antioxidant enzymes such as catalase and superoxide dismutase, which enhances the protective effect.[48]

Furthermore, the anti-inflammatory potential of these products is proved by their ability to reduce the production of pro-inflammatory mediators, such as certain cytokines and enzymes related to chronic inflammation.[49] In vitro trials and experimental models have shown that extracts of honey and propolis from stingless bees decrease the expression of cyclooxygenase-2 (COX-2) and inducible nitric oxide synthase (iNOS), and modulate the innate immune response, which promotes the resolution of inflammatory processes and prevents chronic tissue damage.[47,48] This action is attributed to the synergy between microbial metabolites and plant compounds present in bee products, which act together to regulate inflammatory processes.[50]

The microbiome plays a critical role in this biochemical synergy by contributing to the production of metabolites that enhance these antioxidant and anti-inflammatory properties, resulting in multifactorial effects that would not be achieved by individual compounds alone. This microbial cooperation improves therapeutic efficacy and highlights the importance of conserving biodiversity to maintain the quality and functionality of these products.[51]

These antioxidant and anti-inflammatory properties suggest the potential for products derived from stingless bees to be used in the development of natural therapies for chronic inflammatory diseases and nutraceuticals to promote overall health. Incorporating these products into integrative medicine enables various pathologies to be prevented or treated within a framework, strengthening sustainability and environmental protection.[49-51]

5.3 Immune modulation and its application to metabolic diseases

In the broader context of the microbiome of stingless bees and their nest materials, immune modulation plays a vital role in complementing and amplifying the recognized antimicrobial, antioxidant, and anti-inflammatory properties.[51] Bioactive metabolites derived from the symbiotic microbiota and phytochemical compounds found in honey, propolis, cerumen, and pollen have an impressive capacity to interact with the host's immune system, promoting precise regulation that favours homeostasis and an effective response to pathogens without causing harmful chronic inflammation. This immunomodulatory action is particularly relevant in metabolic diseases, where immune dysfunction plays a central pathogenic role.[52]

Recent research shows that these bee products can influence the activation and proliferation of immune cells, cytokine production, and the expression of key receptors, modulating both innate and adaptive responses.[38] This balanced regulation helps to mitigate the systemic inflammation and oxidative stress that are characteristic of diseases such as type 2 diabetes mellitus, obesity, and metabolic syndrome.[52] These pathologies are highly prevalent worldwide and require safe and effective therapeutic alternatives.[37,38] Experimental models have shown that microbial and phytochemical extracts can improve insulin sensitivity, regulate lipid and carbohydrate metabolism, and reduce the expression of inflammatory markers. This implies a dual mechanism of action that addresses the immunological and metabolic origins of these diseases.[53]

In patients with type 2 diabetes mellitus, systemic inflammation and oxidative stress are important factors in the development of insulin resistance and progressive tissue damage. Clinical and experimental studies have revealed that the topical application or oral administration of stingless bee honey can accelerate the healing of diabetic ulcers thanks to its combined antimicrobial, anti-inflammatory, and local immune-stimulating effects.[54,55] Conversely, animal models have demonstrated that supplementation with these products enhances the activity of antioxidant enzymes, reduces inflammatory markers, and promotes tissue regeneration in areas affected by hyperglycaemia.[52-55]

The ability of the bee microbiome to modulate immune responses is also reflected in the regulation of T cell activation and the expression of immunomodulatory receptors, which allows the balance between inflammation and tissue repair to be regulated.[40,49] This phenomenon is essential for delaying the progression of diabetes and its micro- and macrovascular complications. Studies indicate that these mechanisms contribute to improving both insulin sensitivity and glycolipid metabolism in experimental models, underscoring the multifunctionality of these products as adjuvant therapies.[50,52] Therefore, preserving the microbiome and biodiversity of stingless bees is presented as an integrative conservation strategy that not only protects a valuable biological resource but also ensures the continued production of these natural therapeutic compounds that may have a decisive role in the management of chronic non-communicable diseases such as diabetes.[33,37,48] The interaction between microbiota, inflammation, and metabolism is a field of growing interest, and these bee products offer a promising approach that integrates human health with environmental sustainability.[56]

This integrative approach contributes to our understanding of the therapeutic value of stingless bee products and opens up prospects for developing nutraceuticals and adjuvants for use in conventional therapies.[40,52-55] Furthermore, preserving biodiversity and the health of the bee microbiome is essential for maintaining the quality and availability of these medicinal products. This establishes an indispensable link between biomedical innovation and ecological conservation.[33-40] Therefore, the immunological modulation exerted by the microbiome of stingless bees and their nest materials is a prime example of how biodiversity can provide innovative, sustainable solutions for contemporary medicine.[38,43] These solutions broaden the scope of therapies for chronic metabolic diseases by integrating human health and ecosystem resources and conservation.[47,50-52]

6. Experts on stingless bee conservation inform endeavors in their countries

We were interested to know what actions have governments taken in a few countries. What goverment agencies? A brief outline of historical progress on conservation of stingless bees, and especially the current status on any legislation

6.1 Legal and conservation framework for Philippine stingless bees

Stingless bees have great potential for the future of Philippine agriculture and the economy due to their sustainability, vital role in pollinating both wild and domesticated plant species, and the value of their hive products. To date, 12 species of stingless bees have been documented in the Philippines, of which three have shown strong potential for domestication and for the production of honey, pollen, and propolis.[57] Their use in managed pollination is also expanding, particularly for high-value crops such as mango, rambutan, avocado, and various vegetables.[58] Wild stingless bee populations, found primarily in forests, provide sources of genetic material for natural breeding and conservation. Their hive products also show therapeutic properties.[59-61] Although stingless bees are not yet listed as threatened species under existing wildlife protection laws, their collection and utilization must be carefully regulated to avoid the depletion of wild populations.

6.1.1 Laws relevant to stingless bee conservation

The Philippines has several national laws, standards, and ordinances that regulate wildlife collection, protect forest habitats, and promote sustainable agricultural practices. However, these policies also present gaps that limit their effectiveness for species-specific conservation—particularly for stingless bees whose biology, nesting patterns, and ecological roles differ from those of honey bees.

6.1.2 Republic Act 9147 – Wildlife Resources Conservation and Protection Act

The Wildlife Resources Conservation and Protection Republic Act 9147[62] provides the basic legal foundation for the conservation of wildlife species and their habitats, promoting ecological balance and biological diversity in the Philippines. The law regulates the collection, possession, transport, and trade of wildlife—including insects such as stingless bees—and imposes penalties for unauthorized activities. Its provisions guide national wildlife management and support the development of science-based conservation strategies (Office of the President of the Philippines, 1995)[63]

A key component of RA 9147 is its regulation of bioprospecting, defined as the research, collection, and utilization of biological and genetic resources for scientific or commercial purposes. Bioprospecting activities involving wildlife require a permit from DENR (for terrestrial species) or DA-BFAR (for aquatic species), as well as Prior Informed Consent (PIC) from Indigenous Peoples, local communities, or protected area managers when applicable.

A bioprospecting undertaking ensures equitable access and benefit-sharing, values traditional knowledge, and prevents the exploitation of native species. These provisions are highly relevant to stingless bees, whose wild colonies represent valuable genetic and biochemical resources that must be accessed responsibly.

Complementing RA 9147, of the Organic Beekeeping Code of Practice (COP) (Bureau of Agriculture and Fisheries Standards (2025)[64] stipulates that the collection of wild populations is limited to 30% of nests, leaving 70% within the habitat to maintain natural populations. The COP also regulates the collection of wild bee products and outlines standards for organic beekeeping practices, including colony and hive management, bee health and welfare, pest and disease control, harvesting methods, postharvest handling, packaging, labeling, and record-keeping to ensure sustainability and organic integrity.

6.2 Stingless bee conservation in Bolivia: Current advances in governance, research, knowledge indigenous, collective and individual initiatives

In Bolivia, stingless bees (Meliponini) have acquired significant conservation and socioeconomic relevance through the progressive development of meliponiculture. Some species have demonstrated their capacity for breading and management in box nests, thereby enabling the sustainable production particularly honey and propolis. These hive products exhibit distinctive nutraceutical properties, and well-documented therapeutic and nutritional benefits[35,65-69] Offering particularly valuable livelihood opportunities, and food-security options for indigenous and local communities.

6.2.1 Richness species of stingless bees in Bolivia

To understand the advances in stingless bee conservation in Bolivia, it is first necessary to review knowledge of their diversity. Early foundational contributions of meliponine bees were published by Moure (1950)[70] and Kempff-Mercado (1968).[71] Subsequently, the catalogue of bees (Hymenoptera, Apoidea) in the Neotropical region, recorded 21 genera and 88 species for Bolivia (Camargo et al. 2023).[72] The most recent review documented 121 species distributed across 19 valid genera,[73] with the added description a new species, *Melipona rasmusseni*,[74] bringing the current total to 122. However, it is important to note the possible addition of 15 species described near the borders with Brazil and Argentina (Cespedes-Llave 2024).[73]

6.2.2 Meliponiculture

Of all stingless bees known in Bolivia, at least eight species are managed in stingless bee keeping, which has led to various projects developed since the 1990s. Among them are various projects set up by non-governmental organizations (NGOs), such as the initiatives carried out in the department of Beni, specifically within the Sirionó indigenous communities of Ibiato, promoted by the Biodiversity Support Program WWF/USAID, the Nature Conservancy, and The Wood Resources Institute.[75] Currently, efforts are underway in the Ibare-Mamoré municipal protected area of Trinidad, Beni, promoted through CIBIOMA of the Technical University of Beni Mariscal José Ballivián.[76] Likewise, in Santa Cruz, projects were implemented starting in 2000 in Guaraní indigenous communities with the support of the Wildlife Conservation Society (WCS), as documented in the works of Martínez and Cuéllar (2004),[77] and in settler communities within Amboró National Park supported by the eastern ecology association (ASEO, *Asociación Ecología del Oriente*).[78] Additionally, Chuquisaca NGO Lider and the PASOS Foundation formed associations of meliponiculture producers, becoming a benchmark in stingless bee breeding and production since 2015. NGOs such as the Foundation for the Conservation of the Chiquitano Forest (FCBC, *Fundación para la Conservación del Bosque Chiquitano*), with support from indigenous farmers in eastern Bolivia (APCOB, *Apoyo para el Campesino-Indígena del Oriente Boliviano*), have been promoting research and development of meliponiculture in the Chiquitania region since 2020.[79-80] Other locality such as Vallegrande are in their nascent stages of meliponiculture.[81] Other valuable experiences took place in the Tacana indigenous communities in La Paz, supported by WCS.[82] During 2010 in Tarija, in regions of the Chaco, they worked with the association of beekeepers of the Gran Chaco (ADACHACO, *Asociación de Apicultores del Gran Chaco*) - PUMA Foundation.[83] In Cochabamba, the Yuracaré indigenous communities have promoted meliponiculture.[84]

6.2.3 Law, Statutes and Programs (Governance)

National policies that attempt to include stingless bees arise through the national program for the strengthening and support of beekeeping production (PNFyAPA, Programa Nacional de Fortalecimiento y Apoyo a la Producción Apicola). Under the criterion of resilience to climate change, a variety of studies have been carried out that include preferentially the introduced honey bees (*Apis mellifera*) and also native bees (Meliponini) of economic importance. The following are important aspects of PNFyAPA:

- Bolivia promulgated the Supreme Decree 4632 (1 December 2021) governed by Law 144 (26 June 2011), establishing that better and greater production performance will be promoted within the framework of a plural economy, for traditional, organic, ecological, agricultural, and forestry production intended for domestic consumption, enabling food sovereignty to be achieved and surpluses to be generated, within the framework of local knowledge, practices, and technological innovation based on family, community, associative, and cooperative forms of production.[85]
- Created the PNFyAPA, aim to consolidate and strengthen the national beekeeping sector. Although originally centred on *Apis mellifera*, the programme has progressively incorporated stingless bees.[86,87]
- Execution of support for assigned to the national institute of agricultural and forestry innovation (INIAF, *Instituto Nacional de Innovación Agropecuaria y Forestal*), Bolivian food and derivatives company (EBA, *Empresa Boliviana de Alimentos y Derivados*), and national service of agricultural health and food safety (SENASAG, *Servicio Nacional de Sanidad Agropecuaria e Inocuidad Alimentaria*). SENASAG participates in the PNFyAPA, aimed at specific regulations for

beekeepers and meliponiculturists. For example, they publish general animal health regulations (REGENSA, *Reglamento General de Sanidad Animal*) in the chapter 3.3 has regulated specific requirements for the registration of beekeeping and meliponiculturists in the production establishments (SENASAG, 2022).[88]

- INIAF, seeks to support the strengthening of the beekeeping sector through research, development, validation, and transfer (EPB, 2008).[89]
- EBA, strengthen and consolidate the PNFyAPA for strengthening and supporting beekeeping production, under criteria of resilience to climate change (EPB, 2023).[90]

Despite these advances, hitherto, Bolivia has passed no national law specifically for stingless bees, but departmental and municipal governments have generated regulations, the most notable being:

- The Law 366/2018 on the promotion, conservation, and development of beekeeping in the department of Chuquisaca, which in Article 5 (Chapter 1) includes definitions of meliponiculture and stingless bees. In addition, Chapter 5, Articles 18 and 19 deal with the conservation of the bee population in the department of Chuquisaca (ALDC 2019).[91]
- The municipality of Machareti has issued two regulations
    - Macharetí Municipal Law No. 15 Municipal Law on the Breeding, Management, Conservation, and Protection of Stinging Bees (*Apis mellifera*) and Native Stingless Bees (Meliponinos) (GAMM 2020).[92]
    - Municipal Decree No. 3/2021 Regulations to Machareti Municipal Law No. 15. Municipal Law on the Breeding, Management, Conservation, and Protection of Stinging Bees (*Apis mellifera*) and Native Stingless Bees (Meliponinos) (GAMM 2021).[93]

6.2.4 Advances and lessons learned for stingless bee conservation

In December 2024, the first Bolivian discussion forum on native stingless bees was held, convened by the FAO together with the Ministry of Environment and Water, meliponiculture farmers, academics, and civil society. At that forum, the Bolivian organization for the protection of native bees (OBPAN, *Organización Boliviana de Protección a las Abejas Nativas*) was founded, the first national entity dedicated specifically to stingless bees (OBPAN 2025).[94] Among the issues that arose were: the need for technical, regulatory, and academic funding; the creation of networks among meliponiculture practitioners; the cataloging of species by ecoregion; and insurance for producers against fires or pesticides.

6.2.5 Scientific support to study biodiverse stingless bee nest materials and meliponiculture in Bolivia

The physicochemical characterization of pot-honey,[95,96] its botanical origin,[9-,99] and uses of cerumen[100] and other materials of the nest like pot-honey, pot-pollen and propolis, including women[101,102] have attracted researchers, as well as the relationship between stingless bees and plants.[103] The Bolivian standards for stingless bee honey are needed, and Bolivia has developed a multidisciplinary frame to appreciate their biodiversity and potential medicinal uses. Financial support for science and technology from the government will benefit quality control and discovery of rich stingless bee resources.

6.3 Stingless bee conservation in Guatemala

In Guatemala we currently recognize 33 species of stingless bees,[104] and their presence in the region goes back to the time of the ancient Maya[105] From colonial records we also know that these bees were already understood and valued by Indigenous communities, not only for their biological traits but for their cultural and spiritual importance.[106] Honey and pollen have been traditionally used as food supplements, medicinal resources, and are even considered as elements of family protection.[107] Their role has become increasingly visible in recent years, especially as global attention to pollinator decline has intensified.

Since the early 2000s, the Universidad de San Carlos de Guatemala has taken the lead in studying stingless bees in a more systematic way. This includes documentation of species diversity, distribution, genetics, ecological roles,[108-112] and also the characterization of their nest materials.[113-114] Much of the national conversation about the importance of stingless bees for conservation and food security has grown directly from this body of work. Little by little, other institutions, both government agencies and private organizations, have joined these efforts. The Ministry of Agriculture, especially through the Mediterranean fruit fly control and eradication program, incorporated meliponiculture into its social extension activities, as part of the beekeeping module.[115] Also, the National System of Protected Areas -*Consejo Nacional de Áreas Protegidas* (CONAP)- has contributed to biodiversity and public education initiatives related to these bees.

Over the last 25 years, the visibility of stingless bees in Guatemala has increased noticeably, and this is in large part due to the sustained work coming from the Universidad de San Carlos. Their research, outreach, and technical training programs have consistently brought Meliponini into public discussion, generating interest among local communities, policymakers, government agencies and private organizations. Their resemblance to the familiar honey bee, *Apis mellifera*, has helped the general public quickly link them to ecosystem services such as pollination and honey production. The improvement in public acceptance and conservation actions also stems from the biocultural appeal of stingless bees: people perceive them as gentle, harmless and culturally meaningful, and their condition as native species is especially valued because of their association with traditions of medicinal honey and family protection. These qualities make conservation efforts feel intuitive, relatable, and relevant to Guatemalan identity. Taken together, this indicates that meliponiculture cannot simply replicate the apiculture model: stingless bees embody a strong biocultural identity, and their management and conservation require approaches that integrate cultural, ecological, and social dimensions.

The protected-area agency -CONAP- has formally adhered to the use of global open biodiversity databases such as GBIF,[116] recognizing their importance as essential tools for modern conservation planning. However, records of Meliponini, especially those published by Guatemalan institutions, are still scarce in these platforms. Strengthening national participation and increasing the availability of high-quality data will be crucial for identifying priority species and areas that need biodiverity protection.

In 2025, the first version of a "National Strategy for the Conservation and Sustainable Use of Native Stingless Bees in Guatemala" was released.[117] Although it has not yet been officially launched, the document reflects a structured and collaborative effort to secure the future of these species. Its development involved the Universidad de San Carlos, several government institutions, including the protected area agency, meliponiculturists, and private organizations. The strategy represents the country's first coordinated national framework aimed at promoting meliponiculture, protecting native species, and integrating cultural and social values into conservation planning.

6.4 Legal and conservation framework for stingless bees in Tanzania

Stingless bees are highly regarded in Tanzania as a unique resource, contributing to income generation, pollination services, aesthetics (tourism) and biodiversity. The honey produced by stingless bees has long been appreciated for its distinct flavor and medicinal properties.[118] Eleven species of stingless bees have been documented in Tanzania, representing seven genera of *Axestotrigona*, *Hypotrigona*, *Plebeina*, *Meliplebeia*, *Dactylurina*, *Plebeiella*, and *Liotrigona*.[119] Among these, only few species in the genera *Axestotrigona* and *Hypotrigona* are actively managed for honey production (Mduda et al. 2025).[119] However, the utilization of stingless bee resources in the country raises sustainability concerns, particularly due to the reliance of wild stingless bee colonies for stocking managed hives and honey hunting practices that persist in some regions.[118] Nonetheless, national policies and legislations recognize the importance of conserving these species, and effective implementation of these frameworks will be critical for ensuring their long-term sustainability.

6.4.1 Policies and legislations relevant to stingless bee conservation in Tanzania

In Tanzania, there are various legal and policy frameworks that govern the management of natural resources, and which directly or indirectly promote conservation of bees, including stingless bees. These include the National Beekeeping Policy, Beekeeping Act, Forest Act, Wildlife Conservation Act, and Guidelines for Management and Use of Honeybee Colonies for Pollination Services.

6.4.2 National Beekeeping Policy

The current National Beekeeping Policy of Tanzania was published in 1998 and it encompasses both stinging honey bees and stingless bees, including wild and domesticated colonies (URT, 1998).[120] The policy highlights the uniqueness of stingless bees due to their medicinal honey, and emphasizes the need for conservation of both types of bees amidst emerging threats such as pesticide poisoning, habitat destruction, and land clearing for agricultural expansion and industry development. One of the key policy objectives is to establish bee reserves, including for rare stingless bee species, to enable sustainable management of these species. The policy mandates joint management agreements between government and communities to ensure sustainable management of these bee reserves as breeding grounds for honey bees and stingless bees, and favorable areas for bee product production. Moreover, the policy advocates for environmental considerations to reduce risks which threaten stingless bees by requiring Environmental Impact Assessments (EIA) for projects near bee reserves to prevent habitat degradation, and promoting Integrated Pest Management (IPM) to minimize pesticide exposure.

6.4.3 Bee Keeping Act

The Bee Keeping Act of 2002 (URT, 2002)[121] corroborates with the National Beekeeping Policy by promoting sustainable management and conservation of wild and domesticated bees, including stingless bees, through bee reserves. It delivers the mechanisms for establishing, managing, and protecting these reserves, and identifies prohibited activities to avoid disturbance or destruction of bee habitats. Additionally, the Act regulates trade related to bees and their products including importation, registration, and restrictions to control bee diseases and pests threatening bee populations. Furthermore, The Act mandates environmental impact assessments prior for developments near bee reserves to protect bee populations or habitats from planned activities. It also establishes the Beekeeping Development Fund, currently known as Tanzania Forest Fund (TaFF), which supports research and training, indirectly benefiting stingless bee conservation through sectoral capacity building and awareness creation. Amendment of this Act published in 2023 (URT, 2023a)[122] establish requirements for registration of pollination service providers, and importers and traders of bee products and beekeeping equipment thereby promoting sustainable and responsible practices in stingless bee utilization.

6.4.4 Forest Act and Wildlife Conservation Act

The Forest Act of 2023 (URT, 2023b)[123] and Wildlife Conservation Act of 2022 (URT, 2022) [124] both clearly recognizes bee ecosystems as targets for conservation under national laws. The Forest Act fosters biodiversity conservation within forest ecosystems which are the primary stingless bee breeding grounds through establishment and management of forest reserves from national to village levels. The Act promotes community involvement in forest management which supports protection of bee habitats through sustainable utilization and local stewardship.

The Wildlife Conservation Act places the bee ecosystems and related resources under the custody of a specialized paramilitary service which governs their conservation, management and utilization. Consequently, the Tanzania Forest Services Agency (TFS) converted into a paramilitary service under the Ministry of Natural Resources and Tourism which oversees the development and sustainable management of forest and bee resources. Additionally, TFS has legal powers to prevent, detain and investigate any crime related to forest and bee ecosystems and resources, creating a direct enforcement mechanism for the protection of stingless bee habitats.

The Forest and Wildlife Conservation Acts mandate environmental and wildlife impact assessments before approval and establishment of projects that are likely to affect forest and wildlife species, communities or habitats. This applies to projects involving logging, agricultural expansion, infrastructure development and mining which may affect stingless bee nesting sites.

6.4.5 Guidelines for management and use of honeybee colonies for pollination services

These guidelines that cover both honey bees and stingless bees emphasize on conservation by integrating necessary safety measures during provision of pollination services in order to protect bee colonies by avoiding diseases and pesticide exposure (MNRT, 2022).[125] The guidelines also require pollination service providers to be legally registered to ensure responsible and sustainable practices.

6.5 Conservation of stingless bees in Costa Rica

A National Federation for Conservation (FECON) was created in Costa Rica 40 years ago. Ongoing proposals for conservation of bees wait for approval. We must recognize that bees are diverse, not just the European honey bee *Apis mellifera*, and that we must protect them and take advantage of their contributions without harming their populations. Conserving bee diversity means protecting native bees (including stingless bees, Meliponini) as well as other wild and solitary bees, protecting their habitats (native flowers, natural cavities, soils) and avoiding pesticides and diseases. Conserving means maintaining genetic and ecological diversity to ensure that they continue to play their fundamental role in pollination and ecosystem balance, and preserving the active biomolecules for medicinal uses.[126-128] It is important to use them fairly and equitably. This refers to how we take advantage of the benefits that these bees generate. For example, pollination which enables agriculture and food production. Pot-honey, pot-pollen, cerumen, and propolis from the stingless bee nest. The traditional knowledge of communities that manage meliponines. Stingless bee keepers who conserve bees and their habitats receive real benefits (income, recognition, participation). The participation of farmers, indigenous communities, meliponiculture practitioners, and scientists in decision-making is promoted. In summary, conserving and using bee diversity in a fair and equitable manner means protecting both bees and their habitats and ensuring that the benefits of their existence and management are distributed in a responsible, ethical, and sustainable manner.

On the other hand, Costa Rica is very strict about collecting bees, and permits to export them take a while. There is a National Commission for Biodiversity Management, in Spanish *Comisión Nacional para la Gestión de la Biodiversidad* (CONAGEBIO),[129] which is the permit office for samples that will be used for genetic analyses. The obligations of CONAGEBIO[129] are primarily focused on the development of national policies pertaining to the conservation and sustainable utilization of biodiversity, as well as issues related to education, public awareness, research, and the transfer of technology. It serves as the authoritative entity responsible for establishing and overseeing adherence to regulations governing access to genetic and biochemical resources, regarded as assets within the public domain, thereby ensuring the preservation, conservation, and restoration of traditional knowledge linked to the utilization of biodiversity elements, framed in the Biodiversity Law of the Ministry of Agriculture and Livestock since 1998.[130]

There are many causes that are affecting the biodiversity of different species of flora and fauna, but the fragmentation and loss of habitat is one of the main ones. Therefore, preservation, restoration, and connectivity of the different natural landscapes is one of the main challenges for the conservation of natural areas. Biological corridors arise from the needs to connect the different protected areas that were becoming islands, affecting the mobility of species (Morera et al. 2021).[131] The use of stingless bees as indicators of connectivity in biological corridors is a valuable tool for the conservation and sustainable management of ecosystems, as it allows us to understand and mitigate the effects of habitat fragmentation and ensure the preservation of biodiversity (Reyes-Novelo et al. 2009).[132]

6.6 Experience of El Salvador in Stingless Bee's Conservation of Biodiversity

At present, El Salvador does not have a comprehensive unified national Biodiversity Law specifically dedicated to the conservation, sustainable use, and restoration of biological diversity. Although several legal instruments exist — including the Environmental Law (*Ley de Medio Ambiente*, 1998),[133] the Protected Natural Areas Law (*Ley de Áreas Naturales Protegidas*, 2005),[134] and provisions related to forest and wildlife management —

these frameworks remain sectoral and fragmented, addressing biodiversity concerns in a dispersed manner rather than through an integrated, cohesive legal system. As a result, many native species and ecosystems lack comprehensive institutional safeguards.

In this context of limited formal protection, the CREVAS–JICA–UES Project has been working to safeguard the biodiversity of native stingless bees (Meliponini), which represent both ecologically essential pollinators and culturally significant species in Mesoamerica. Our approach combines scientific research, community-based management, environmental education, and territorial regeneration.

6.6.1 Key contributions of the CREVAS Project

• Strengthening community-led meliponiculture initiatives for species such as *Melipona beecheii* and *Tetragonisca angustula*, supporting biodiversity conservation, women and youth participation, and sustainable rural livelihoods.
• Developing improved hive systems and establishing a Meliponini (Stingless Bee) Colony Regeneration Center, contributing to species recovery, monitoring, and resilience against environmental threats; and ensuring the establishment of nurseries for native melliferous plants, through which seedlings are produced and distributed free of charge to restore habitats, expand forage availability, and reinforce local ecological networks.
• Promoting co-creation–based technical innovation, including improved hive technologies (e.g., INPA-style boxes), collaborative quality control and traceability, and the development of new stingless-bee-derived products.
• Training programs for farmers, students, technicians, and local residents, fostering mutual learning, knowledge transfer, entrepreneurship, and long-term stewardship of native pollinators.
• Environmental education programs co-created with schools, universities, botanical gardens, and local communities, cultivating a conservation-oriented culture and strengthening territorial pride and identity.
• Publication of an illustrated children's book (García Rodríguez and Kimura, 2025),[135] co-created to introduce young audiences to the world of stingless bees, integrating traditional knowledge with scientific understanding and nurturing future environmental leaders.
• Installation of bee hotels in botanical gardens, primary schools, and public parks, contributing to ecological corridor formation and providing hands-on learning environments for children and local residents.
• Building a collaborative territorial platform that brings together producers, universities, public institutions, private companies, and civil society to integrate biodiversity conservation with local development strategies—aligned with CREVAS's three pillars: 1. Territorial value creation, 2. Co-developed economic models, and 3. Embedding knowledge and technology in the territory.
• Through these combined efforts, the project demonstrates that value is not extracted from nature but co-created with it, and that meliponiculture can serve as a flagship territorial strategy in El Salvador—not for profit, but as part of our responsibility to the Earth.

This work highlights the experience of the JICA–UES CREVAS Project as a model of biodiversity conservation in a country where national biodiversity legislation remains limited. In addition, to advancing scientific understanding of native stingless bees, the project emphasizes that developing mission-driven, community-based enterprises is essential for addressing social challenges while promoting environmental stewardship.

These efforts reflect the core mission of the project and our shared responsibility to the planet, recognizing that long-term conservation is possible only when it is linked to sustainable livelihoods and locally rooted economic opportunities.

Through co-created initiatives—such as producer training, improved hive technologies, territorial education programs, and the development of a children's book, the project supports community actors in integrating biodiversity protection with value-added economic activities. This holistic perspective provides an important foundation for community-led conservation models in El Salvador and beyond.

6.6.2 Conclusions JICA–UES CREVAS Project

This project is being implemented within the framework of the JICA technical cooperation project, a joint initiative between the Japan International Cooperation Agency (JICA) and the University of El Salvador (Universidad de El Salvador, UES), the country's largest and oldest public university. CREVAS is the Spanish acronym for *Creando Valor Agregado para El Salvador*, translated as Creating Added Value for El Salvador. The technical cooperation project aims to strengthen agro-industrial value chains and promote biodiversity conservation through research, capacity development, and community-based innovation.

Within this collaborative structure, CREVAS places particular emphasis on the conservation and sustainable management of native stingless bees (Meliponini). Activities being implemented include ecological monitoring, development of improved hive technologies, the establishment of a Bee Colony Regeneration Center, and training programs for producers, students, and local community organizations.

The project also integrates environmental education—such as co-created curricula with schools and universities and the publication of an illustrated children's book on stingless bees—to foster long-term biodiversity stewardship at the territorial level. These combined efforts provide an important foundation for understanding and demonstrating community-based conservation models in a country where comprehensive biodiversity legislation remains limited. The project is being implemented over a five-year period, from August 2021 to August 2026.

6.7 Ecuador has the highest density of stingless bee biodiversity

With 200 stingless bee species (P. Vit and D.W. Roubik, personal observations) in a small country of 283,561 km^2, Ecuador hosts the highest density of stingless bees. Ecuador has two environmental codices to protect biodiversity, an Organic Codex of the Environment *Código Orgánico del Ambiente* (2017)[136] and a Regulaion of the Organic Codex of the Environment *Reglamento al Código Orgánico del Ambiente* (2019).[137]There is ancestral knowledge of stingless bee keeping in evey province except Galapagos, and the meliponine nest was considered the first pharmacy of Ecuadorian ancestors (S. Loayza, during the 2025 Scienific Encounter of Stingless Bees in his Meliponario Nativa).[138] The *Ministerio del Ambiente, Aguas y Transicion Ecologica* (MAATE) Ministry of Environment, Water and Ecological Transition was invited for a talk on biodiversity conservation, but instead, a commission came calling the stingless bee keeper and the stingless bee scientist trafficking wild fauna, threatening to close the international event with more than 100 participants, including students of three local schools. It was explained that according to UNESCO, an established stingless bee apiary like Meliponario Nativa, protects the biodiversity of stingless bees, promotes traditional and scientific knowledge, empowers women, showing a non-timber productive option in tropical forests[139] as evidenced by frequent meetings organized to praise stingless bees, and practice sustainable meliponiculture.

Considering that the environment is an Ambient Ministry matter, stingless bee keeping is an Agriculture and Livestock Ministry matter, and medicinal research is a matter of a Health Ministry and a Science and Technology Ministry, all these government agencies should optimize joint efforts in a *One Biodiversity* vision and action to benefit the *One Health* concept.

6.8 Biodiversity and stingless bees' conservation in Brazil, the country with most species

Brazil is the 5th largest country in the world, with 8,516,000 km^2, occupying about 48% of the entire territorial area of South America. It is also one of the most diverse countries in vegetation formations, such as the enormous Amazon Rainforest, 60% of which is in Brazilian territory, the Atlantic Forest, which runs along the coast; and important formations such as the Araucaria Forest and the *Mata dos Cocais*, in addition to parts of other biomes such as the *Cerrado* and the *Caatinga*, which have trees and more open formations, totaling six major biomes: Amazon, Cerrado, Atlantic Forest, Caatinga, Pantanal, and Pampa.[140] As a consequence, Brazilian biodiversity is one of the richest on the planet, harboring about 20% of all known species in the world, including 1,965 cataloged bee species, among them more than 250 species of stingless bees,[14] among the about 500 Neotropical, and 605 global species estimated in 2023.[2]

6.8.1 Brazilian laws on environmental protection and biodiversity

Brazilian biodiversity, however, faces challenges such as habitat loss, invasive species, overexploitation of resources, and climate change.[141-144] Thus, the country has federal agencies that are part of the National Environmental System (SISNAMA) and have distinct but complementary roles in Brazilian environmental management: CONAMA (National Environmental Council), which is a collegiate, consultative, and deliberative body that establishes norms, criteria, and guidelines for the country's environmental policy; IBAMA (Brazilian Institute of the Environment and Renewable Natural Resources), a federal agency responsible for the execution and oversight of environmental policy at the national level, exercising environmental police power; and the Chico Mendes Institute for Biodiversity Conservation (ICMBio), a federal agency created specifically to manage and protect federal Conservation Units (UCs) and promote research and conservation of biodiversity.

These institutions operate based on federal specific laws, decrees, and regulations that govern the protection of the environment and biodiversity (Law No. 6,938/1981 - National Environmental Policy);[145] created the National System of Conservation Units, aiming to protect natural areas of ecological importance (Law No. 9,985/2000 - SNUC);[146] protect the Atlantic Forest, one of the most threatened biomes in the country (Law No. 11,428/2006 - Atlantic Forest Law);[147] established rules for the protection of native vegetation, determining percentages of native forest that cannot be deforested on each rural property, varying according to the biome (Law No. 12,651/2012 - Forest Code)[148] and set the administrative infractions and sanctions related to the environment (Decree No. 6,514/2008, detailing the federal process for investigating these infractions, according to Law No. 9,605/98 - Environmental Crimes Law).[149,150] These laws, although seeking the protection of biodiversity as a whole, have a great impact on stingless bees, since they are totally dependent on the conservation of the habitats in which they live to nest, find food, protect themselves from predators, and reproduce.

6.8.2 Brazilian legislation on stingless bees

Biodiversity conservation is a crucial issue in Brazil, especially when it comes to stingless bees. These bees are fundamental for the pollination of various native wild and cultivated plants, contributing significantly to biodiversity and the economy at both local and national levels.

An important law for stingless bees in Brazil is No. 8.171/1991, known as the Agricultural Policy Law.[151] It mandates that agricultural policy should encourage the recovery and rational management of natural resources, as well as the preservation of the environment. It provides the basis for sustainable agriculture and livestock farming, which indirectly supports the conservation of native bees, but operational and protection standards are detailed in specific environmental and regional legislation.

Specifically, regarding stingless bees, Brazilian legislation is relatively recent and aims to promote the conservation and sustainable use of the many species native to the country, and especially those selected by stingless bee keepers for meliponiculture. Some of the main regulations include:

- The Decree No. 5,741/2006 - Regulates the Unified System for Attention to Agricultural Health (SUASA),[152] which organizes the actions of surveillance and sanitary defense of animals and plants in Brazil. The relationship of this decree with stingless bees (meliponiculture) lies mainly in the inspection and health requirements for the commercialization of their products.

- The CONAMA Resolution No. 496/2020:[153] Disciplines the sustainable use and management of native stingless bees in meliponiculture - CONAMA Resolution No. 496/2020 is the main Brazilian legal framework that regulates the sustainable use and management of native stingless bees (meliponiculture), establishing guidelines for modern stingless bee keepers and differentiating the activity from traditional stingless bee keeping, with clearer rules for obtaining colonies, commercialization of products and the need for environmental authorization (or simplified registration) for different sizes of meliponaries, aiming at the conservation of species and ecological balance.

- The ICMBio Ordinance No. 665/2021[154] – Establishes the National Catalog of Native Stingless Bees, which indicates the states of the federation where the species of bees of the Meliponini tribe naturally occur in Brazil. It determines that the breeding of native stingless bees is restricted to the geographical region of natural occurrence of the species, according to this Catalog, as determined in Article 7 of CONAMA Resolution No. 496/2020. In addition to federal laws, decrees, resolutions, and ordinances, several Brazilian states have specific legislation regulating meliponiculture, complementing federal legislation, especially CONAMA Resolution No. 496/2020.[155-157]

Although legislation on the conservation and sustainable use of stingless bees has advanced in Brazil in recent decades, the country's vast size, diversity of species and ecosystems, differing interests of meliponiculturists, and bureaucratic procedures have hindered greater and faster progress. Regulation and awareness of the importance of conserving stingless bees are fundamental to ensuring their survival and sustainable use. To this end, it is necessary to strengthen oversight, awareness campaigns, and cooperation among municipal, state, and federal governments, civil society, and the private sector to protect stingless bees in Brazil.

7. Conservation of biodiversity and biocultural knowledge

According to Locey and Lennon (2016),[158] overarching biodiversity theories and rank among biology's most powerful predictive tools is the backbone of scaling laws. Yet rules established for plants and animals are seldom tested on microbes—and often don't hold up. Consequently, it remains uncertain whether biodiversity's scaling laws extend across evolutionarily distant life domains, encompassing every metabolic strategy and scale of abundance. Microbial diversity transcends earlier expectations across all microbiome sizes—from the tiniest to the most expansive—unfolding in consistently predictable patterns.[158]

The United Nations Quadripartite—FAO, UNEP, WHO, and WOAH[159]—has devised a comprehensive blueprint for confronting global health challenges at the convergence of human, animal, plant, and environmental systems, named the One Health Joint Plan of Action (2022–2026) using the acronym OHJPA[159].The concept and new challenges of microbiome were revisited.[160] Microbiomes encompass bacteria, archaea, fungi, diverse microeukaryotes, and viruses that reside in multiple hosts and environments, where their varied compositions and metabolic adaptability underpin essential biological processes.[159,160] The exclusion of microbiomes from global health strategies underscores the field's relative infancy, despite its essential role in meeting OHJPA objectives. Microbiomes drive vital processes—nutrient cycling, pathogen suppression, antimicrobial-resistance management, human health, and environmental resilience—making their integration indispensable for success. Therefore, microbiome should be wisely included in the OHJPA, human, animal, plant, environment and microbiome systems, as suggested this year[161], and highlighted here considering One Biodiversity for stingless bees.

The biocultural knowledge also needs conservation. In Asia, diverse species of stingless bees share the same name, e.g. Channarong in Thailand, Kelulut in Malaysia and some regions of Indonesia. In the Neotropics is different, one species of stingless bees is named differently according to the location, and habitat. For example, the most widespread Neotropical *Tetragonisca angustula* is mostly named Angelita in Colombia, Ecuador, and Venezuela; Chumelo in El Salvador, Jataí in Brazil, Mariola in Costa Rica and Nicaragua, Ramichi in Peru, Señorita in Bolivia, and Yatei in Paraguay. This richness of ethnic names for stingless bees further expands with the diverse cultures of native people, as –presented in Table 9 and illustrated in Fig. 11 for Bolivia–

Table 9. List of stingless bees from Bolivia having ethnic names in Spanish and/or some of the seven indigenous languages

Stingless Bees								
Scientific taxa	Languages of ethnic names							
	Spanish	Quechua	Tacana	Yuracaré	Sirionó	Yuqui	Guaraní (Tupí o Ava)	Monkox Chiquitano
Paratrigona Schwarz, 1938	Norita	Ilinchupa	–	–	–	–	–	–
Partamona ailyae Camargo, 1980	Burro, Burrito	–	–	–	Ibi rôquî	Eruchimbé	Aruyabá	–
Partamona vicina Camargo, 1980	–	–	–	–	–	–	Sarquita	Mesupurabo
Oxytrigona Cockerell, 1917	Cagafuego	Chakalari	–	–	–	–	Sañaro, Sicaé	Noborirox

Stingless Bees								
Scientific taxa	Languages of ethnic names							
	Spanish	Quechua	Tacana	Yuracaré	Sirionó	Yuqui	Guaraní (Tupí o Ava)	Monkox Chiquitano
Scaptotrigona bipunctata (Lepeletier, 1836)	–	–	Eire debe	–	–	–	Jobobosi	–
Scaptotrigona polysticta Moure, 1950	Hallpa negra	–	–	Bussa	Irao Rete	–	Suro, Obobosí, Jovovosí	Nomesinanax
Scaptotrigona depilis (Moure, 1942)	Negro, Negrillo	Ch'iru	Didi macho	Bussa Wosso	Tisua	–	Obobosi, Bobosi,	Patakiyaukux
Scaptotrigona nigrohirta Nogueira and Santos-Silva 2022	–	–	–	–	–	Tisoa	–	–
Scaptotrigona postica (Latreille, 1807)	Negra	Ch'iru	Tumija thuani	–	Tisua	–	Jobobosi, Obobosi	–
Scaptotrigona xanthotricha Moure, 1950	–	–	–	Maparre	–	–	–	–
Geotrigona Moure, 1943	–	–	Cuatiuasha Sicae	–	–	–	–	–
Ptilotrigona lurida (Smith, 1854)	–	–	–	Siwilo	Abura	–	–	–
Tetragona clavipes (Fabricius, 1804)	Señora, Bora negra	–	–	Ssawayu	–	Isabarí	Bora	Paxaibikiox
Tetragona goettei (Friese, 1900)	Bora amarilla	–	–	–	Abura	Eracõquichaé	–	Paxaibikiox
Trigona pallens (Fabricius, 1798)	–	–	Tua dagua	–	–	–	–	–
Trigona fuscipennis Friese, 1900	–	–	–	–	–	Quigüejuá	–	–
Trigona hypogea Silvestri, 1902	Sombra sucha de palo	Ch'iru	–	–	–	Yojorembé	–	Nuxiukax
Trigona dallatorreana Friese, 1900	–	–	–	–	–	–	Sicaé	–
Trigona branneri Cockerell, 1912	–	Macho Huata	–	–	Irao jua Sicharô	–	Topoé	–
Trigona silvestriana (Vachal, 1908)	–	–	–	–	–	Chiichiiyá, Eruguasué	–	–
Trigona recursa Smith, 1863	–	–	–	–	–	–	–	Jovovosi, Penoqui
Cephalotrigona capitata (Smith, 1854)	Burra	–	Paubade	–	Oro, Erisha	–	–	Numakayux
Tetragonisca angustula (Latreille, 1811)	Señorita	–	–	Pichinewe	–	Yiti	Yatei	–
Tetragonisca fiebrigi (Schwarz, 1938)	Señorita	–	–	–	–	–	Yatei	Nomesanama
Tetragonisca weyrauchi (Schwarz, 1943)	Abeja perico	–	–	Yaya	–	–	–	–
Frieseomelitta Ihering, 1912	Mermelada	–	–	–	–	–	–	–
Plebeia Schwarz, 1938	Sapito, Boca de sapo	–	–	–	Chiarô sequîtubie	–	–	–
Plebeia alvarengai Moure, 1994	–	Chojñiri	–	–	–	–	Parabita	Nomosinoma
Plebeia peruvicola Moure, 1994	–	–	–	–	–	–	Parabita	–
Plebeia droryana (Friese, 1900)	Boca de vieja	–	–	–	Nyichi	–	–	Nausupux

Stingless Bees								
Scientific taxa	Languages of ethnic names							
	Spanish	Quechua	Tacana	Yuracaré	Sirionó	Yuqui	Guaraní (Tupí o Ava)	Monkox Chiquitano
Lestrimelitta rufipes (Friese, 1903) *Lestrimelitta rufa* (Friese, 1903)	Abeja limon, Burro	–	–	–	Ira Ÿosa Iseî	–	Oresepeó, Cayasan	Noborisepes
Nannotrigona melanocera (Schwarz, 1938)	Negrita, Señorita negra	–	–	–	Chiaro sokï tubie	–	–	–
Scaura latitarsis (Friese, 1900)	Lame ojo grande	Waka ñuñu	–	–	–	Eriquiorubí	–	–
Melipona quinquefasciata Lepeletier, 1836	–	–	–	–	Sucuasue	–	–	–
Melipona tumupasae Schwarz, 1932	–	–	–	–	–	–	Ereréu orito	–
Melipona grandis Guérin, 1844	–	–	Biua uanu	–	–	Erubususã	Ereréu de los bayos o barcina	–
Melipona brachychaeta Moure, 1950	Tancarillo	–	–	Choromo	–	–	Moro Moro	–
Melipona crinite Moure et Kerr, 1950	–	–	–	Bashti	–	–	–	–
Melipona eburnea Friese, 1900	–	–	–	Shepeste	–	–	–	–
Melipona flavolineata Friese, 1900	–	–	Ekuna uanu uanu	–	–	Quigüeguá	–	–
Melipona nebulosa *Camargo, 1988*	–	–	–	–	–	–	Ereréu marimono	–
Melipona rufescens Friese, 1900	–	–	–	–	Nyocoishii	–	–	–
Melipona rufiventris Lepeletier, 1836	–	–	Moro moro	–	Sucuasue	Quigüeté	Ereréu choca	Nopemox
Melipona fuliginosa Lepeletier, 1836	–	–	–	–	Sucuasue	–	Ereréu negra	–
Trigonisca Moure, 1950	Lame ojo chica, Lagañera	–	–	–	–	–	–	Nusutasi

Sources: Spanish,[83,95] Quechua,[103] Tacana [82], Yuracaré,[84] Sirionó,[75,103] Yuqui,[10] Guaraní,[103] Monkox Chiquitano,[71,80,103]
Author: AA Céspedes-Llave

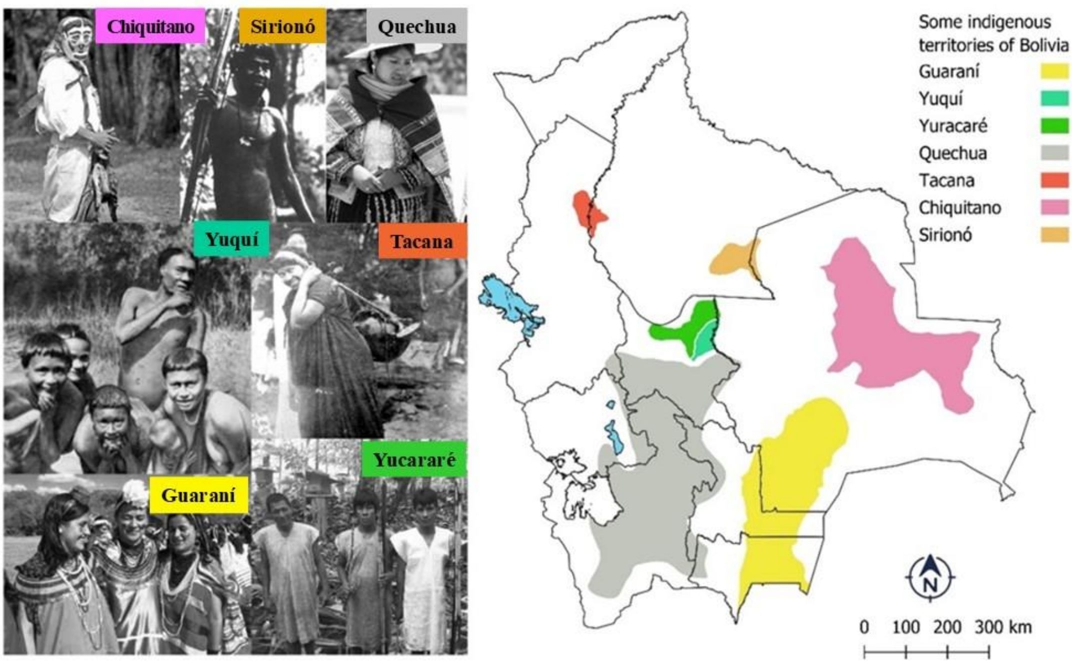

Fig. 11. Selected indigenous territories of Bolivia where meliponiculture is practiced

The map was modified from Rojk (2006)[162] and Rodriguez (2007)[163]. Images of native people available under Creative Commons Attribution-ShareAlike license 4.0 International (CC BY-SA 4.0) and GNU Free Documentation License on Wikipedia include: Quechua (Yves Picq, 2010)[164] and Tacana (in Cordoba, 2015)[165]. Yuquí (Mbyá Yuki) and Sirionó (Wegner, 1936)[166]; and Chiquitano (APCOB, 2025).[79] Images reproduced with permission of the authors include: Guaraní (Villarroel, 2016) ;[167] and Yuracaré (Pinto, 2022).[168]

8. Bees you can see and taste

Microbes are too small to see and we don't really know where the bees get them, but we suppose it's in flowers. Such a vital part of this equation still goes largely without study. One of the main reasons that stingless bees "SBs" are popular is that they don't have a functional sting, but as any stingless bee keeper knows, we need protection when we work with them because they bite and they get after you in ways that can't be ignored. It's also a fact that most of these stingless bee species have honey that doesn't particularly taste that good but it is free and also better than going to the pharmacy and paying for a remedy that may not work the way we would like it to. At least with the bee products they're largely innocuous, and they may be beneficial, but they are certainly economically preferable to many of the options in our modern world. If we can look and see the basis for some positive action by these same little creatures, it would be the plants that need pollinators. And flowers, as already mentioned, supply the floral hubs whereby pollinating bees obtain some of their valuable mutualists of the microbial world. Of course, regarding pollination, stingless bees don't do the job the best way, for there are bigger bees living in the wild, and they do a lot more pollinating. Perhaps one day we will learn to appreciate them too. *Clinical stingless bee honeys may surprise us.*

In this article written 25 years ago, revaluing meliponiculture in Latin America was based on the worldview of *taking care of tame bees to protect forests.*[169] The central idea highlights traditional management and respect for stingless bees as natural and cultural native people heritage. The author emphasizes that meliponiculture is not just honey production, but a sustainable system that links environmental care with production. It is based on the need to conserve these species in the face of threats such as deforestation and the use of pesticides. It seeks to position meliponines and their products (pot-honey, pot-pollen, cerumen, and propolis) as valuable resources, promoting their management in tropical regions. The importance of education and recognition of traditional knowledge is valued to guarantee the survival of these bees.

The remarkable diversity of stingless bees calls for greater consumer vigilance to safeguard genuine pot-honey from counterfeit versions—such as *Apis mellifera* honey or sugar-based substitutes—offered at lower prices. In many tropical countries, where pot-honey production predominates, labeling regulations remain scarce. Educated consumers from ropical and non-tropical counries like Spain[173], stand to benefit from the honey's medicinal uses and protect their entomological origin. Moreover, should therapeutic properties be confirmed for honey produced by certain stingless bee species and habitats, consumers need to become familiar with its sensory characteristics to accurately connect the insect origin with the claimed remedy.[173]

Conclusions and a glance of UNESCO support for biodiversity conservation in future

Our first bibliometric study on conservation of stingless bees (2000–2025) provided minute and broad details on the topic. Biodiversity of stingless bees was reviewed for potential roles in bioactive components of materials of the nest pot-honey, pot-pollen, cerumen, and propolis, and derived therapeutic uses. Additionally, microbiome research supports conservation of stingless bee species by identifying factors that promote health and adaptability, especially under environmental stress and habitat loss. The practical relevance of stingless bee microbiome research spans agriculture, food safety, medicine, and conservation. Harnessing microbial diversity and function can improve colony management and product value, while supporting ecosystem services, enhancing medicinal applications and conservation of one biodiversity. Legislation protecting stingless bees was revised for at least one country in each tropical continent: Africa (Tanzania), America (Bolivia, Brazil, Costa Rica, Ecuador, El Salvador, and Guatemala), and Asia (the Philippines). Australia from Oceania has no biodiversity legislation for conservation of stingless bees –like most of the tropical countries– and Brazil is leading on these legal initiatives.

P. Vit needs to declare UNESCO proactive appraisal of stingless bee keepers as protectors of biodiversity conservation is beneficial in a tropical world of inadequate assessment insufficient to perceive that role, and prone to discredit functions of stingless bee keepers and scientists as *trafficking wild fauna*. Hope the *Ministerio del Ambiente, Agua y Transición Ecológica* from Ecuador will learn the ancestral knowledge of their country, and perhaps bring a stingless bee colony to schools as one model to take care of nature, learn the art of responsible meliponiculture, and especially nurturing protection of biodiversity of stingless bee conservationists for future generations.

Celebrating first insect legal rights of stingless bees in the Peruvian Amazon

A final note during production of this article to inform a key achievement for stingless bee conservation reported in The Guardian.[174] Awareness on challenges posed to stingless bees by climate change, deforestation, pesticides, and microplastics, as well as competition against European and Africanized honey bees, was advocated by Rosa Vásquez Espinoza, founder of Amazon Research Internacional (ARI), the Earth Law Center (ELC), and the International Union for the Conservation of Nature (IUCN). After their campaign, the first global ordinances of two Peruvian Municipalities, Satipo in the Avireri Vraem reserve, and Nauta in the Loreto region; were approved in October and December 2025 respectively.[174] This is a motivation for other municipalities and countries, to protect their stingless bee pollinators, their biodiversity, the ecosystems, and the precious materials of their nests used for nutritional, medicinal, and artistic purposes. Peru has about 170 species of stingkess bees (C. Rasmussen, personal communication). It is a great honor, stingless bees from Peru will inspire legal protection of other stingless bees of the world. A visionary action to protect stingless bee nest materials including functions of microbiome associated with stingless bees.

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