frontiers in Bee Science

TYPE Systematic Review
PUBLISHED 29 July 2026
DOI 10.3389/frbee.2026.1904918

OPEN ACCESS

EDITED BY
Jose Octavio Macias-Macias,
University of Guadalajara, Mexico

REVIEWED BY
Nuria Torrescano,
El Colegio de la Frontera Sur, Mexico
Carla Ghiglione,
National Scientific and Technical Research Council (CONICET), Argentina

*CORRESPONDENCE
José Américo Saucedo-Uriarte
jose.saucedo@untrm.edu.pe

RECEIVED 09 June 2026
REVISED 08 July 2026
ACCEPTED 13 July 2026
PUBLISHED 29 July 2026

CITATION
Ruiz-Llontop D, Paucar Y, Bardales W and Saucedo-Uriarte JA (2026) *Apis mellifera* bee: importance, challenges, and its impact on agriculture in Peru. *Front. Bee Sci.* 4:1904918. doi: 10.3389/frbee.2026.1904918

Apis mellifera bee: importance, challenges, and its impact on agriculture in Peru

Deysi Ruiz-Llontop[1], Ysai Paucar[2], William Bardales[3] and José Américo Saucedo-Uriarte[2,4*]

[1]Estación Experimental Agraria Vista Florida, Instituto Nacional de Innovación Agraria, Chiclayo, Peru, [2]Facultad de Ingeniería Zootecnista, Biotecnología, Agronegocios y Ciencia de Datos, Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Chachapoyas, Peru, [3]Instituto de Investigación en Ganadería y Biotecnología, Facultad de Ingeniería Zootecnista, Biotecnología, Agronegocios y Ciencia de Datos de la Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Chachapoyas, Peru, [4]Grupo de Investigación en Biodiversidad, Taxonomía y Genética de Abejas – GIBITAGE, Instituto de Investigación en Ganadería y Biotecnología, Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Chachapoyas, Peru

Bees are fundamental to the health of both natural ecosystems and agricultural systems, providing essential pollination services that support biodiversity and agriculture. In Peru, they play an important role in pollinating major agricultural crops such as coffee, blueberries, avocados, citrus fruits, and cacao, among others; at the same time, they help preserve biodiversity. However, bee populations in the country face significant threats, including habitat loss driven by deforestation and agricultural expansion, the spread of parasitic pests like *Varroa destructor*, pesticide exposure, and the effects of climate change. These stressors have profound implications for bee health, foraging efficiency, and reproductive success. This review synthesizes recent research on the state of bee populations and apiculture in Peru, drawing on a comprehensive dataset of 89 studies published between 1914 and 2024. It examines the key challenges facing Peruvian *A. mellifera* bee, including the impact of environmental stressors, the sustainability of beekeeping practices, and the regional distribution of research efforts. Additionally, the review explores the importance of grassland ecosystems as critical habitats for pollinators and their role in supporting agricultural productivity. The review identified significant knowledge gaps in Peru, including limited geographic coverage, insufficient understanding of pollination ecology and ecosystem services, and a lack of studies quantifying the economic value of pollination for agriculture. By identifying research gaps and proposing future directions, this article seeks to advocate for the adoption of sustainable agricultural practices in Peru to safeguard *A. mellifera*.

KEYWORDS
apiculture, Apis mellifera, beekeeping, biodiversity, ecosystem services, environmental sustainability

1 Introduction

Pollinators are important because they enable the production of crops and the development of wild plants, maintain the landscape, generate products for family farming, generate a fundamental ecosystem service, and contribute to the balance of the ecosystem with positive environmental, economic, and social effects (Mutavi et al., 2022; Yilmaz et al., 2023). Therefore, bees (*Apis mellifera* L.) are indispensable to the global ecosystem and agriculture, serving as primary pollinators for many plants essential for natural ecosystems and human food production (Kumar and Khan, 2023). The pollination service is vital for producing approximately one-third of the world's food crops and contributes significantly to agricultural economies worldwide (IPBES, 2016; Reddy et al., 2022).

The bees populations have experienced significant declines due to the combined effects of habitat loss and fragmentation, agrochemical exposure, pathogens, invasive species, and climate change. These factors threaten essential ecosystem services, including pollination, plant diversity, food security, and human well-being (Potts et al., 2010). In particular, honeybees have been increasingly exposed to agrochemicals associated with the reduction in floral resource availability and diversity, as well as to emerging parasites and pathogens unintentionally spread through human activities (Goulson et al., 2015). Additionally, the intensification of land use, climate change, and the spread of exotic species and diseases represent major drivers of pollinator decline, requiring improved management strategies for the establishment and sustainability of apiaries (Vanbergen and IPI, 2013).

In Peru, *Apis mellifera* populations face multiple interacting pressures that threaten colony sustainability and the development of apiculture. Habitat loss caused by deforestation and agricultural expansion reduces the availability of essential floral resources, limiting forage availability for bee colonies (MINAM, 2009; Rojas et al., 2021). Furthermore, the spread of pests, particularly the parasitic mite *V. destructor*, compromises colony health by increasing susceptibility to diseases (Airahuacho and Rubina, 2021). The intensive use of agricultural pesticides, especially organophosphates and carbamates, has also been associated with negative effects on bee health, including alterations in foraging behavior and reproductive performance (Montes et al., 2023; Chávez-Dulanto et al., 2024). Climate change represents an additional challenge, as changes in precipitation patterns and extreme climatic events modify flowering cycles and reduce nectar and pollen availability (Fernandez-Palomino et al., 2023; Chávez-Jiménez et al., 2024).

The interaction among environmental, sanitary, and climatic pressures generates an increasingly uncertain scenario for bee populations, with potential consequences for ecological balance and agricultural productivity. Therefore, strengthening sustainable management practices, sanitary monitoring, technological innovation, and research initiatives is essential for ensuring the long-term development of apiculture in Peru. In this context, Peruvian Law No. 32685 recognizes apiculture and pollination as strategic productive activities and establishes mechanisms aimed at addressing these challenges through the implementation of the National System of Apiculture and Pollination, as well as the promotion of research and support systems for producers (Congreso de la República del Perú, 2026).

This review aims to explore the key areas of research related to bee breeding and their significance in Peruvian ecosystems. Over the years, various studies have high-lighted the role of *A. mellifera* in pollination, food security, and environmental health, but significant knowledge gaps remain. By reviewing recent literature, this study provides a comprehensive overview of the state of research on *A. mellifera* in Peru, identifying the most pressing issues faced by these vital pollinators, and suggesting pathways for future research. Additionally, this review discusses the geographical distribution of bee studies in Peru and their relationship with the country's diverse ecosystems.

2 Materials and methods

2.1 Review protocol and reporting guidelines

This study was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA, 2020) guidelines. The review aimed to systematically identify, evaluate, and synthesize the available scientific evidence regarding bee diversity, pollination services, threats, apiculture, and agricultural importance in Peru.

The review process included four sequential stages: (i) literature identification, (ii) screening, (iii) eligibility assessment, and (iv) inclusion of studies for qualitative synthesis. A PRISMA flow diagram was used to document the study selection process.

2.2 Search strategy

A comprehensive literature search was conducted between January and March 2025 using international scientific databases and institutional repositories. The following databases were consulted: Scopus, Web of Science Core Collection, Google Scholar, Taylor & Francis Online, Latindex. In addition, institutional repositories from public universities, including Universidad Nacional Agraria La Molina, Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Universidad Nacional Pedro Ruiz Gallo, Universidad Nacional de Cajamarca, Universidad Nacional de la Amazonía Peruana, Universidad Nacional de Trujillo, and Universidad Nacional del Centro del Perú, were explored. Private universities such as Universidad Científica del Sur and Universidad Privada Antenor Orrego were also included in the search process.

The search strategy combined keywords related to bees, pollination, agriculture, biodiversity, and Peru using Boolean operators. The principal search string was: (pollination OR food security OR bees in Peru OR *Apis mellifera* in Peru OR bees OR *Apis mellifera*). AND (agriculture OR biodiversity OR apiculture OR ecosystem services). Additional searches incorporated specific terms such as: honey bees, pollination services, bee products, honey, propolis, beeswax, pollen, *V. destructor*. Searches were performed in English and Spanish to maximize retrieval of relevant literature.

2.3 Eligibility criteria

Studies were selected according to predefined inclusion and exclusion criteria.

Inclusion criteria

- Focused on bees, pollination, apiculture, bee products, bee health, biodiversity, or ecosystem services in Peru.
- Were published between 1914 and 2024.
- Included original research articles, short communications, technical reports with scientific data, and academic theses.
- Presented sufficient methodological information and clearly described study objectives and results.
- Were available in English or Spanish.

2.4 Exclusion criteria

- Did not focus on Peru.
- Addressed pollinators without specific information on *A. mellifera*.
- Consisted solely of conference abstracts, editorials, opinion articles, or nonscientific reports.
- Were duplicate records retrieved from multiple databases.
- Did not provide sufficient information for data extraction.

2.5 Study selection process

All references retrieved from databases and repositories were exported and independently reviewed by the authors. The study selection process consisted of three phases; in the first phase, studies were identified by reviewing titles and abstracts to identify potentially relevant studies. The second phase was the selection of studies; duplicate records were removed, and the remaining studies were evaluated based on their titles and abstracts, in accordance with the eligibility criteria. Finally, in the third phase, the eligibility assessment was conducted, which consisted of reviewing the full texts to determine their relevance and suitability for inclusion in the systematic review. Discrepancies regarding the inclusion of studies were resolved through discussion among the authors until a consensus was reached.

2.6 Data extraction

For each selected study, information was extracted on studies conducted in Peru, then the topics related to pollination, apiculture, bee products, bee health, biodiversity, or ecosystem services in Peru were identified.

Studies were subsequently classified into thematic categories according to their primary focus: Bee diversity and characterization, colony performance, feeding and nutrition, reproduction, bee health, honey production, beeswax, propolis, pollen, apiculture, and pollination services.

2.7 Data synthesis and analysis

Statistical analysis was performed using descriptive statistics. For the spatial representation of scientific output, the absolute frequencies of studies related to the research topic were calculated for each region of Peru. This information was used to create a thematic map that allowed visualization of the geographic distribution and concentration of research at the national level. Likewise, the most frequently used keywords in studies on *A. mellifera* in Peru were analyzed by calculating their frequencies of occurrence and represented graphically using a word cloud, where the size of each term was proportional to its frequency of use in the reviewed literature. This procedure was developed using the statistical software R version 4.5.1 (2025-06–13 UCRT), employing the wordcloud and RColorBrewer libraries for generating and customizing the graphic visualization.

3 Results

3.1 Study selection

The literature search identified studies from scientific databases and institutional repositories related to bees, pollination, apiculture, and bee products in Peru. Following the screening and eligibility assessment process, 89 studies published between 1914 and 2024 met the inclusion criteria and were included in the qualitative synthesis (Figure 1).

The selected studies comprised 29 (32.6%) peer-reviewed research articles, 3 (3.4%) short communications, and 56 (64%) academic theses (Figure 1). Given that most of the literature found consists of theses, the quality of these studies could lead to biased conclusions. The temporal distribution of publications revealed a notable increase in research activity during the last decade, reflecting growing scientific interest in pollinators, apiculture, and ecosystem services in Peru.

3.2 General characteristics of bee in Peru

The reviewed literature covered a broad range of topics associated with bee biology, apiculture, pollination services, and bee products. Eleven thematic categories were identified during data extraction (Table 1). Characterization and diversity studies represented one of the largest thematic groups, focusing on species identification, taxonomy, ecology, and distribution. Research on bee health, particularly studies related to *V. destructor*, constituted another important category. A substantial proportion of studies addressed bee products, especially honey, propolis, pollen, and beeswax. Research on colony performance, nutrition, reproduction, and pollination services was comparatively less frequent.

3.3 Diversity of *A. mellifera* research topics

The keyword analysis identified the main topics researched in the field of beekeeping in Peru. In the Figure 2 presents the most

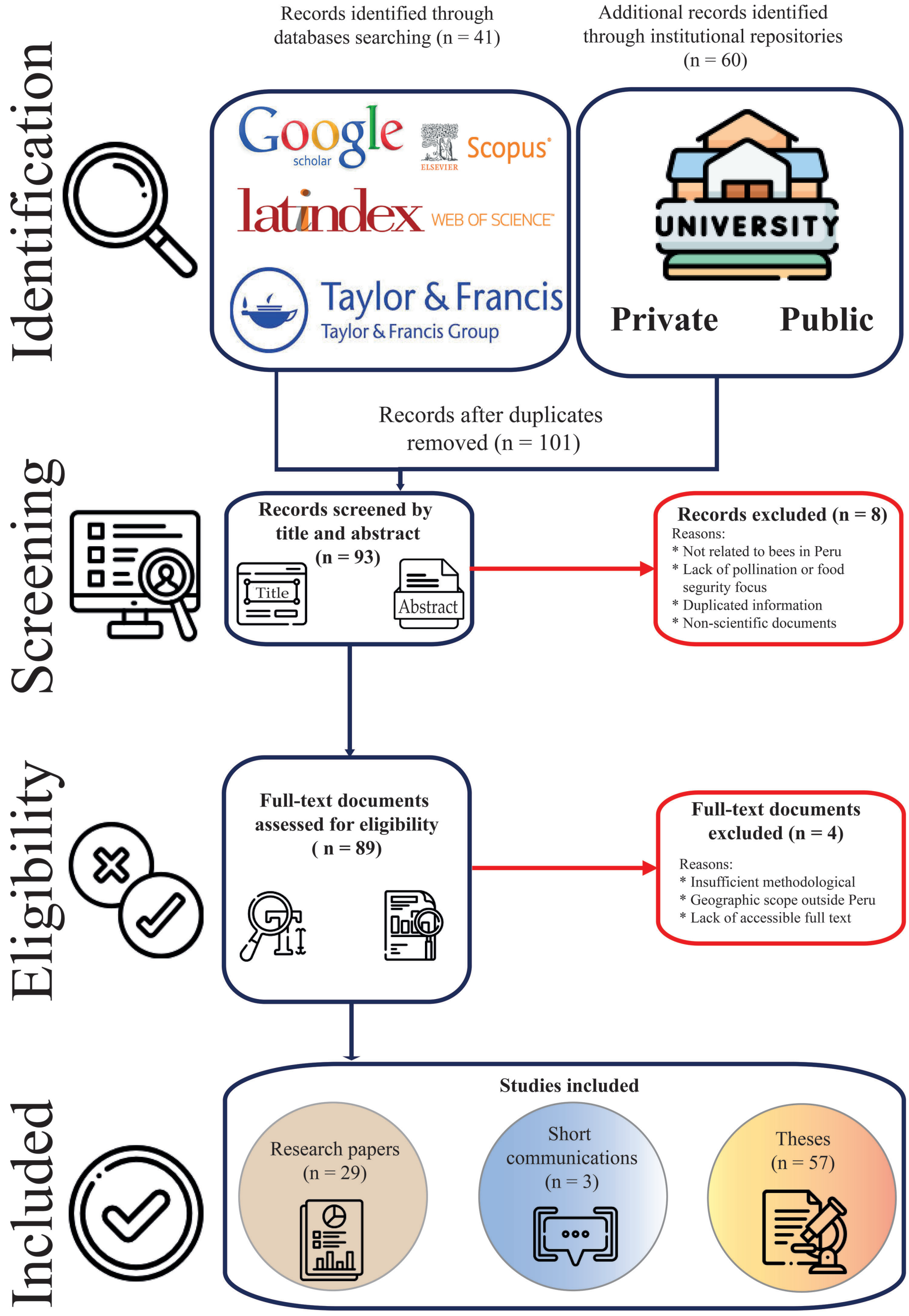

FIGURE 1
The systematic screening of relevant literature was meticulously conducted using PRISMA guidelines, with studies retrieved from prominent scientific databases.

frequently used keywords in Peruvian bee research. The most frequently used keyword in bee research in Peru was "Honey," with 15 occurrences and a percentage of 5.28%, indicating that honey is the central focus of the analyzed studies. *A. mellifera* was the second most frequent term at 4.58%, high-lighting the importance of this species as the primary organism of study. The third most frequent term was *V. destructor*, at 2.46%. This percentage reflects the mite's relevance as one of the main health threats to bee colonies. Subsequently, the terms diversity and beekeeping each registered 2.11%. The presence of diversity demonstrates the scientific interest in the biological, genetic, and ecological diversity associated with bees and their ecosystems. beekeeping, on the other hand, confirms the importance of beekeeping management and production systems in the evaluated literature. The terms Peru, pollinator, and products were found with a frequency of 5 occurrences (1.76%). The terms beekeeper and bees each reached 1.41%. This suggests that some of the research focuses on both beekeepers and general aspects related to bees.

Words such as Behavior, Hygienic behavior, Pollen, Propolis, and *Streptococcus mutans* each showed 1.06%. Several other terms

TABLE 1 General characterization of the studies analyzed, number of investigations, description and bibliographic reference.

Area of study	Studies number	Short description	Reference[1]
Characterization	22	Focused on the identification and description of bees, their behavior, diversity, and environment.	(Cockerell, 1914; Taylor, 1977; Kent, 1989; Heard, 1994; Pérez-Castro et al., 2002; Rasmussen, 2009; Nemésio and Rasmussen, 2014; Marroquín, 2014; Gade, 2015; Mejía, 2017; Caroy, 2018; Aliaga, 2006; Beltrán-Tolosa et al., 2020; Calizaya-Melo et al., 2021; Chávez-Galarza et al., 2021; Marconi et al., 2023; Valladolid et al., 2022; Cotrina-Sanchez et al., 2023; Delgado et al., 2023; Gaslac, 2024; Picón, 2024; Rasmussen and Sánchez, 2024)
Performance	2	Examined bee hive performance, with research conducted in La Libertad and Lima. Notable studies include Oré (2016), which analyzed metrics related to queen bees, and Medina and Ccoñas (2018), which evaluated A. mellifera colony metrics.	(Oré, 2016; Medina and Ccoñas, 2018)
Feeding and Nutrition	4	Reviewed the impact of protein supplements on bee colony health, highlighting improvements in population, posture, and weight.	(Medina and Ccoñas, 2018; Porras, 2023; Blas, 2024; Vásquez, 2024)
Reproduction	1	Investigated the effect of cryoprotectants on honey bee drone sperm viability, emphasizing the importance of genetics for long-term bee reproduction.	(Amen, 2019)
Health	15	Examined how V. destructor affects bee health, focusing on various control treatments. Most research was conducted in northern Peru, including regions like Tumbes, Piura, and Cajamarca.	(Morillo, 2015; Tejada and Morón, 2015; Guerrero-Padilla et al., 2013; Reyes, 2016; Airahuacho and Rubina, 2021; Díaz et al., 2021; López, 2014; Murga-Moreno et al., 2021; Yancce, 2021; Polo et al., 2022; Tello, 2022; Airahuacho et al., 2023; Francia, 2023; Nestares, 2023, Owusu and Skevas, 2024)
Bee products honey	22	Primarily in La Libertad, explored honey quality, its use in dermatology, and market strategies. Most studies used experimental designs.	(Pasco and Sánchez, 2010; Carreño, 2013; Escriba, 2014; Noé, 2015; Arroyo and Arroyo, 2017; Coronel, 2017; Hayayumi, 2017; Requier et al., 2018; Cerna, 2019; Avilés and Matos, 2009; Samaniego, 2019; Vela, 2019; Baiocchi, 2021; Cabrera and Chuquibala, 2021; Ormeño et al., 2021; Sánchez, 2021; Quevedo et al., 2022; Cabrera, 2023; Delgado and Espinoza, 2023; Verano, 2023; Tejada-Purizaca et al., 2024)
Bee products beeswax	5	Investigated the use of beeswax in preserving blueberries, comparing it to other edible coatings.	(Párraga, 2018; Abanto, 2018; Newson, 2018; García et al., 2019; Delgado, 2024)
Bee products propolis	8	Demonstrated propolis's beneficial properties, including antifungal, antibacterial, and anti-inflammatory effects. Most research was conducted in La Libertad, with a few in Cajamarca and Junín.	(Saavedra et al., 2013; Álvarez, 2014; Arévalo, 2014; Rojas, 2014; Castro et al., 2006; Camino, 2022; Zavaleta-Rengifo et al., 2022; Reyes, 2023)
Bee products pollen	4	Explore different factors that affect pollen production in A. mellifera bees.	(Velazco, 2006, León, 2008; Leiva et al., 2021; Paredes and Bryant, 2019)
Apiculture	4	Focused on honey production and challenges in various regions, including the impact of deforestation, the economic reliance of beekeepers, and the variability in honey and other hive products.	(Fernández, 2018; Estela, 2019; Gonzales, 2019; Vega, 2024)
Pollination	3	Focused on pollination and its impact on different agricultural crops (avocado, sweet potato)	(Iglesias, 2007; Rubiños, 2014; Basurto, 2021)

[1]Research consulted from Google Scholar, Scopus, Latindex, Web of Science, Taylor and Francis from 1914 to 2024.

also had 0.70% each, including Agroforestry systems, Amazon, Antibacterial effect, Apoidea, Coffee, Composition, Dehydration, Pollination, Surveys, Sustainable development, and Vernonia. These terms reflect the multidisciplinary scope of the studies, integrating ecological, agricultural, microbiological, environmental, and socioeconomic aspects.

Most of the terms had 0.35% each. Among them are words related to: specific bee products, plants, chemical properties, health aspects, Agroecological practices.

3.4 Geographic distribution of bee research in Peru

The regional distribution of the studies revealed a marked concentration of research in specific areas of Peru. La Libertad had the highest frequency, with 25 studies representing 28% of the total, indicating that this region is the main center of apicultural research activity in the country. Lima (12%) and Junín followed with 12 studies (13%), while Cajamarca registered 10 studies (11%),

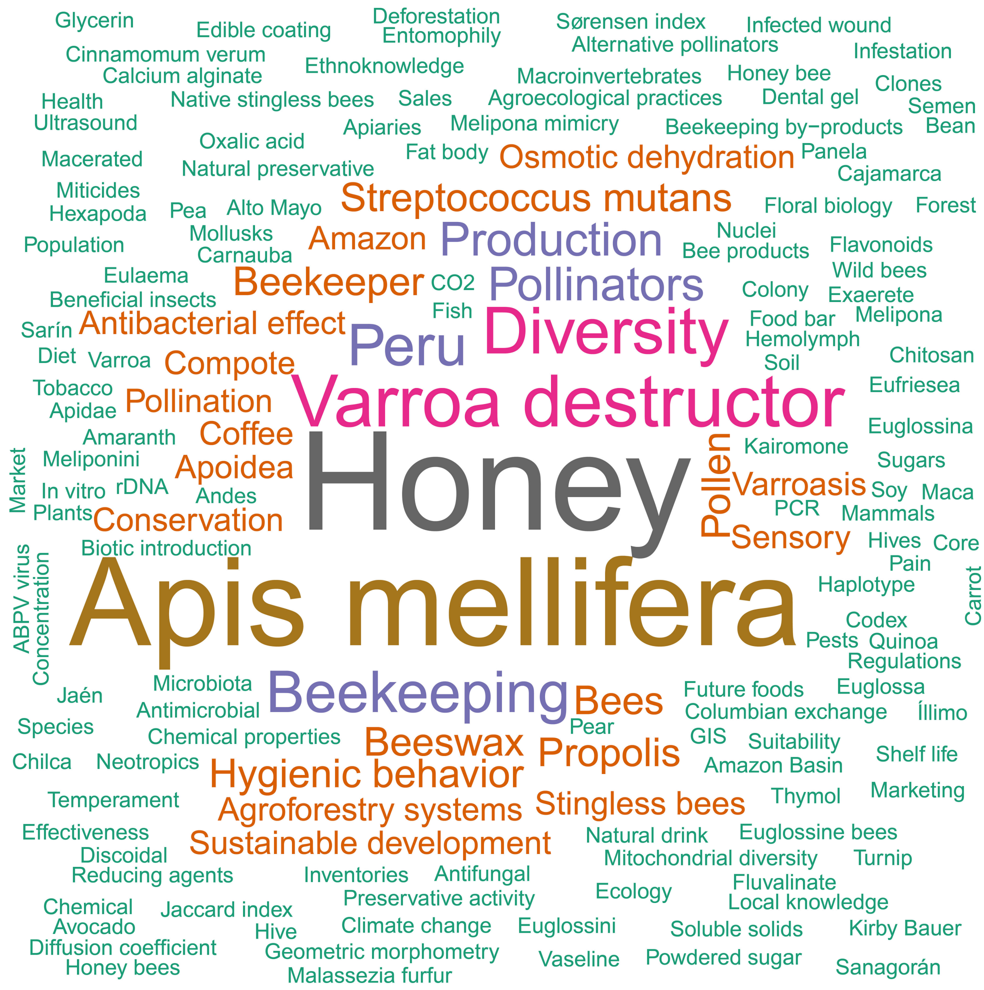

FIGURE 2
The most frequently used keywords in Peruvian beekeeping research, using a word cloud.

highlighting the relevance of these regions in the development of scientific research related to apiculture and bee products. Intermediate frequencies were observed in Amazonas with 6 studies (7%), Lambayeque and Loreto with 5 studies each (6%), and San Martín with 4 studies (5%). In contrast, Piura and Tumbes showed lower participation, with 3% and 2%, respectively. The remaining regions, including Arequipa, Pasco, Huancavelica, Tacna, Madre de Dios, and Ucayali, each represented only 1% of the total studies, reflecting limited scientific output in these areas (Figure 3; TS 1).

Given that Peru has 24 departments and one constitutional province with a special regime (Callao), the results show that several regions did not register any studies related to the topic evaluated. Among the regions without records are Áncash, Apurímac, Ayacucho, Cusco, Huánuco, Ica, Moquegua, and Puno, in addition to the Constitutional Province of Callao (Figure 3).

Research on *A. mellifera* has been reported in five regions of Peru; however, no research was reported in regions such as Tacna, Moquegua, Arequipa, Puno, Cusco, Apurimac, Ayacucho, Ica, Huancavelica, Madre de Dios, Ucayali, Pasco, Huánuco, and Ancash. In these regions, climatic conditions are unfavorable for A. mellifera breeding, which is why research and government institutions do not prioritize studies on this species.

4 The importance of *A. mellifera* in Peruvian ecosystems

A. mellifera play a crucial role in the Peruvian ecosystems for several reasons (Figure 4). One of them is because they are responsible for pollinating many plants, including many that are vital for food production (IPBES, 2016). Bee species are linked to the rich diversity of endemic plants found in the high Andean ecosystems of Peru (Calizaya-Melo et al., 2021). Additionally, in San Martin, bees contribute to the diversity of local orchids, a species of significant economic and aesthetic value to the community (Rasmussen, 2009; Nemésio and Rasmussen, 2014).

Furthermore, bees contribute to nutrient cycling and soil fertility due to their waste such as feces and death of individuals, and pollen breaks down into organic nitrogen that plants can absorb as inorganic nitrogen adding essential nutrients to the soil (Mishra et al., 2013; Filipiak, 2023; Shahmshad, 2023). Beltrán-Tolosa et al. (2020) in their study in Andean-Amazon Peru reported that soil organisms and pollinators enhance soil fertility and boost crop production.

A. mellifera are a critical part of the food chain (Figure 4) since many animal species depend on plants pollinated by bees (Abrol, 2012; Devkota et al., 2024; Srilipta et al., 2024). A substantial amount of food

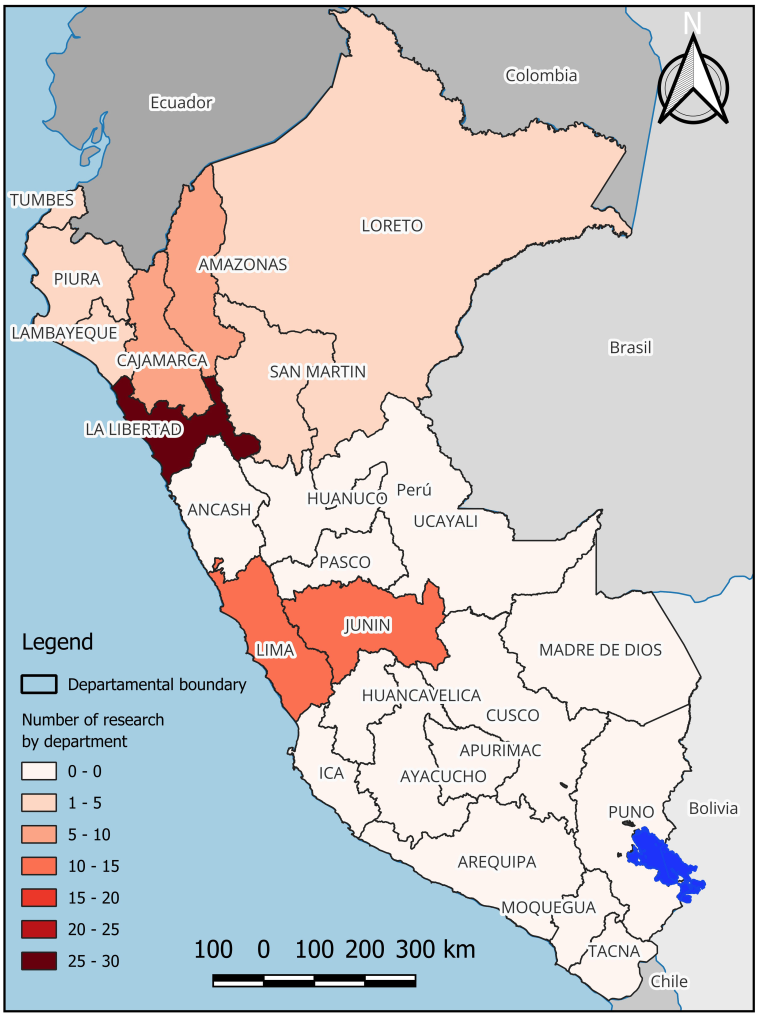

FIGURE 3
Geographic distribution of bee research studies in Peru.

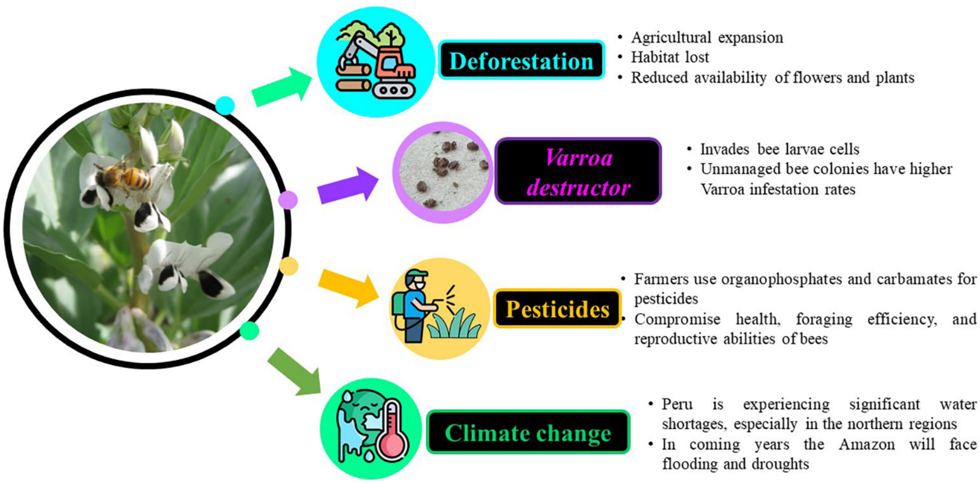

FIGURE 4
The crucial role of *A. mellifera* in Peruvian ecosystems.

crops depends on bee pollination, which immediately impacts food security and the agricultural economy (Delgado-Carrillo et al., 2024). For example, a study in Ecuador showed that the yield of pea crops (*Pisum sativum* L., var. Television) increased due to the action of bees as pollinators (García, 2019). Additionally, a study on sweet cherry pollination (Eeraerts et al., 2019) found that while honey-bees were efficient pollinators for this crop, other species such *Osmia cornuta* or solitary bees proved to be more effective.

The soils of Peru are distinguished by their high concentrations of metals such as Arsenic, Cadmium, and Lead, exceeding Peru's Environmental Quality Standards (Bedoya-Perales et al., 2023). Bee products like wax, honey, and pollen can serve as bioindicators of environmental disturbances, with bees potentially collecting micro-plastic pollution (Cortés-Corrales et al., 2024) and acting as biomonitors for heavy metal levels in the air (Ccechi et al., 2023). For example, a study in Peru found that many local products, including honey and propolis, exceed World Health Organization safety standards for metals such as Cd and Pb, often at higher levels than reported elsewhere (Tejada-Purizaca et al., 2024). Additionally, products like beeswax and propolis aid in preserving certain food products and extending their shelf life. For example, García et al. (2019) in Tacna, found that using beeswax 40% and carnauba wax 60% had better results for increasing the useful life in pears (*Pyrus communis*). Another study in Lima used propolis to preserve the peach nectar highlighting its antimicrobial effect (Zavaleta-Rengifo et al., 2022). Finally, honeybees can be used in the treatment of different conditions or diseases in some Peruvian communities (Delgado and Espinoza, 2023).

5 Challenges faced by apiculture in Peru

Nowadays, many factors affect bees such as habitat loss due to land use changes, the use of pesticides, diseases, and climate change (Albacete et al., 2023; Brunet and Fragoso, 2024; Figure 5). One of the primary issues is habitat loss due to deforestation (Deforested area in Peru, period 1990-2000: 1 496 317.56 ha) and agricultural expansion (44.18% of the deforested areas), converting forests and jungles into agricultural land reduces the availability of flowers and plants that bees need for food and reproduction (MINAM, 2009; Freitas et al., 2009; Rojas et al., 2021). This loss of natural habitats also impacts plant biodiversity, decreasing the variety of plants available to bees, and limiting their nectar and pollen sources essential for bees to thrive (Crenna et al., 2017).

Another major challenge is the presence of pests and diseases affecting *A. mellifera*. In Peru, *V. destructor*, a parasitic mite, is particularly problematic (Figure 5). This mite invades bee larvae cells and reproduces within them, weakening colonies and making them more susceptible to other diseases (Airahuacho and Rubina, 2021). The geometric morphometry of this ectoparasite has been evaluated in the north of Peru (Díaz et al., 2021). Also, it was found that unmanaged bee colonies have higher Varroa infestation rates (particularly near human settlements), and their infestation decreases with higher altitudes (Polo et al., 2022). A recommended strategy to combat efficiently *V. destructor* is to select hives with good hygienic behavior rather than relying on acaricides, due to the potential contamination risks of these chemical treatments to both

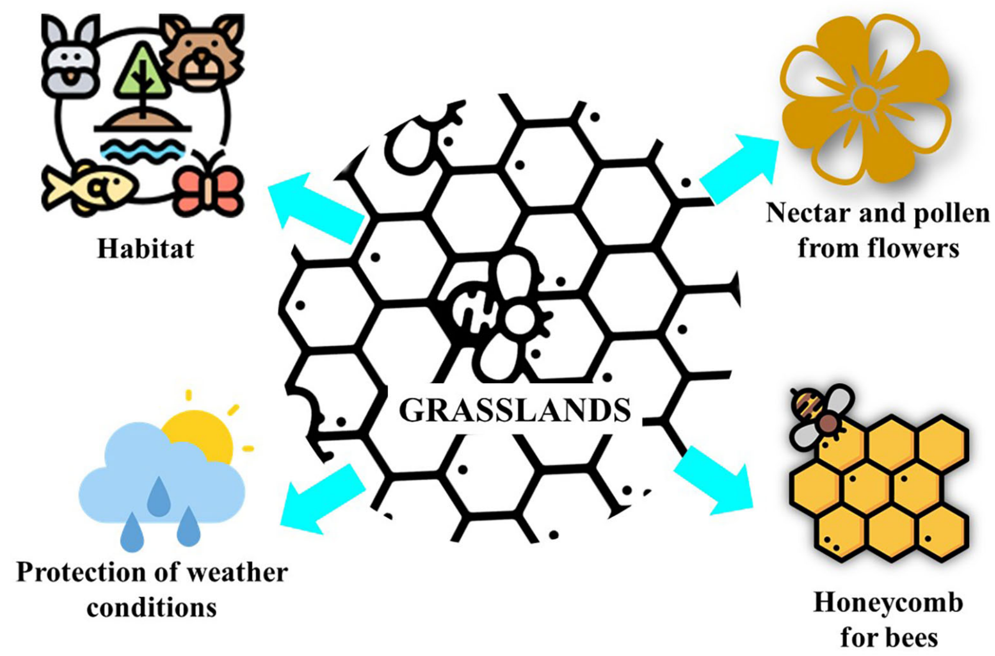

FIGURE 5
Principal challenges faced by apiculture in Peruvian ecosystems.

human consumption of bee products and the environment (Airahuacho and Rubina, 2021).

Additionally, pesticides used in agriculture play a crucial role in the decrease in bee populations (Brunet and Fragoso, 2024). There are limited studies on the impact of these chemicals on the health of *A. mellifera* in our country. In Lima's coastal valleys, farmers predominantly use organophosphates and carbamates for pesticides (Chávez-Dulanto et al., 2024). Additionally, its use extends to the south of Peru (Cusco), where its impact on the arthropofauna was associated with potato (*Solanum tuberosum*) cultivation (Montes et al., 2023). Additionally, pesticides used in intensive agriculture are toxic to bees, compromising their health, foraging efficiency, and reproductive abilities, contributing significantly to the overall decline in bee populations (Freitas et al., 2009; Zhao et al., 2021).

Finally, climate change and extreme weather conditions are exacerbating the problems confronted by bees (Landaverde et al., 2023). Variations in temperature and climate change affect flowering availability which can cause gaps in the availability of pollen, disrupting honeybee foraging and potentially harming their colonies (van der Sluijs and Vaage, 2016). Prolonged droughts and heavy rains can disrupt plant flowering and reduce the amount of nectar and pollen available to bees (Bobiş et al., 2024). Peru is experiencing significant water shortages, especially in the northern regions, worsened by climate change and the El Niño effect (Chávez-Jiménez et al., 2024). Climate forecasts suggest that the Upper Amazon will face drier conditions, while the Andes could see increased rainfall, potentially resulting in extreme flooding and droughts (Fernandez-Palomino et al., 2023). Adapting to these changes presents an additional challenge for bee populations in an increasingly unpredictable environment (Figure 5).

6 Peruvian agriculture and their relationship with *A. mellifera*

Livestock in the Peruvian Amazon rely on native and cultivated pastures as the main source of feeding (MIDAGRI, 2017; Echevarría et al., 2019). Also, grasslands provide a crucial habitat for pollinators (Dylewski et al., 2024). There are 20,976,028 hectares of natural pastures in the high Andean area of Peru (MINAM, 2010). The Andean grassland ecosystems in Peru exhibit a unique floristic diversity, characterized by natural grass species that vary depending on the vegetation category, such as tussock grasses, puna grass, and wetlands. Also, these areas support the local fauna and provide forage for livestock, especially cattle, alpacas, vicunas, and sheep, which are vital to local economies (Mamani et al., 2013; Estrada et al., 2023; Yaranga et al., 2024). However, an extensive part of the grasslands is in a degradation process (Mamani et al., 2013). Although, there are already some grassland conservation and preservation areas in Peru such as the National Sanctuary of Ampay, upcoming conservation efforts are urgently required (Tovar et al., 2012; Soto et al., 2024).

Grasslands offer essential habitats for *A. mellifera* by providing a diverse range of flowering plants that supply nectar and pollen throughout the growing season (Figure 5), ensuring a stable food source for various bee species (Kimoto et al., 2012). The structural elements of grasslands, such as a mix of grasses, herbs, and undisturbed areas, offer important nesting sites and protection from predators and extreme weather conditions, and more diverse and abundant floral resources (Öckinger and Smith, 2007; Smith et al., 2016). This diversity of food and habitat supports the health and survival of bee populations, which are crucial for maintaining the ecological balance of these ecosystems (Smith et al., 2016; Albrecht et al., 2023).

Additionally, grasslands play a significant role in agricultural systems by serving as buffer zones between agricultural fields and natural habitats (Figure 6), reducing the impact of intensive farming practices on bees (Albrecht et al., 2023). Grasslands also provide pollination services to nearby crops, enhancing agricultural productivity and food security (Tanda, 2022). Conservation and sustainable management of grasslands are vital for preserving these habitats, ensuring that bees continue to thrive, and supporting ecosystem health and agricultural systems (Keyser et al., 2022).

The impact of pollination on agriculture is profound, as pollinators are essential to produce many crops that contribute to

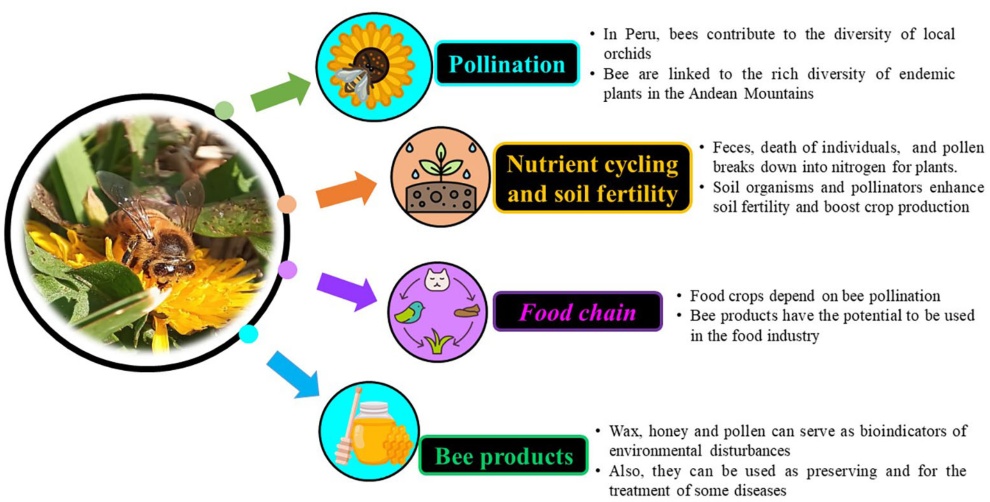

FIGURE 6
Impact of grasslands on *A. mellifera* in Peru.

human diets (Wendee, 2015). The decrease in pollinator populations presents a major risk to global food systems, impacting crop yields and nutritional quality (Devkota et al., 2024; Brunet and Fragoso, 2024). Pollinators, particularly *A. mellifera*, are crucial for the reproductive success of many crops. For instance, in Jalisco, Mexico, watermelon (*Citrullus lanatus*) and green tomato (*Solanum lycopersicum*) crops showed a complete lack of fruit production without pollinators, highlighting their dependency on these services (Delgado-Carrillo et al., 2024).

In Peru, *A. mellifera* are essential for pollinating several key crops, significantly impacting agricultural productivity and quality. For instance, coffee (*Coffea arabica*) and cacao (*Theobroma cacao*) plants rely heavily on bees for effective pollination, which enhances fruit set and quality, which is crucial for the country's major coffee and chocolate industries (Jezeer and Verweij, 2015; Vansynghel et al., 2023). Furthermore, bees aid in fertilizing various fruits, such as camu-camu (*Myrciaria dubia*) and tomato (*Solanum lycopersicum*), enhancing the yield and quality of these crops (Rick, 1958; Peters and Vasquez, 1987; Sousa et al., 2021).

7 Knowledge gaps identified

The synthesis revealed important gaps in the current state of knowledge regarding *A. mellifera* in Peru. The most notable gaps are:

- In regions such as La Libertad, Amazonas, Cajamarca, Lima, and Junín, various studies have been conducted on *A. mellifera*; however, priority should be given to studies in regions with no studies or fewer than five. We encourage research and government institutions to prioritize research initiatives in these areas.
- Information on honey, *V. destructor*, pollen, beeswax, hygienic behavior, production, and conservation was addressed in the studies found. However, limited information is available on pollination networks, plant-pollinator interactions, ecosystem-level services, pollinator landscape ecology, and few studies have quantified the economic value of pollination services for Peruvian agriculture.

These gaps highlight the need for future multidisciplinary research to improve under-standing of bee diversity, ecosystem services, and conservation priorities in Peru.

8 Limitations and perspectives

This review has limitations, as the evidence base consists primarily of unpublished undergraduate theses, which could influence the conclusions. The available literature shows a strong bias toward *A. mellifera*, limiting the representativeness of the conclusions regarding the overall diversity of native bees and wild pollinators in Peru. The uneven geographic distribution of research efforts highlights significant regional biases that may affect the national representativeness of current knowledge.

Future research should prioritize comprehensive assessments of native bee diversity, pollinator-plant interactions, and ecosystem services using standardized monitoring approaches. Strengthening national research networks and long-term biodiversity monitoring programs will be essential to reducing geographic and taxonomic knowledge gaps. Furthermore, integrating scientific evidence with public policies, conservation strategies, and sustainable beekeeping practices will be crucial to improving pollinator protection and promoting resilient beekeeping systems in Peru.

9 Conclusions

A. mellifera are vital to the ecological and agricultural health of Peru, playing an essential role in pollinating a wide range of native plants and key crops such as coffee, cacao, and tomato, which are critical to the country's economy. However, they face a myriad of threats, including habitat loss from deforestation and agricultural expansion, pest infestations, pesticide exposure, and the accelerating impacts of climate change. These challenges, compounded by gaps in scientific understanding, underscore the urgent need for sustainable land management practices and the preservation of critical habitats like grasslands. Effective conservation strategies, grounded in comprehensive research, are crucial to ensuring the survival of *A. mellifera*, which in turn will safeguard both biodiversity and agricultural productivity in the region.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material. Further inquiries can be directed to the corresponding author.

Author contributions

DR: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. JS: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. WB: Data curation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. YP: Formal Analysis, Funding acquisition, Resources, Software, Supervision, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This research was funded by Vicerrectorado de Investigación of the Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas.

Acknowledgments

We are grateful to the Vicerrectorado de Investigación of the Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas by funded this research.

Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frbee.2026.1904918/full#supplementary-material

SUPPLEMENTARY TABLE 1
The relevant literature included in the study; TS 2: Geographic distribution of bee research studies in Peru.

References

Abanto, M. G. (2018). (Universidad Nacional de Cajamarca). Available online at: http://hdl.handle.net/20.500.14074/2937 (Accessed June 3, 2025).

Abrol, D. P. (2012). "Decline of pollinators," in *Pollination Biology* (Springer, Dordrecht), 545–601. doi: 10.1007/978-94-007-1942-2_17

Airahuacho, F., Jiménez, V., Rubina, S., and Velásquez, C. (2023). Evaluación de productos alternativos naturales en el control de Varroa destructor en abejas melíferas (Apis mellifera). *Rev. Investigaciones Veterinarias del Perú* 34, e23741. doi: 10.15381/rivep.v34i3.23741

Airahuacho, F. E., and Rubina, S. (2021). Varroa destructor: una amenaza mortal para la colmena de Apis mellifera. *Peruvian Agric. Res.* 3, 40–51. doi: 10.51431/par.v3i1.664

Albacete, S., Sancho, G., Azpiazu, C., Rodrigo, A., Molowny-Horas, R., Sgolastra, F., et al. (2023). Bees exposed to climate change are more sensitive to pesticides. *Global Change Biol.* 29, 6248–6260. doi: 10.1111/gcb.16928

Albrecht, M., Bossart, S., Tschanz, P., Keller, T., and Sutter, L. (2023). Grassland extensification enhances nest densities of ground-nesting wild bees. *J. Appl. Ecol.* 60, 2550–2560. doi: 10.1111/1365-2664.14527

Aliaga, P. (2006). (Universidad Nacional de Ucayali). Available online at: https://hdl.handle.net/20.500.14621/1849 (Accessed September 1, 2025).

Álvarez, M. (2014). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/1130 (Accessed October 26, 2025).

Amen, E. J. L. (2019). (Universidad Nacional Agraria La Molina). Available online at: https://hdl.handle.net/20.500.12996/4353 (Accessed August 4, 2025).

Arévalo, C. (2014). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/1111 (Accessed June 23, 2024).

Arroyo, O. R., and Arroyo, J. R. (2017). (Universidad Nacional del Centro del Perú). Available online at: http://hdl.handle.net/20.500.12894/4772 (Accessed November 17, 2025).

Avilés, H. A., and Matos, R. A. (2009). Análisis comparativo de la calidad fisicoquímica, microbiológica y organoléptica de la miel de abeja (Apis mellifera) producida en diferentes regiones de Perú. *Rev. Investigación Universitaria* 1, 5–11. Available online at: https://revistas.upeu.edu.pe/index.php/riu/article/view/682.

Baiocchi, A. F. (2021). ú (Universidad Nacional Agraria La Molina). Available online at: https://hdl.handle.net/20.500.12996/4678 (Accessed June 5, 2025).

Basurto, J. E. (2021). (Universidad Nacional Agraria La Molina). Available online at: https://hdl.handle.net/20.500.12996/4677 (Accessed July 5, 2025).

Bedoya-Perales, N. S., Neimaier, A., Maus, D., Escobedo-Pacheco, E., Eduardo, K., and Pumi, G. (2023). Patterns of accumulation and baseline values for metals in agricultural soils from a copper mining region in southern Peru. *Environ. Nanotechnology Monit. Manage.* 20, 100896. doi: 10.1016/j.enmm.2023.100896

Beltrán-Tolosa, L. M., Cruz-Garcia, G. S., Solis, R., and Quintero, M. (2020). Mestizo farmers' knowledge of entomofauna is reflected in their management practices: A case study in the Andean-Amazon foothills of Peru. *Front. Sustain. Food Syst.* 4, 539611. doi: 10.3389/fsufs.2020.539611

Blas, L. (2024). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/26851 (Accessed May 10, 2025).

Bobiş, O., Bonta, V., Moise, A. R., Paşca, C., Giurgiu, A. I., and Dezmirean, D. S. (2024). Impact of weather changes on bee families development and production with special reference to the Transylvania area. *Sci. Papers. Ser. D. Anim. Sci.* 67, 239–260. Available online at: https://animalsciencejournal.usamv.ro/pdf/2024/issue_1/Art26.pdf

Brunet, J., and Fragoso, F. P. (2024). What are the main reasons for the worldwide decline in pollinator populations? *CABI Rev.* 19, 1–10. doi: 10.1079/cabireviews.2024.0016

Cabrera, H. (2023). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/18074 (Accessed August 12, 2025).

Cabrera, S. M., and Chuquibala, Z. M. (2021). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/19310 (Accessed August 23, 2025).

Calizaya-Melo, Y. A., Aguilar, M. L., and López-Tejeda, E. (2021). Abejas altoandinas (Hymenoptera: Apoidea) en Arequipa, Perú. *Acta Biológica Colombiana* 26, 295–302. doi: 10.15446/abc.v26n3.86011

Camino, X. (2022). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/8655 (Accessed September 17, 2025).

Caroy, R. (2018). (Universidad Nacional de Trujillo). Available online at: https://repositorio.unitru.edu.pe/entities/publication/b94353a3-e778-489c-8e0b-cad73048b94f (Accessed May 14, 2026).

Carreño, J. M. (2013). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/681 (Accessed February 11, 2026).

Castro, E. P., Cano, R. Y., Dávila, C. E., Euán, J. Q., Kasuhiro, A., and Macias, O. M. (2006). Caracterización bioquímica de las abejas nativas de dos ecosistemas distintos de la Selva Central del Perú. *Prospectiva Universitaria en Ingeniería Y. Tecnología* 3, 18–21. doi: 10.26490/uncp.prospectivauniversitaria.2006.3.1290

Ccechi, M., Basso, M., Cantatore, D., Moliné, M., Fernández, N., Domínguez, E., et al. (2023). Las abejas melíferas (Apis mellifera) como biomonitores de contaminación ambiental por metales pesados. *Rev. Científica Abejas Y. Apicultura* 21, 3–12. doi: 10.52559/eunk.v2i1.31

Cerna, E. J. (2019). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/15654 (Accessed January 9, 2025).

Chávez-Dulanto, P. N., Vögler, O., Helfgott-Lerner, S., and Carvalho, F. (2024). Insights on the use of pesticides in two main food-supplier coastal valleys of Lima City, Peru. *Agrochemicals* 3, 181–208. doi: 10.3390/agrochemicals3030013

Chávez-Galarza, J., López-Montañez, R., Jiménez, A., Ferro-Mauricio, R., Oré, J., Medina, S., et al. (2021). Mitochondrial DNA variation in Peruvian honey bee (Apis mellifera L.) populations using the tRNAleu-cox2 intergenic region. *Insects* 12, 641. doi: 10.3390/insects12070641

Chávez-Jiménez, A., Quevedo, V., Bravo, D., and Chapilliquen, D. (2024). Evaluating the impact of climate change in Northern Peru by analyzing homogeneous regions based on different climate variables and precipitation trend changes. *EGU Gen. Assembly 2024* 2024(EGU24), 3690. doi: 10.5194/egusphere-egu24-3690

Cockerell, T. D. A. (1914). Recs from Ecuador and Perú. *J. New York Entomological Soc.* 22, 306–328. Available online at: https://dn760107.eu.archive.org/0/items/biostor-104209/biostor-104209.pdf.

Congreso de la República del Perú (2026). “Ley N.° 32685, Ley que promociona el fortalecimiento de la apicultura y la polinización como actividades productivas estratégicas del agro,” in *Diario Oficial El Peruano*. (Lima). Available online at: https://busquedas.elperuano.pe/dispositivo/NL/2531442-1 (Accessed May 14, 2026).

Coronel, J. R. (2017). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/10084 (Accessed February 5, 2025).

Cortés-Corrales, L., Flores, J. J., Rosa, A., Jozef, J. M., Van der Steen, J., Vejsnæs, F., et al. (2024). Evaluation of microplastic pollution using bee colonies: An exploration of various sampling methodologies. *Environ. pollut.* 350, 124046. doi: 10.1016/j.envpol.2024.124046

Cotrina-Sanchez, A., García, L., Calle, C., Sari, F., Bandopadhyay, S., Rojas-Briceño, N. B., et al. (2023). Multicriteria analysis in apiculture: A sustainable tool for rural development in communities and conservation areas of Northwest Peru. *Land* 12, 1900. doi: 10.3390/land12101900

Crenna, E., Sala, S., Polce, C., and Collina, E. (2017). Pollinators in life cycle assessment: Towards a framework for impact assessment. *J. Cleaner Prod.* 140, 525–536. doi: 10.1016/j.jclepro.2016.02.058

Delgado, C. A. (2024). (Universidad Nacional de la Amazonía Peruana). Available online at: https://hdl.handle.net/20.500.12737/11122 (Accessed January 18, 2025).

Delgado, C., and Espinoza, R. (2023). Physicochemical parameters and chemoprofiling of honey of two species of stingless bees in the Peruvian Amazon. *Food. Humanities* 1, 1145–1156. doi: 10.1016/j.foohum.2023.08.017

Delgado, C., Mejía, K., Rasmussen, C., and Romero, R. (2023).Traditional knowledge of stingless bees (Hymenoptera: Apidae: Meliponini) in the Peruvian Amazon. Available online at: https://www.jstor.org/stable/48732537 (Accessed May 21, 2026).

Delgado-Carrillo, O., Martén-Rodríguez, S., Ramírez-Mejía, D., Novais, S., Quevedo, A., Ghilardi, A., et al. (2024). Pollination services to crops of watermelon (Citrullus lanatus) and green tomato (Physalis ixocarpa) in the coastal region of Jalisco, Mexico. *PloS One* 19, e0301402. doi: 10.1371/journal.pone.0301402

Devkota, K., Ferreira, A. B., Timberlake, T. P., and dos Santos, C. F. (2024). The impact of pollinator decline on global protein production: Implications for livestock and plant-based products. *Global Ecol. Conserv.* 50, e02815. doi: 10.1016/j.gecco.2024.e02815

Díaz, A. P., Leiva, L. A., Rodriguez, R., Hurtado, C., Rodríguez, J., and Díaz, L. (2021). Determinación por morfometría geométrica de Varroa sp. (Acari: Varroidae), ectoparásito de Apis mellifera L. costa norte del Perú, 2018. *Arnaldoa* 28, 717–726. Available online at: https://www.scielo.org.pe/pdf/arnal/v28n3/2413-3299-arnal-28-03-717.pdf

Dylewski, Ł., Białas, J., Szymysł, A., and Banaszak-Cibicka, W. (2024). Pollinator assemblages in grasslands along river valleys depend on the urban matrix and local habitat scale variables. *Ecol. Indic.* 159, 111687. doi: 10.1016/j.ecolind.2024.111687

Echevarría, M., Pizarro, D., and Gómez, C. (2019). Alimentación De Ganadería En Sistemas Silvopastoriles De La Amazonía Peruana (Lima, Peru). Available online at: https://www.researchgate.net/publication/335542022 (Accessed June 15, 2026).

Eeraerts, M., Vanderhaegen, R., Smagghe, G., and Meeus, I. (2019). Pollination efficiency and foraging behaviour of honey bees and non-Apis bees to sweet cherry. *Agric. For. Entomol.* 22, 75–82. doi: 10.1111/afe.12363

Escriba, W. E. (2014). (Universidad Nacional del Centro del Perú). Available online at: http://hdl.handle.net/20.500.12894/4000 (Accessed October 21, 2025).

Estela, L. (2019). (Universidad Nacional Pedro Ruiz Gallo). Available online at: https://hdl.handle.net/20.500.12893/6107 (Accessed July 3, 2025).

Estrada, A., Astete, D., Cárdenas, J., Alvarez, D., Bejar, J., and Moscoso, J. (2023). Sistemas aéreos no tripulados y sensores remotos pasivos para clasificar microecosistemas de pastizales altoandinos. *Rev. la Facultad Agronomía (LUZ)* 40, 1–20. doi: 10.47280/RevFacAgron(LUZ).v40.n4.05

Fernandez-Palomino, C. A., Hattermann, F. F., Krysanova, V., Vega-Jácome, F., Lavado, W., Bronstert, A., et al. (2023). *Climate change impact on water budget and hydrological extremes across Peru, EGU General Assembly, Vienna, Austria*, EGU23–17281. doi: 10.5194/egusphere-egu23-17281

Fernández, J. (2018). (Universidad Nacional de Cajamarca). 24–28. Available online at: http://hdl.handle.net/20.500.14074/5258 (Accessed June 18, 2025).

Filipiak, M. (2023). Wild bee is an important contributor to the nutrient cycle, as shown by biogeochemical niche analysis of Osmia bicornis. *SSRN Electronic J.*, 4591616. doi: 10.2139/ssrn.4591616

Francia, G. R. (2023). (Universidad Nacional Agraria La Molina). Available online at: https://hdl.handle.net/20.500.12996/6094 (Accessed July 22, 2025).

Freitas, B., Imperatriz-Fonseca, V. L., Medina, L., Peixoto, A., Galetto, L., Nates-Parra, G., et al. (2009). Diversity, threats and conservation of native bees in the Neotropics. *Apidologie* 40, 332–346. doi: 10.1051/apido/2009012

Gade, D. (2015). Particularizing the Columbian exchange: Old World biota to Peru. *J. Historical Geogr.* 48, 26–35. doi: 10.1016/j.jhg.2015.01.001

García, J. R. (2019). (Escuela Superior Politécnica de Chimborazo). Available online at: http://dspace.espoch.edu.ec/handle/123456789/14116 (Accessed April 10, 2025).

García, H., Zúñiga, H., and Carhuaz, D. (2019). Evaluación de la vida útil postcosecha de pera (Packham's Triumph) mediante recubrimiento con cera de carnauba y cera de abeja. *Ingeniería Investiga* 1(1), 09–25. Available online at: https://revistas.upt.edu.pe/ojs/index.php/ingenieria/article/view/119.

Gaslac, J. B. (2024). (Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas). Available online at: https://repositorio.untrm.edu.pe/handle/20.500.14077/3825 (Accessed October 3, 2025).

Guerrero-Padilla, A. G., Florián, J., and Guerrero, J. F. (2019). (Universidad Nacional de Cajamarca). Available online at: http://hdl.handle.net/20.500.14074/3468 (Accessed July 12, 2025).

Goulson, D., Nicholls, E., Botías, C., and Rotheray, E. L. (2015). Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. *Science* 347, 1255957. doi: 10.1126/science.1255957

Guerrero-Padilla, A., Florián-Florián, J., and Florián-Guerrero, J. (2013). Uso de fertilizantes y plaguicidas en el distrito de Poroto, Trujillo-La Libertad, 2013. *SCIÉNDO.* 16 (1), 91–102. Available online at: https://revistas.unitru.edu.pe/index.php/SCIENDO/es/article/view/634/pdf_8 (Accessed March 10, 2026).

Hayayumi, M. L. (2017). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/2466 (Accessed March 7, 2025).

Heard, T. A. (1994). Behaviour and pollinator efficiency of stingless bees and honey bees on macadamia flowers. *J. Apic. Res.* 33, 191–198. doi: 10.1080/00218839.1994.11100870

Iglesias, A. (2007). (Universidad Nacional Agraria La Molina). Available online at: https://hdl.handle.net/20.500.12996/3661 (Accessed January 8, 2025).

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (2016). The Assessment Report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services on Pollinators, Pollination and Food Production (Bonn, Germany: Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services). Available online at: https://files.ipbes.net/ipbes-web-prod-public-files/downloads/pdf/individual_chapters_pollination_20170305.pdf (Accessed January 5, 2026).

Jezeer, R. E., and Verweij, P. A. (2015). Shade grown coffee—Double dividend for biodiversity and small-scale coffee farmers in Peru (The Hague, The Netherlands: Hivos). Available online at: https://www.researchgate.net/profile/Rosalien-Jezeer/publication/301694173_Shade_grown_Coffee-_Double_dividend_for_biodiversity_and_small-scale_farmers_in_Peru/links/57231dcc08ae262228a88332/Shade-grown-Coffee-Double-dividend-for-biodiversity-and-small-scale-farmers-in-Peru.pdf (Accessed June 23, 2026).

Kent, R. B. (1989). The African honeybee in Peru: An insect invader and its impact on beekeeping. *Appl. Geogr.* 9, 237–257. doi: 10.1016/0143-6228(89)90026-X

Keyser, P., Buehler, D., Fike, J., Finke, D., Fuhlendorf, S., Martin, J., et al. (2022). The birds and the bees: Producing beef and conservation benefits on working grasslands. *Agronomy* 12, 1934. doi: 10.3390/agronomy12081934

Kimoto, C., DeBano, S. J., Thorp, R. W., Taylor, R. V., Schmalz, H., DelCurto, T., et al. (2012). Short-term responses of native bees to livestock and implications for managing ecosystem services in grasslands. *Ecosphere* 3, 88. doi: 10.1890/ES12-00118.1

Kumar, G., and Khan, M. S. (2023). “Insects as crop pollinators,” in *Insects as Service Providers*. Ed. Omkar, (Springer, Singapore), 37–64. doi: 10.1007/978-981-19-3406-3_3

Landaverde, R., Rodriguez, M. T., and Parrella, J. A. (2023). Honey production and climate change: Beekeepers' perceptions, farm adaptation strategies, and information needs. *Insects* 14, 493. doi: 10.3390/insects14060493

Leiva, L. A., Díaz, A. P., Hurtado, C. A., Rodriguez, R., Contreras, M., and Rodríguez, J. C. (2021). Activación de trampas Sundance y la producción de polen en Apis mellifera L. *Arnaldoa* 28, 625–632. Available online at: https://www.scielo.org.pe/pdf/arnal/v28n3/2413-3299-arnal-28-03-625.pd

León, F. (2008). (Universidad nacional del Centro del Perú). Available online at: http://hdl.handle.net/20.500.12894/2929 (Accessed May 12, 2024).

López, S. A. (2014). (Universidad Nacional de la Amazonía Peruana). Available online at: http://repositorio.unapiquitos.edu.pe/handle/20.500.12737/3963 (Accessed October 16, 2025).

Mamani, G., García, A., and Durand, F. (2013). Manejo y utilización de praderas naturales en la zona altoandina (Lima, Peru: Instituto Nacional de Innovación Agraria (INIA). Available online at: http://repositorio.inia.gob.pe/handle/20.500.12955/755 (Accessed June 13, 2026).

Marconi, M., Ramírez, D. U., Mendoza, A. C., Vecco-Giove, C. D., Luna, J. O., Baikova, L., et al. (2023). An updated molecular phylogeny of the stingless bees of the genus Trigona (Hymenoptera, Meliponini) of the northern Peruvian forests. *J. Hymen. Res.* 96, 751–760. doi: 10.3897/jhr.96.105311

Marroquín, T. A. (2014). (Universidad Nacional del Centro del Perú). Available online at: https://repositorio.uncp.edu.pe/server/api/core/bitstreams/16761a42-dc08-4652-95d0-f61dfe2de087/content (Accessed March 2, 2026).

Medina, B., and Ccoñas, R. (2018). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/10914 (Accessed December 12, 2025).

Mejía, K. (2017). (Universidad Nacional de Cajamarca). Available online at: https://repositorio.unc.edu.pe/handle/20.500.14074/1679 (Accessed May 8, 2026).

Ministerio de Desarrollo Agrario y Riego (MIDAGRI) (2017). Plan Nacional De Desarrollo Ganadero 2017–2027 (Lima, Peru: Ministerio de Desarrollo Agrario y Riego). Available online at: https://www.midagri.gob.pe/portal/download/pdf/dg-ganaderia/plan-nacional-ganadero-2017-2027.pdf (Accessed June 15, 2026).

Ministerio del Ambiente (MINAM) (2009). Mapa De Deforestación De La Amazonía Peruana – 2000. Available online at: https://sinia.minam.gob.pe/documentos/mapa-deforestacion-amazonia-peruana-2000 (Accessed January 5, 2026).

Ministerio del Ambiente (MINAM) (2010). Mapa De Pastos Altoandinos 2010 (Lima, Peru: Ministerio del Ambiente). Available online at: https://sinia.minam.gob.pe/mapas/mapa-pastos-altoandinos-2010 (Accessed June 18, 2026).

Mishra, A., Afik, O., Cabrera, M. L., Delaplane, K. S., and Mowrer, J. E. (2013). Inorganic nitrogen derived from foraging honey bees could have adaptive benefits for the plants they visit. *PloS One* 8, e70591. doi: 10.1371/journal.pone.0070591

Montes, A., Minaya, D., and Iannacone, J. (2023). Impact of pesticides on the arthropofauna associated with potato (Solanum tuberosum) cultivation in Cusco, Peru. *Rev. la Sociedad Entomològica Argent.* 82, 404–413. doi: 10.25085/rsea.820404

Morillo, M. A. (2015). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/9008 (Accessed July 21, 2025).

Murga-Moreno, C. A., Vargas-Rocha, L., Chávez-Farro, M., Hobán-Vergara, C., and Ortiz-Oblitas, P. (2021). Prevalencia de Varroa spp. correlacionada al factor productivo y temperamental en el apiario de la Universidad Nacional de Cajamarca, Perú. *Rev. Investigaciones Veterinarias del Perú* 32, e18845. doi: 10.15381/rivep.v32i3.18845

Mutavi, D., Liang, H., Ochola, A., Lv, M., Wang, Q.-F., and Yang, C.-F. (2022). Pollinator diversity benefits natural and agricultural ecosystems, environmental health, and human welfare. *Plant Divers.* 44, 429–435. doi: 10.1016/j.pld.2022.01.005

Nemésio, A., and Rasmussen, C. (2014). Sampling a biodiversity hotspot: The orchid-bee fauna (Hymenoptera: Apidae) of Tarapoto, northeastern Peru, the richest and most diverse site of the Neotropics. *Braz. J. Biol.* 74, S33–S44. doi: 10.1590/1519-6984.20412

Nestares, A. R. (2023). (Universidad Nacional del Centro del Perú). Available online at: http://hdl.handle.net/20.500.12894/9203 (Accessed July 2025).

Newson, L. A. (2018). Piety, beeswax and the Portuguese African slave trade to Lima, Peru, in the early colonial period. *Atlantic Stud.* 16, 144–162. doi: 10.1080/14788810.2018.1434284

Noé, C. (2015). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/1617 (Accessed November 24, 2025).

Öckinger, E., and Smith, H. G. (2007). Semi-natural grasslands as population sources for pollinating insects in agricultural landscapes. *J. Appl. Ecol.* 44, 50–59. doi: 10.1111/j.1365-2664.2006.01250.x

Oré, J. C. (2016). (Universidad Nacional Agraria La Molina). Available online at: https://hdl.handle.net/20.500.12996/2850 (Accessed December 5, 2025).

Ormeño, J., Castillo, T., Garay, R., and Vallejos, G. (2021). Calidad de miel producida por "abejas nativas" (Meliponini) en la región San Martín, Perú. *Arnaldoa* 28, 139–148. Available online at: https://www.scielo.org.pe/pdf/arnal/v28n1/2413-3299-arnal-28-01-139.pdf.

Owusu, M., and Skevas, T. (2024). Adoption and intensity of use of personal protective equipment by agricultural pesticide handlers: Empirical evidence from Peruvian agriculture. *J. Cleaner Prod.* 446, 141433. doi: 10.1016/j.jclepro.2024.141433

Paredes, R., and Bryant, V. M. (2019). Pollen analysis of honey samples from the Peruvian Amazon. *Palynology* 44, 344–354. doi: 10.1080/01916122.2019.1604447

Párraga, N. (2018). (Universidad Nacional del Centro del Perú). Available online at: http://hdl.handle.net/20.500.12894/4789 (Accessed October 5, 2025).

Pasco, G. A., and Sánchez, F. R. (2010). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/2629 (Accessed February 8, 2026).

Pérez-Castro, E. E., May-Itzá, W. D. J., and Quezada-Euán, J. J. G. (2002). Thirty years after: A survey on the distribution and expansion of Africanized honey bees (Apis mellifera) in Peru. *J. Apic. Res.* 41, 69–73. doi: 10.1080/00218839.2002.11101071

Peters, C., and Vasquez, A. (1987). Estudios ecológicos de camu-camu (Myrciaria dubia). I. Producción de frutas en poblaciones naturales. *Acta Amazonica* 16–17, 161–174. doi: 10.1590/1809-43921987171174

Picón, L. M. (2024). (Universidad Nacional de Cajamarca). Available online at: https://repositorio.unc.edu.pe/handle/20.500.14074/6252 (Accessed October 13, 2025).

Polo, J. L., Alvarado, J. C., and Valderrama, S. M. (2022). Determinación del índice de infestación por Varroa destructor en colonias de Apis mellifera, en condiciones naturales. *Rev. Ambiente Comportamiento Y. Sociedad* 5, 55–68. doi: 10.51343/racs.v5i1.799

Porras, E. (2023). (Universidad Nacional del Centro del Perú). Available online at: http://hdl.handle.net/20.500.12894/10233 (Accessed July 11, 2025).

Potts, S. G., Biesmeijer, J. C., Kremen, C., Neumann, P., Schweiger, O., and Kunin, W. E. (2010). Global pollinator declines: trends, impacts and drivers. *Trends Ecol. Evol.* 25, 345–353. doi: 10.1016/j.tree.2010.01.007

PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (2020). guidelines PRISMA 2020. Available online at: https://www.prisma-statement.org/prisma-2020?utm_source=chatgpt.com (Accessed December 8, 2025).

Quevedo, T., Gastulo, J., and Santa Cruz, A. (2022). Elaboración de una barra alimenticia de kiwicha, polen y miel de abeja. *Rev. Investigación Científica Y. Tecnológica Llamkasun* 3, 130. doi: 10.47797/llamkasun.v3i1.92

Rasmussen, C. (2009). Diversity and abundance of orchid bees (Hymenoptera: Apidae, Euglossini) in a tropical rainforest succession. *Neotrop. Entomol.* 38, 66–73. doi: 10.1590/S1519-566X2009000100006

Rasmussen, C., and Sánchez, E. (2024). Taxonomic impediment for conservation: The case of bees in an undersampled tropical mid-elevation site, San Martín, Peru. *Insects* 15, 544. doi: 10.3390/insects15070544

Reddy, P. V. R., Rajan, V. V., Mani, M., Kavitha, S. J., and Sreedevi, K. (2022). "Insect pollination in horticultural crops," in *Trends in Horticultural Entomology*. Ed. M. Mani (Springer, Singapore). doi: 10.1007/978-981-19-0343-4_15

Requier, F., Antúnez, K., Morales, C. L., Aldea Sánchez, P., Castilhos, D., Garrido, P. M., et al. (2018). Trends in beekeeping and honey bee colony losses in Latin America. *J. Apic. Res.* 57, 657–662. doi: 10.1080/00218839.2018.1494919

Reyes, F. R. (2016). (Universidad Nacional Agraria La Molina). Available online at: https://hdl.handle.net/20.500.12996/2755 (Accessed August 30, 2025).

Reyes, E. (2023). (Universidad Nacional de Trujillo). Available online at: https://hdl.handle.net/20.500.14414/18188 (Accessed June 5, 2025).

Rick, C. M. (1958). The role of natural hybridisation in the derivation of the cultivated tomatoes of western South America. *Econ. Bot.* 12, 346–367. doi: 10.1007/BF02860023

Rojas, C. (2014). (Universidad Nacional de Cajamarca). Available online at: http://hdl.handle.net/20.500.14074/406 (Accessed July 19, 2025).

Rojas, E., Zutta, B. R., Velazco, Y. K., Montoya-Zumaeta, J. G., and Salvà-Catarineu, M. (2021). Deforestation risk in the Peruvian Amazon basin. *Environ. Conserv.* 48, 310–319. doi: 10.1017/S0376892921000291

Rubiños, Y. (2014). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/795 (Accessed July 6, 2025).

Saavedra, K. I., Rojas, C., and Delgado, G. E. (2013). Características polínicas y composición química del polen apícola colectado en Cayaltí (Lambayeque, Perú). *Rev. Chil. Nutrición* 40, 71–78. doi: 10.4067/S0717-75182013000100011

Samaniego, M. (2019). Incidencia de los gastos de ventas de la miel de abeja en la rentabilidad de la empresa Camayo que opera en los departamentos de Junín y Huancavelica 2014–2015. *Strategy* 1, 58–65. Available online at: http://hdl.handle.net/20.500.12894/5368.

Sánchez, A. (2021). (Universidad Nacional de Cajamarca). Available online at: http://hdl.handle.net/20.500.14074/4247 (Accessed August 9, 2025).

Shahmshad, A. K. (2023). Review of the role of bees as ecosystem engineers in nature. *Sci. Rev. Biol.* 2, 1–6. doi: 10.57098/SciRevs.Biology.2.4.1

Smith, G. W., Debinski, D. M., Scavo, N. A., Lange, C. J., Delaney, J. T., Moranz, R. A., et al. (2016). Bee abundance and nutritional status in relation to grassland management practices in an agricultural landscape. *Environ. Entomol.* 45, 338–347. doi: 10.1093/ee/nvw005

Soto, C., Jiménez, W., Pérez-Almeida, I., and Marín, C. (2024). Prediction of high Andean grasslands biomass in the upper zone of the National Sanctuary of Ampay, Peru, for promoting adequate management of natural grasslands. *J. Sustain. Dev.* 12, 1120503. doi: 10.13044/j.sdewes.d12.0503

Sousa, F., Pinto, C. E., de Brito, R. M., Imperatriz-Fonseca, V. L., and Giannini, T. C. (2021). Edible fruit plant species in the Amazon forest rely mostly on bees and beetles as pollinators. *J. Econ. Entomol.* 114, 710–722. doi: 10.1093/jee/toaa284

Srilipta, S. S., Panda, S., Bhoi, P., and Choudhary, S. (2024). Beekeeping development for sustainable production, environmental monitoring and environmental threats. *Futuristic Trends in Agriculture Engineering & Food Sciences*. 3, V3B24P1C2. doi: 10.58532/V3BCAG24CH2

Tanda, A. (2022). Wild bees and their conservation. *Indian J. Entomol.* 84, 726–736. doi: 10.55446/IJE.2021.64

Taylor, O. R.Jr. (1977). The past and possible future spread of Africanized honeybees in the Americas. *Bee World* 58, 19–30. doi: 10.1080/0005772X.1977.11097632

Tejada, G., and Morón, M.Á. (2015).Exceptional observations on species of Gymnetis (Coleoptera: Cetoniidae) in honey bee hives (Hymenoptera: Apidae) in Peru. Available online at: https://www.scielo.org.mx/pdf/azm/v31n1/v31n1a27.pdf (Accessed May 12, 2026).

Tejada-Purizaca, T. R., García-Chevesich, P. A., Ticona-Quea, J., Martínez, G., Martínez, K., Morales-Paredes, L., et al. (2024). Bioaccumulation of heavy metals in Peruvian foods and medicines. *Foods* 13, 762. doi: 10.3390/foods13050762

Tello, C. Y. (2022). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/9506 (Accessed June 9, 2025).

Tovar, C., Duivenvoorden, J., Sánchez-Vega, I., and Seijmonsbergen, A. (2012). Recent changes in patch characteristics and plant communities in the Jalca grasslands of the Peruvian Andes. *Biotropica* 44, 321–330. doi: 10.1111/j.1744-7429.2011.00820.x

Valladolid, M., Chapoñan, H. W., Seminario, R. G., Labán, P. G., Díaz, N., Deza, C. A., et al. (2022). Abejas nativas sin aguijón en Tumbes, Perú: Caracterización genómica y comunidad bacteriana. *Manglar* 19, 153–159. doi: 10.17268/manglar.2022.019

Vanbergen, A. J., and Insect Pollinators Initiative (2013). Threats to an ecosystem service: pressures on pollinators. *Front. Ecol. Environ.* 11, 251–259. doi: 10.1890/120126

van der Sluijs, J. P., and Vaage, N. S. (2016). Pollinators and global food security: The need for holistic global stewardship. *Food Ethics* 1, 75–91. doi: 10.1007/s41055-016-0003-z

Vansynghel, J., Thomas, E., Ocampo-Ariza, C., Maas, B., Ulloque-Samatelo, C., Zhang, D., et al. (2023). Cross-pollination with native genotypes improves fruit set and yield quality of Peruvian cacao. *Agric. Ecosyst. Environ.* 357, 108671. doi: 10.1016/j.agee.2023.108671

Vásquez, P. G. (2024). (Universidad Privada Antenor Orrego). Available online at: https://hdl.handle.net/20.500.12759/31651 (Accessed August 7, 2025).

Vega, J. (2024). (Universidad Nacional de Cajamarca). Available online at: http://hdl.handle.net/20.500.14074/6872 (Accessed May 14, 2025).

Vela, S. P. (2019). (Universidad Nacional de la Amazonía Peruana). Available online at: http://repositorio.unapiquitos.edu.pe/handle/20.500.12737/6542 (Accessed January 2025).

Velazco, A. (2006). (Universidad Nacional del Centro del Perú). Available online at: http://hdl.handle.net/20.500.12894/2950 (Accessed September 7, 2025).

Verano, G. (2023). (Universidad nacional del Centro del Perú). Available online at: http://hdl.handle.net/20.500.12894/9601 (Accessed May 18, 2024).

Wendee, N. (2015). Pollinator power: Nutrition security benefits of an ecosystem service. *Environ. Health Perspect.* 123, A21–A23. doi: 10.1289/ehp.123-A21

Yancce, J. E. (2021). (Universidad Nacional Agraria La Molina). Available online at: https://hdl.handle.net/20.500.12996/4657 (Accessed June 11, 2025).

Yaranga, R., Pizarro, S., Cano, D., Cosme, F., Zapata, C., and Orellana, J. A. (2024). Determining the composition, floristic diversity, and value of ecological importance in Andean grassland ecosystems according to the altitudinal gradient in the Huacracocha micro-watershed, Peru. *Innov. Biol. Sci.* 2, 42–62. doi: 10.9734/bpi/ibs/v2/3407G

Yilmaz, M., Gültekin, Y., and Gültekin, P. (2023). Evaluation of honey bees within the scope of sustainable development goals and ecosystem services. *Düzce Univ. J. Sci. Technol.* 5, 2397–2408. doi: 10.29130/dubited.1383016

Zavaleta-Rengifo, A., Lozano-Lévano, C., and Villaseca-Robertson, A. (2022). Evaluación microbiológica de la vida útil de néctar de durazno con propóleo como conservante natural. *Biotempo* 19, 177–184. doi: 10.31381/biotempo.v19i2.4843

Zhao, H., Mashilingi, S. K., Liu, Y., and An, J. (2021). Factors influencing the reproductive ability of male bees: Current knowledge and further directions. *Insects* 12, 529. doi: 10.3390/insects12060529