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Ecosystem Services and Sustainability of Kelulut Stingless Beekeeping

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Abstract

Kelulut stingless bees play a crucial role as pollinators for numerous crops. Since cultivating honey can contribute to food security and promote sustainable agricultural practices, it is thus essential to identify the ecosystem services provided by kelulut stingless beekeeping for sustainable honey farming. A comprehensive literature review was conducted with the aim of (1) identifying the ecosystem services associated with kelulut stingless beekeeping and (2) determining the factors influencing its sustainability. The literature review used two search databases, Google Scholar and ScienceDirect, with relevant keywords, and the findings were summarized and interpreted by referring to recent studies. Additionally, a SWOT analysis was conducted to assess the factors influencing the sustainability of Kelulut stingless beekeeping. It was revealed that there are three main ecosystem services of stingless bee keeping: provisioning services (honey products), regulating services (pollination, impact on the food chain, and biodiversity), and cultural functions (tourism and education). The sustainability of ecosystem services provided by kelulut stingless beekeeping depends on several factors, such as the strength of the local community, farmers' skills, and biodiversity, as indicated in the SWOT analysis table. This paper provides valuable insights for future studies, aiding in developing sustainable management strategies for stingless bee colonies and enhancing their productivity based on the characteristics of ecosystem services and their influencing factors.

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INTRODUCTION

Ecosystem services encompass the goods and services, including the biotic and abiotic, as components of nature, directly enjoyed, consumed or used, to yield human well-being (Hein et al., 2006). These services are categorized into three main types: provisioning services (such as food, materials, and energy), regulating services (including water purification and pollination), and cultural functions (involving human enjoyment and aesthetic values) (Fitter et al., 2010; Haines-young & Potschin, 2018; Ranganathan et al., 2008). Understanding the roles and functions of ecosystem services is important for conservation efforts, spatial planning, and environmental assessment to ensure sustainable development and ecosystem protection (Affek, 2018).

Non-Timber Forest Products (NTFP) cultivation products are strongly related to sustainable development and ecosystem protection principles. One such product is kelulut stingless beekeeping, which plays a unique role in ecosystem services, especially pollination. Stingless bee pollination contributes to high-quality honey production for human consumption and natural vegetative propagation. Bees of all sorts pollinate approximately 75 percent of global plants essential for human food (Norris et al., 2010). This fact highlights the significance of bees not only for the conservation of plants and animals but also for long-term food production (Easton-Calabria et al., 2019; Huryn, 1997).

Stingless wild bees of various species are known as pollinators of many wild plant species and honey producers. Different types of honey, including honey bees (*Apis* spp.), stingless bees (*Melipona* and *Trigona* spp.), nectar wasps, and certain species of honey ants, are produced by certain bees and insects as their pollinators (Resh & Cardé, 2009). Among these, honey bees (*Apis* spp.) and stingless bees (*Melipona* and *Trigona* spp.) are considered as the main pollinators. As a widely-cultivated type of bee for honey production, honey bees have been extensively studied. In a similar vein, stingless bees, which are locally known as Kelulut, are also commonly cultivated. Although generally producing less honey, they compensate with their propolis production, which is claimed to be six times more abundant than that of honey bees (*Apis* spp.) (Brown et al., 2020; Kothai & Jayanthi, 2015). The bioactive components of propolis produced by stingless bees and the phenolic compounds, flavonoids, and vitamin C found in honey are believed to have therapeutic effects and high economic value.

Stingless bees, locally known as "Kelulut" in the Indo-Malaya region, are one of the most widely distributed bees that can be found almost in every continent. Indonesia's largest population of stingless bees is found on the island of Kalimantan (Norowi et al., 2010; Wahyuningtyas et al., 2021). The *Kelulut* group mostly consists of various stingless bee species, including *Trigona apicalis, T. drescheri, T. fuscibasis,* *T. fuscobalteata, T. insica, T. itama, T. laeviceps, T. melina,* and *T. Terminate* (Syafrizal et al., 2012).

There has been a growing interest among farmers in cultivating kelulut stingless bees due to their easier management compared to that of honey bees (*Apis* spp.), which require more specialized care (Roubik, 2006; Wahyuningtyas et al., 2021). Of the aforementioned various species of stingless bee, *Trigona itama* is the most commonly raised species by farmers in Indonesia and Malaysia (Wahyuningtyas et al., 2021). Malaysia has made significant financial gain from the trade of honey commodities produced by *Trigona itama* cultivation, leading to the expansion of stingless bee farming (Norowi et al., 2010).

While previous studies on *kelulut* stingless bees have mainly focused on the nutritional properties (Martínez-Puc et al., 2022; Nordin et al., 2018) and chemical compounds (Agussalim et al., 2022; de Melo et al., 2020; Isidorov et al., 2023) found in their honey products as well as the important roles of various related elements (Biluca et al., 2017; Ranneh et al., 2018), there have been few studies on the role of *kelulut* beekeeping in ecosystem services, particularly in terms of provisioning services, regulating services, and cultural functions. Existing studies on ecosystem services of bee species predominantly focus on honey bees (*Apis* spp.) (Ghosh et al., 2020), but only limited information is available on stingless bees (*Kelulut*).

Understanding the ecosystem services that *kelulut* stingless beekeeping provides is crucial for their conservation within the broader ecosystem. Given the scarcity of references discussing the ecosystem services of stingless bees, an initial study is necessary to map out the roles and functions of *kelulut* beekeeping to establish its position in the current research landscape. This study aims to fill in the gap in the ecosystem services of *Kelulut* bees in order to identify the ecosystem services associated with *kelulut* honey beekeeping and determine some influential factors in its sustainability.

RESEARCH METHODS

The research is a desk review using a thematic analysis of the existing literature to achieve the research objectives (Cooper, 1998; Randolph, 2009; Snyder, 2019). This approach was selected given its alignment with the initial research objective of exploring the current state of stingless bee "Kelulut" ecosystem services, which could serve as a primary reference for future research. A literature review was employed to gather various references concerning *Kelulut* bees from two credible secondary data repositories: Google Scholar and ScienceDirect. The collected articles address Kelulut ecosystem services and important topics interconnected with the main topic. The collected articles were subsequently analyzed descriptively and narratively by referring to the procedure of the desk review as recommended by Samnani et.al (2017), encompassing the following steps:

a. Framing the Review Question: This initial step identifies the problem and develops constructive research objectives.
b. Relevant Literature Search: The literature search and exploration of relevant references with the research objectives were performed by employing pre-defined keywords and vocabulary. The literature and reference were selected using inclusion and exclusion criteria by primarily focusing on data directly related to the research problem and objectives.

c. Quality Assessment in Literature Review: The collected data and references were evaluated in terms of their validity and relevance to the research problem and objectives in order to ensure their contribution to the substance and essence of the study.
d. Summarizing Evidence: During this stage, the researcher engaged in studying, examining, filtering, analyzing, establishing boundaries and parameters, mapping the substance, and constructing significant findings related to the research problem. This activity particularly involved summarizing key information into tables, textual representations, or graphics.
e. Interpreting Findings: The final step aims to develop research findings, rephrase the substance, systematically present the findings, and make recommendations for future research. Figure 1 below shows a concise illustration of the literature review procedures that were adapted from Samnani et al. (2017).

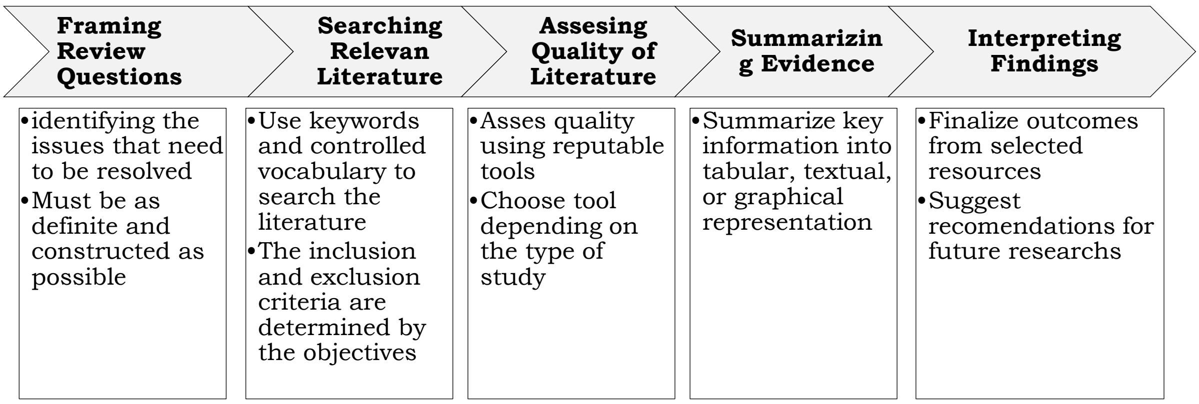

Figure 1. Stages in conducting the review

SWOT method was applied as an additional analysis to identify some factors affecting the sustainability of *Kelulut* stingless beekeeping. It was also intended to elaborate the strengths, weaknesses, opportunities and threats of the ecosystem services of Kelulut stingless beekeeping, based on evidence from previously published research (secondary data). The data were presented descriptively and narratively by way of outlining the research findings, presenting analysis, and comparing the findings with relevant additional literature.

RESULTS AND DISCUSSION

Identification of Kelulut Stingless Beekeeping Ecosystem Services

A careful examination of various literature articles obtained from Google Scholar and ScienceDirect databases using some targeted keywords such as “Kelulut honey”, “stingless bees” and “ecological benefits”, generated the following three categories of classification, summary of the relevant information and some groups of ecosystem services of stingless beekeeping: supply/provisioning services, biological process/regulating services and cultural functions, as presented in Figure 2.

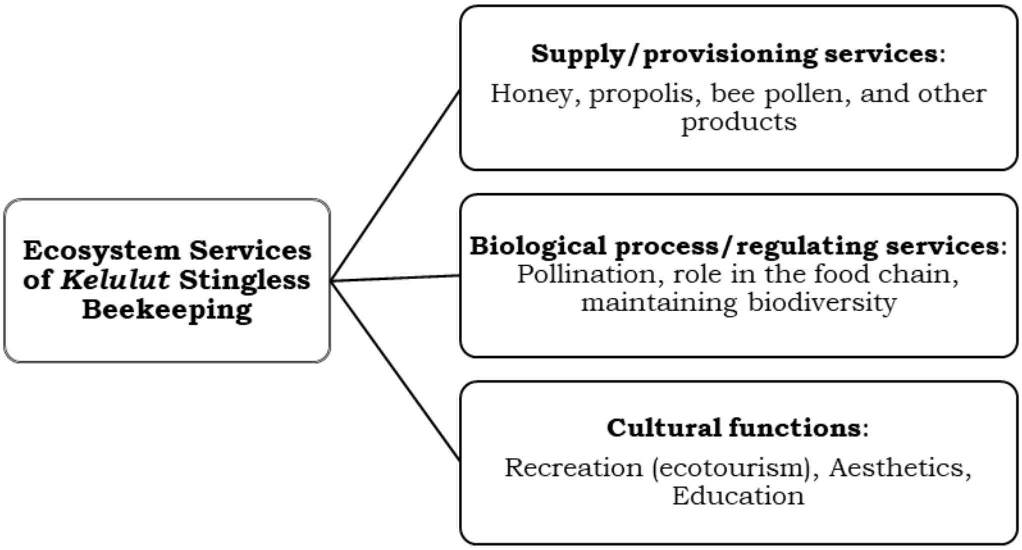

Figure 2. Ecosystem Services of Kelulut Stingless Beekeeping

a. *Provisioning Services*

In terms of provisioning services, stingless beekeeping has been significantly producing natural products that are highly beneficial to humans. These products include honey, royal jelly, propolis, bee pollen, beeswax, and bee venom (Ichwan et al., 2016). Stingless bee honey is a distinctive product given its active compounds, such as saponins, flavonoids, and phenols (Santos et al., 2021) but lacks alkaloids, tannins, triterpenoids, and steroids (Adalina et al., 2020). Stingless bee honey also contains various antioxidant, antimicrobial and immunomodulatory compounds (Ahmad Tarmizi Wan Yusop et al., 2019; Tuksitha et al., 2018; Villacrés-Granda et al., 2021) as well as other essential compounds such as carbohydrates, vitamins, minerals, enzymes, organic compounds, free amino acids and volatile compounds that contribute to its color, aroma and flavor (Pavlova et al., 2018). There are numerous factors to influence the nutritional content and beneficial compounds in honey production by stingless bees, including environmental quality, food sources for honey bees (nectar sources), climate fluctuations, honey maturity level, and processing and storage processes (Fitrianingsih et al., 2014; Pavlova et al., 2018).

In addition to these factors, stingless bees' habitat plays a crucial role in honey production. The suitable and strategic landscape as a habitat for stingless bees to obtain sufficient food sources greatly affect colony growth (Roubik, 2006; Wahyuningtyas et al., 2021). Landscapes or areas where bees can find flora as food sources can contribute to colony growth, especially if the preferred flora species have desirable nectar content (Wahyuningtyas et al., 2021). The rubber plant is an excellent nectar supplier for stingless bees (Adalina et al., 2020).

Stingless bees also generate more propolis than regular honey bees (Wasiaturrahmah et al., 2022). Propolis is recognized as an exceptional product with numerous pharmacological activities since its diverse chemical composition allows can serve as an antioxidant, antibacterial, anticancer, antifungal, anti-inflammatory, antiviral, antidiabetic, and antitumor agent (Ibrahim et al., 2016).

b. *Regulating Services*

The biological processes or regulating services are essential for the reproduction of most plants worldwide. Stingless bees play a vital role in pollination and help plants reproduce reliably. These services improve agricultural landscapes in various regions, including Germany (Kuppler et al., 2023).

Regulating services can be divided into pollination, food chain, and biodiversity. Bees, particularly social bees such as stingless bees, are widely recognized as the most important pollinators in the world (Danforth et al., 2006). Social bees have a broader range for finding food than solitary bees (Grüter & Hayes, 2022), implying that their pollination services contribute to the natural landscape expansion. Bees are effective pollinators as they primarily rely on floral resources for food (Easton-Calabria et al., 2019) and have branched hairs on their bodies that facilitate efficient attachment and transport of pollen grains (Stavert et al., 2016).

When stingless bees forage for food, which mainly consists of pollen from flowers, they indirectly act as pollinators for those flowers (Bąk-Badowska et al., 2019; Kuppler et al., 2023; Meléndez-Ramirez et al., 2018). This indirect pollination also affects the characteristics of the honey they produce (Rahman et al., 2019; Syafrizal et al., 2020, 2012).

Stingless bees in Indonesia gather nectar and pollen from various flowering plants, including the kapok tree (*Ceiba pentandra*), rubber tree (*Hevea braziliensis*), rambutan tree (*Nephelium lapaceum*), coffee plant (*Coffea sp.*), calliandra (*Caliandra calothyrsus*), and rosewood (*Dalbergia* sp.), to produce honey (Widiarti & Kuntadi, 2012). The quality of the honey varies and can be determined by its color, and darker honey will be more acidic (Syafrizal et al., 2020).

In their specific environment, stingless bees, which are prey for various predators (including *Ectatomma tuberculatum*), reflect their vulnerability in the food web. In addition, lonchura birds and ants are known to also prey on stingless bees (Janra et al., 2021; Syafrizal et al., 2020), with ants ambushing them at the entrance of their nests (Ostwald et al., 2018). Other predators include dragonflies, certain wasps, spiders, frogs, lizards, birds, and monkeys (Kofi et al., 2010).

Stingless bees also play a crucial role in biodiversity protection. Their pollination function assists the natural vegetative propagation, indirectly contributing to the preservation of biodiversity. Stingless bees visit various plants, including grasses, trees, shrubs, climbing plants, and lianas, as well as economically important crops, timber plants, fiber plants, medicinal plants, and ornamental plants (Roubik, 2006; Wahyuningtyas et al., 2021) . They are even observed approaching exotic plant species alongside the local vegetation that serves as their food source (Bąk-Badowska et al., 2019; Pavlova et al., 2018; Wahyuningtyas et al., 2021). The diversity of plants used as food sources by various stingless bee species is evident from records of their visits to wild plants worldwide, including 535 plant genera for *Trigona spinipes* and *Meliponini* in general (Roubik, 2006; Wahyuningtyas et al., 2021).

c. *Cultural Functions*

In addition to providing resources and helping with natural processes, stingless beekeeping has a favorable impact on culture. This is achieved through intangible services that are used in tourism and education. In terms of education, stingless beekeeping can provide the community with valuable knowledge about farming techniques, processing methods, and the important role of these bees in the ecosystem (Nugraha, 2021). It can also help expand the understanding of the general public, students, and scientists about the significance of stingless bees in a broader ecological context.

In the tourism industry, the unique characteristics of stingless bees and their products can attract visitors to engage in educational tours to villages or locations where these bees are cultivated. This fact can generate a positive economic impact on the community and beekeepers, improving the livelihoods of stingless bee farmers and the overall economic well-being of the village (Ghosh et al., 2020; Lestari et al., 2020; Purboyo et al., 2022; Sidabutar et al., 2022). In the future, there is potential to develop stingless beekeeping as Entomotourism, a type of tourism that allows visitors to interact with and learn more about these bees by visiting cultivation sites, reading informational boards, and participating in guided hikes (Lemelin, 2020).

Sustainability of Ecosystem Services of Kelulut Stingless Beekeeping

In this study, besides identifying the ecosystem services provided by stingless beekeeping, the strengths, weaknesses, opportunities, and threats related to the sustainability of this ecosystem service were also identified through a SWOT analysis. The results of this identification are presented in Table 1 below.

Table 1. SWOT Analysis of Stingless Beekeeping Ecosystem Services

Strengths	***Weaknesses***
1. Serving as social capital of the local community 2. Being easy to maintain 3. Requiring well-trained farmers 4. Can be done alongside crop cultivation 5. Providing numerous beneficial honey products *6.* Having stable prices	1. Internal conflict issues 2. The lack of capacity building (outdated production tools, limited cultivation techniques, and lack of focus in the community) 3. 3. Conservation and further study issues
Opportunities	***Threats***
1. Generating local government support 2. The high economic value of honey products 3. Therapeutic properties *4.* Increasing consumer demand	1. Predators of stingless bees 2. Natural competition with other bees for food sources 3. Population growth 4. Climate factors

The sustainability of a cultivation activity should be assessed based on two main factors: (1) the ability of farmers and the rural community to manage cultivation activities and (2) how environmental resources can support sustainable production that can be renewed. It is important to thoroughly examine the capacity of the farming community and evaluate its impact on the biodiversity conservation.

According to Febriani dan Saputra (2018), social support within the community plays a crucial role in farmers' capacity to sustain the stingless beekeeping ecosystem. Well-trained farmers with a good understanding of maintaining stingless bees are considered essential for the sustainability of this activity. The pollination function provided by stingless bees is also strategically important for environmental support and the sustainability of cultivation (Norowi et al., 2010).

However, both aspects have not reached the desired level because stingless bee farmers in some areas still lack the expected capacity. Internal conflicts within the community are also pervasive, besides the farmers' lack of the necessary skills and resources for cultivating stingless bees. Outdated tools, limited techniques, and poor planning contribute to these challenges (Febriani & Saputra, 2018; Norowi et al., 2010; Pribadi et al., 2020). Additionally, there is a lack of comprehensive understanding regarding the biology, ecology, and behavior of stingless bees (Norowi et al., 2010), making it difficult to fully grasp the relationship between cultivation and conservation efforts.

There are several opportunities to optimize the benefits of cultivation and the pollination function of stingless bees. These include developing technology, innovating methods, and enhancing the skills of farmers in domesticating stingless bee species. Analyzing the bees' food requirements to maximize their pollination function, preserving the diversity of stingless bees through landscape management, and raising public awareness through promotion are also crucial for ecosystem preservation and the conservation of living creatures, including stingless bees (Norowi et al., 2010).

Furthermore, integrating stingless beekeeping with agricultural ecosystems can support plant pollination, promoting ecosystem conservation and sustainable cultivation practices (Adam et al., 2020). Proper measures should be taken to control predatory threats such as cockroaches, beetles, and ants, as well as address natural competition with other bee species for food sources to ensure the sustainability of stingless beekeeping in agricultural ecosystems (Janra et al., 2021; Ostwald et al., 2018; Rahman et al., 2019; Roubik, 1978, 1980). Care should be taken when using pesticides in agriculture, as stingless bees are highly vulnerable to their effects compared to other bee species (Arena & Sgolastra, 2014). Pesticide exposure can affect bee foraging behavior, reducing the honey production in quantity and quality (Stuligross et al., 2023).

Additionally, changes in land use, agricultural intensification, and climate can impact population growth of bees. Sunlight radiation, temperature, humidity, light, and rainfall intensity are among the climate factors that need to be considered (Astolfi et al., 2022; Buchori et al., 2020; Salatnaya et al., 2020; Souza-Junior et al., 2019; Straub et al., 2022).

CONCLUSION

This literature review seeks to generate a comprehensive summary of the Kelulut stingless bee studies. This summary can advance scientific knowledge and developing sustainable strategies for cultivating Kelulut honey. From the literature review, it is clear that stingless bees have an important role in vegetative propagation, biodiversity protection, and provision of high-quality food, which are ecosystem services provided by cultivation. These services can be categorized into three aspects: (1) Provisioning services, where stingless beekeeping produces honey and propolis, which both generate health benefits; (2) Regulating services, where stingless beekeeping acts as an artificial ecosystem that enhances pollination, supports the food chain, and contributes to biodiversity conservation; and (3) Cultural functions, where cultivating stingless bees serves as ecotourism and an educational opportunity for the public to participate in their conservation. The sustainability of stingless beekeeping depends on the community's capacity to improve production facilities, enhance the skills of farmers, and maintain biodiversity as a food source for the bees. This literature review study provides theoretical and practical information to enhance sustainable stingless beekeeping.

RECOMMENDATION

A limited number of scientific studies summarize and analyze the overall ecosystem services provided by stingless beekeeping based on previous research findings. Therefore, this research is valuable in providing initial findings for future researchers interested in analyzing the economic value of ecosystem services provided by stingless bees in cultivation ecosystems. This study can also serve as a starting point for future research on conserving stingless bee species in a broader environmental context.

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