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Article

Beekeeping and Managed Bee Diversity in Indonesia: Perspective and Preference of Beekeepers

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Abstract: There is a high diversity of bees in the tropics, including honey bees and stingless bees, which are the main sources for honey and other ecosystem services. In Indonesia, beekeeping practices have been developed for centuries, and they have been part of many cultural practices in many traditional communities. The objective of this research was to study the beekeeping status and managed bee diversity in Indonesia and to investigate beekeepers' perspectives on the factors and obstacles related to beekeeping. Direct interview and online interview were conducted to gain data on bees and beekeepers. In total, 272 beekeepers were interviewed across 25 provinces. Samplings of honey bees and stingless bees were also done during direct interviews for further identification and, when possible, pollen identification. All data and specimens were then sent to IPB Bogor for compilation and identification. We recorded 22 species of bees, including 3 species of honey bees and 19 species of stingless bees, that are reared by Indonesian beekeepers, with *Apis cerana* and *Tetragonula laeviceps* as the most common species. Our research also found that the majority of beekeepers fall into the category of the younger generation (30–39 years old) with educational background mostly from senior high school. Based on the beekeepers' perspectives, there are several obstacles to beekeeping, especially the occurrence of death of bee foragers attributed to climate, food source, and pesticides. In conclusion, there is a need to develop a strategy for beekeeping and bee conservation in Indonesia, especially for adaptation and mitigation from environmental changes with a particular focus on climate and land-use change.

Keywords: honey bees; stingless bees; traditional beekeeping; pests; climate change

1. Introduction

Bees provide invaluable ecosystem services in Asia especially Indonesia such as pollination services and their production of honey, brood, propolis, wax, bee pollen, royal jelly, and bee venom [1,2]. Eusocial bees are diverse in Indonesia and encompass three groups, i.e., honey bees, stingless bees, and bumble bees, each of which stores resources such as honey in their nests [3]. The high richness of species and uniqueness of the distribution of eusocial bees in Indonesia may relate to the country's broad geographic expanse, varied topological and environmental landscape, and complex geological history [4]. Indonesia has recorded five species of native honey bees [5,6], at least 46 species of stingless bees, and two species of bumble bees [3]. Some species are recorded in all the islands of Indonesia, and some species are not. For instance, a stingless bee species, *Tetragonula laeviceps*, is widely distributed and covering the whole of Indonesia, while bumble bees (*Bombus* spp.) are only found in the highlands of Java and Sumatera [7,8]. A recent study in Jambi, Sumatera, found 39 species of bees, including both the honey bees and the stingless bees [9].

The native people of Indonesia have used honey for a long time, hunting for honey from both wild honey bees and stingless bees. Although regional beekeeping has been developed from traditional to modern hives and methods, traditional beekeeping remains in practice using local honey bees and stingless bees. Based on [10], national honey production reached 51,338 L in 2020, with the highest production in Java island amounting to 41,614 L (81.06%). While data for national honey production are not recorded properly, scattered evidence demonstrates that honey production by hunting *Apis dorsata* has taken a large role in national honey production [11]. However, production from *Apis mellifera* in Indonesia has tended to decrease owing to changing food sources, pests, and climate change [3]. In the last decade, rearing of stingless bees has gradually been developed and has resulted in the increase production of medicinal honey, propolis, and their derivative products. Indonesia needs to develop beekeeping by enhancing both existing natural ecosystems and semi-natural habitats as sources of food and also promoting native stingless bees [3].

This paper investigates beekeeping practices and provides updates on managed bee diversity in Indonesia. The result will be a very valuable information for bee conservation as well as to achieve sustainable honey production. The challenges for beekeeping include how to improve bee protection from the unpredictable environment and how to increase the quality of life and income of beekeepers [2]. Global declines in honey bees and wild bees have been linked to pathogens, climate change, habitat fragmentation, and pesticide application [12,13]. The potential threat from insecticides such as neonicotinoid to flowering crops has been the subject of considerable debate [14]. Neonicotinoids have been shown to increase mortality in honey bees by impairing their homing ability [15] and reducing the reproductive success of bumble bees and solitary bees [16]. The short-term exposure to imidacloprid and ethion adversely affects honey bee foragers, and chronic exposure to glyphosate may affect pollination success [17], although other studies have identified no effects [16]. There is limited information from replicated studies on the longer-term survival of honey bee colonies following exposure [18]. Landscape-scale experiments under real world agricultural conditions are needed to integrate spatial, temporal, and species-specific variation in order to understand the impacts of neonicotinoids on bees [16,18].

The colony collapse disorder (CCD) phenomena was recorded for the first time from the survey of beekeepers in USA, and it was then extensively monitored in USA from 2006 to 2016 [19–28]. It was also followed by researchers in China from 2013 to 2017 [29] and other countries [30–32]. FAO [33] also conducted a global survey of honey bees and pollinators around the world. In Indonesia, there is a lack of data on CCD and other data pertaining to bee population, managed bee diversity and beekeepers' practices. This research was conducted to study the bee diversity that are being managed by beekeepers across Indonesia and to investigate the beekeepers' perspectives on the factors that affect bee populations and their products. Previous research found that the population of honey bees is affected by habitat types and that beekeepers prefer to put their hives isolated from agricultural areas [34]. There was indication of the population decline of *A. cerana* in East Java, although the result was not conclusive. More research is needed to understand whether population decline of honey bees is happening in Indonesia. This research was also aimed to understand the beekeepers' perspectives on factors affecting bee populations and their product such as pollen and beeswax. Studies in Europe detected pesticide residue in honey bees products from Spain [35], Germany [36], Greece [37], and France [38], while in Indonesia, traces of residues has been detected, albeit at very low concentrations [34].

2. Materials and Methods

2.1. Selected Area for Survey Research

Based on our previous research in Java (see [34]), beekeepers have recently kept not only honey bees but also stingless bees for their honey and propolis production. Therefore, the survey research was conducted in the center of honey bee or stingless bees production in different areas in Indonesia. We initiated the inventory of beekeepers or honey bees or stingless bees' production area in Indonesia by taking into consideration the geographical representative which include Sumatera, Java, Kalimantan, Sulawesi, Bali, Nusa Tenggara, and Maluku (Figure 1, Table 1). The beekeepers were selected based on representation of each province in Indonesia. The number of samples were chosen based on proportion of beekeepers in each geographical area.

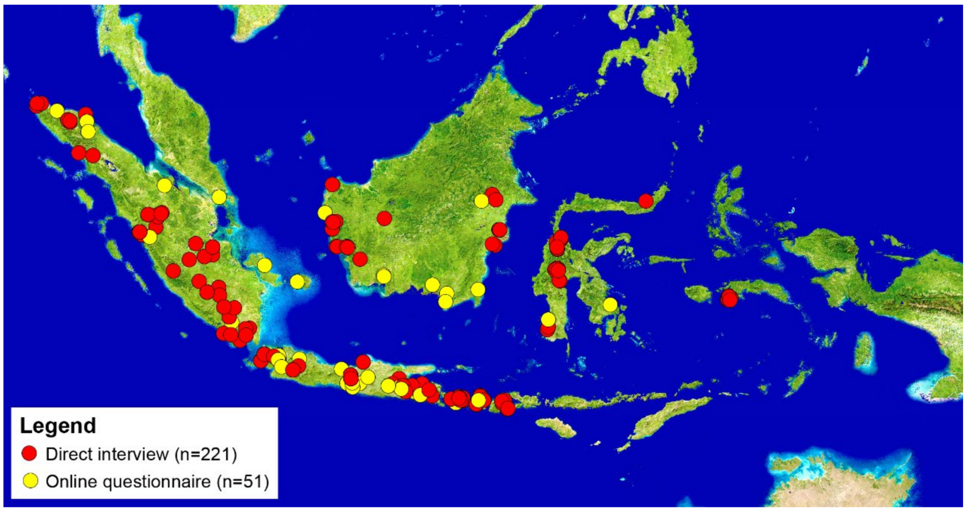


Figure 1. Map of research survey of beekeepers in Indonesia.

Table 1. Selected region and number of beekeepers per region.

No.	Province	Direct Interview	Online Questionnaire	Total
	Sumatera			
1.	Aceh	10	5	15
2.	North Sumatera	1		1
3.	Riau	7	1	8
4.	Bangka Belitung Islands		2	2
5.	Riau Islands		1	1
6.	Jambi	10		10
7.	West Sumatera	10	1	11
8.	South Sumatera	11		11
9.	Lampung	10	1	11
	Java			
10.	Banten	24	1	25
11.	West Java	9	6	15
12.	Central Java	24	6	30
13.	Special Region of Yogyakarta		2	2
14.	East Java	10	8	18
	Kalimantan			
15.	West Kalimantan	13	2	15
16.	Central Kalimantan		2	2
17.	South Kalimantan		4	4
18.	East Kalimantan	7	1	8
	Sulawesi			
19.	North Sulawesi	1		1
20.	Central Sulawesi	12		12
21.	South-East Sulawesi		1	1
22.	South Sulawesi	16	2	18
	Other province			
23.	Bali	15	4	19
24.	West Nusa Tenggara	21	1	22
25.	Maluku	10		10
	Total	**221**	**51**	**272**

In total, we surveyed 272 beekeepers through direct interviews (221 beekeepers) and online questionnaires (51 beekeepers). Direct interviews were conducted by short interview with beekeepers and sampling their honey bees or stingless bees as well as their products. In the implementation, we involved the branches of Entomological Society of Indonesia (PEI) to collect the data and to sample the specimens (honey bees products). The manual procedure was shared with all branches of PEI for sampling such as the collection method, location coordinate, interview questionnaire, and environmental factors. All data and specimens were sent to Bogor Agricultural University (IPB University) Bogor for compilation.

2.2. Beekeeper Interview and Sampling of Bees

In each direct interview with beekeepers, we interviewed beekeepers and collected honey bees and stingless bees for later identification in the laboratory. The purpose of the interview was to acquire information about beekeepers' profile as well as products of honey bees and stingless bees. We used the questionnaire, which was then modified into Google Form format to the collection of data easier (Supplementary Materials Table S1). The online questionnaire was simplified to make it easier for beekeepers to fill out the form.

2.3. Data Analysis

Information of beekeeper perspectives on factors affecting bee population and their products were analyzed using descriptive statistics. Based on the coordinate of each beekeeper location, analyses of beekeeping landscapes in Indonesia were conducted using ArcGIS. The significant difference between initial numbers of hives and recent hives owned by different beekeepers in relation to business scale and educational background from all beekeepers was analyzed using analysis of variance (ANOVA). All analyzes were performed using R statistical software [39].

3. Results

3.1. Profile of Beekeepers in Indonesia

Based on direct interviews and online questionnaires that were derived from 272 beekeepers in Indonesia, we found that the majority of beekeepers' ages are between 30 and 39 years old (34%) and that their educational background is mostly senior high school (31%) followed by higher education (29%) (Figure 2). Most of the beekeepers have 3–5 years experience in beekeeping business (43% of the respondents), and many of them trained themselves on beekeeping (53% autodidact) (Figure 3).

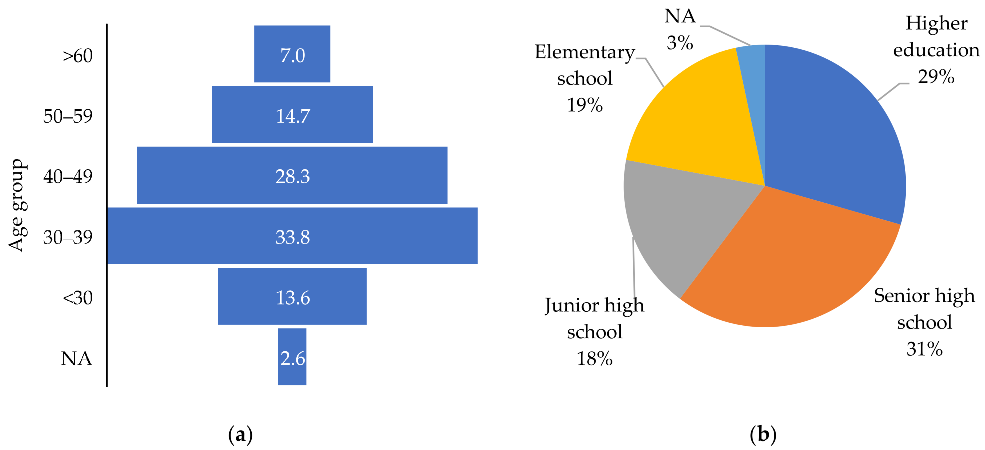


Figure 2. Profile of beekeepers based on (**a**) age groups and (**b**) educational background.

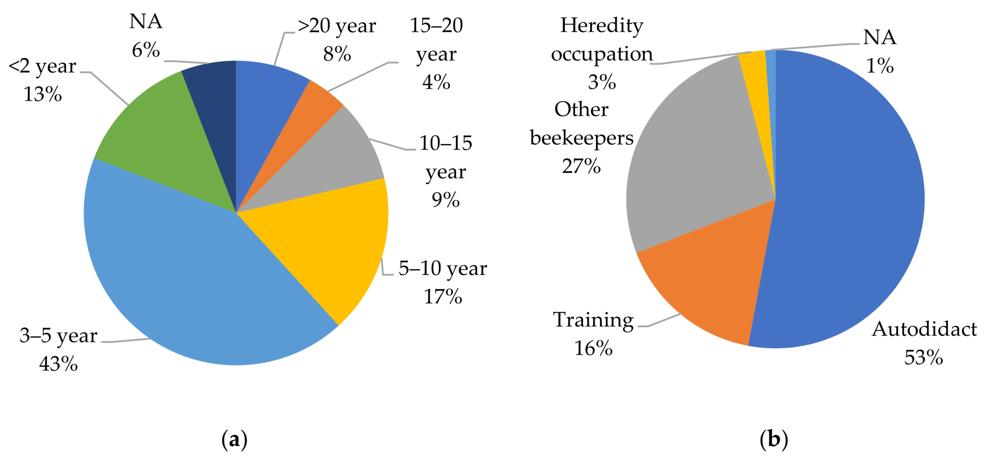


Figure 3. Experience as beekeepers based on (**a**) length of time as beekeepers and (**b**) acquiring knowledge of rearing bees.

We found different business scale of beekeepers between starting and recent rearing ($F_{3,\,478}$ = 19.030, p < 0.0001; Figure 4). Beekeepers that started rearing of bees with low number of hives (less than 20 hives and between 20–50 hives) significantly increase their hives to enlarge the business scale, while beekeepers that start with a high number of hives (between 51–150 hives or above 150 hives) did not increase their hives. In addition, we did not find significant different between education background with the number of hives or business scale ($F_{3, 468} = 1.699$, $p = 0.166$).

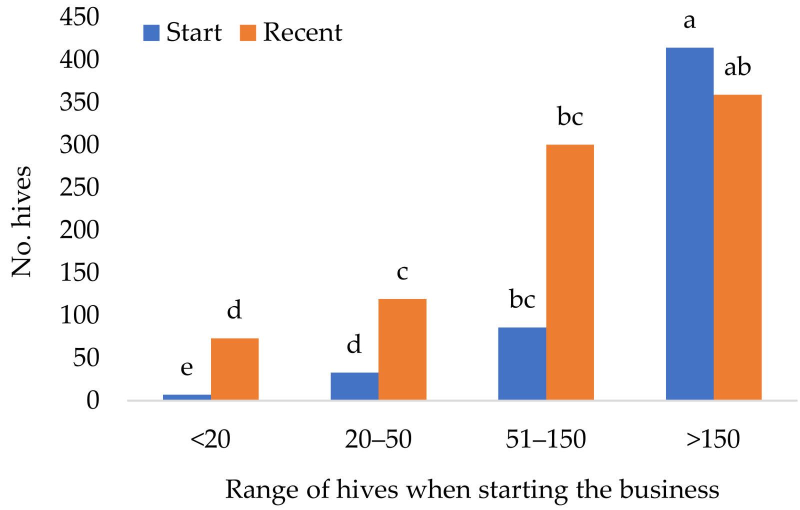


Figure 4. The change of hives numbers that are reared by beekeepers between the start of the beekeeping rearing and recent rearing ($F_{3, 478} = 19.030$, $p < 0.0001$). Data were log-transformed before analysis to reach normal distribution. Bar with different letters is significantly different at $p < 0.05$ according to the Tukey test.

3.2. Diversity of Honey Bees and Stingless Bees Reared by Beekeepers in Indonesia

Data on diversity of bees were only collected from the data of direct interview ($n = 221$). From direct interview, we could recheck the species name between beekeepers and specimens, while we could not confirm the species of bees from the online questionnaire due to the fact that the specimens from online questionnaires were unavailable.

In total, we found 22 species bees, including 3 species of honey bees and 19 species of stingless bees, that are reared by beekeepers in Indonesia (Table 2). The island of Sumatera has the highest species richness of bees (16 species) followed by Java (10 species) and Kalimantan (10 species). The honey bee *Apis cerana* is the most common species that was recorded in all islands. Several species are only recorded in specific islands such as *Apis nigrocincta* in Sulawesi, *Tetragonula melanocephala* in Nusa Tenggara, and *Homotrigona fimbriata* in Kalimantan. Similarly, *Tetragonula minangkabau*, *Heterotrigona bakeri*, *Heterotrigona erythogastra*, and *Lophotrigona canifrons* were only recorded in Sumatera (Table 2).

Table 2. Diversity of honey bees and stingless bees that are reared by beekeepers in different islands in Indonesia. The numbers indicate the number of respondents (n = 221), and some respondents may have several bee species.

No.	Species	Sumatera	Java	Kalimantan	Sulawesi	Bali	Nusa Tenggara	Maluku	Total
	Honey bees								
1.	*Apis mellifera*	6	25	1	3			1	36
2.	*Apis cerana*	22	22	2	12	4	1	3	66
3.	*Apis nigrocincta*				3				3
	Stingless bees								
4.	*Tetragonula laeviceps*	18	29	6	10	12	15	1	91
5.	*Tetragonula biroi*	1	5						6
6.	*Tetragonula drescheri*	3	1						4
7.	*Tetragonula clypearis*						2	4	6
8.	*Tetragonula sapiens*		2		5				7
9.	*Tetragonula fuscobalteata*	3		6	4		4	1	18
10.	*Tetragonula melanocephala*						1		1
11.	*Tetragonula minangkabau*	1							1
12.	*Tetragonula sarawakensis*	1	1						2
13.	*Tetrigona binghami*			2					2
14.	*Tetrigona apicalis*	6		1					7
15.	*Tetrigona melanoleuca*	1							1
16.	*Heterotrigona bakeri*	1							1
17.	*Heterotrigona erythogastra*	1							1
18.	*Heterotrigona itama*	32	5	14					51
19.	*Homotrigona fimbriata*			1					1
20.	*Geniotrigona thoracica*	9	1	7	1				18
21.	*Lepidotrigona terminate*	10	1	2					13
22.	*Lophotrigona canifrons*	1							1
	No. species	**16**	**10**	**10**	**7**	**2**	**5**	**5**	**22**

We found that *A. cerana* and *Tetragonula laeviceps* (stingless bee) were the most chosen bees species reared by beekeepers (Figure 5). Both *A. cerana* and *Tetragonula* were recorded in almost all survey areas, and the distribution pattern is depicted in Figure 6a,b.

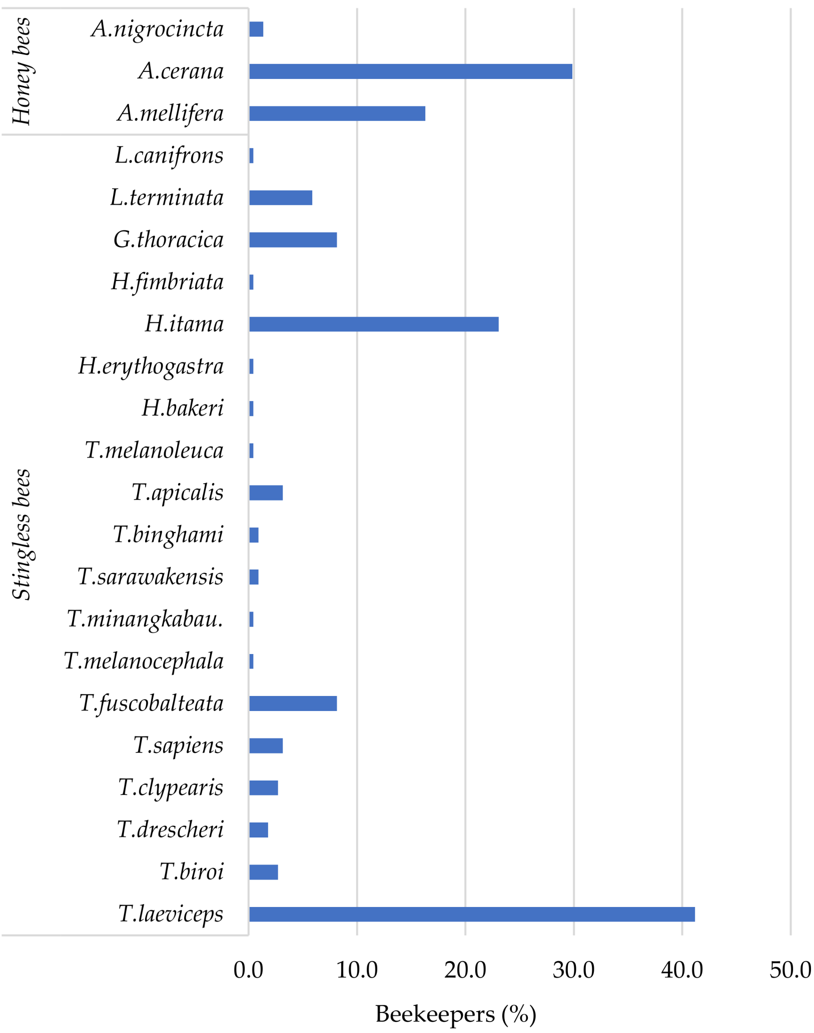
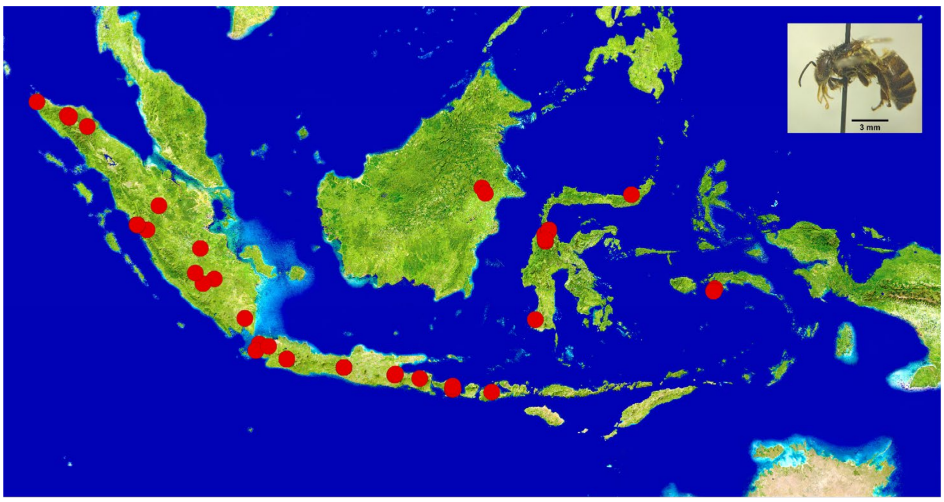
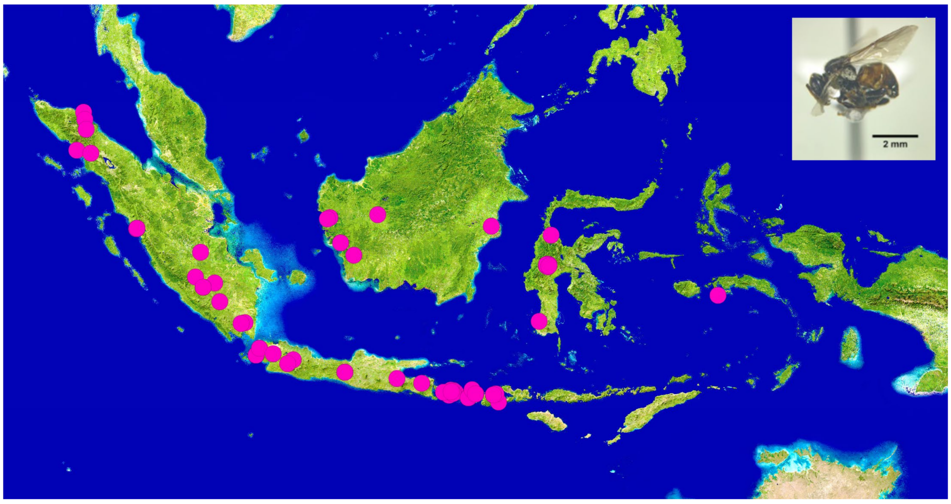


Figure 5. The preferences of beekeepers for selecting the species of honey bees and stingless bees (n = 221).



(**a**)

Figure 6. *Cont.*



(**b**)

Figure 6. Distribution map of the most dominant bees, (**a**) *Apis cerana* and (**b**) *Tetragonula laeviceps*.

3.3. Beekeepers Perspective on Factors Affecting Bees Population

Based on the interview, beekeepers are very aware of the occurrence of death of bee foragers (57%) (Figure 7a) and that the important factor affecting the deaths is climate (31%) (Figure 7b). This perspective is shown especially among beekeepers who put their hives in forest and plantation land-use types (Figure 8). In contrast, in rice fields, home gardens, and other fields, food sources and pesticides are more of a dominant factor causing the death of bee foragers.

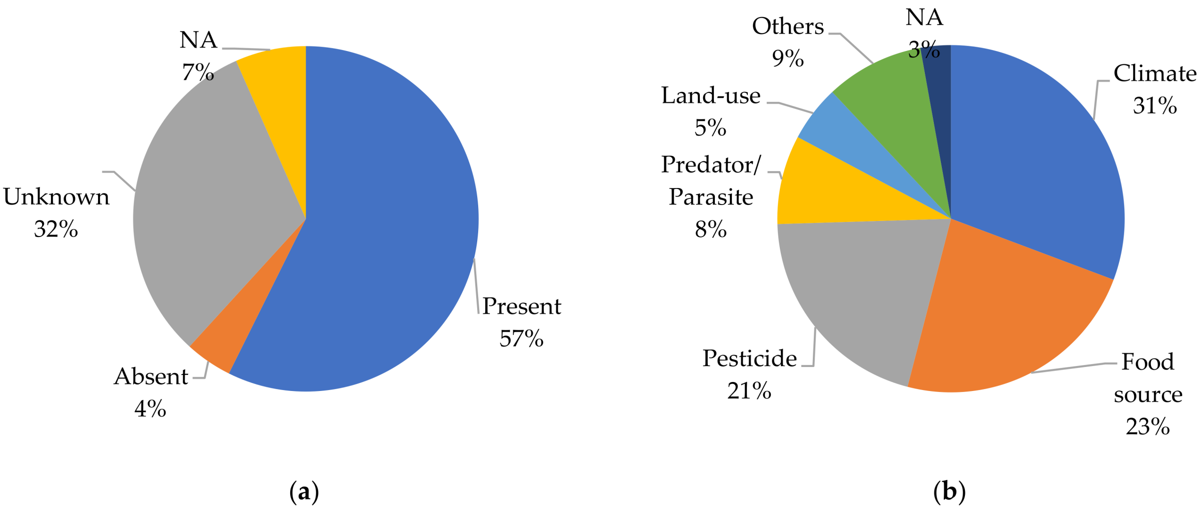


Figure 7. The knowledge of beekeepers on (**a**) the occurrence of bee forager death and (**b**) the factors affecting the death.

Predators and parasites are also considered to affect the bees population (8%, Figure 7b). Based on the beekeepers' information, the most important predators that kill the bees are ants and geckos (Figure 9). Although *Vespa* sp. is as common predator of bees, the effect of this species seems below that of ants and the gecko.

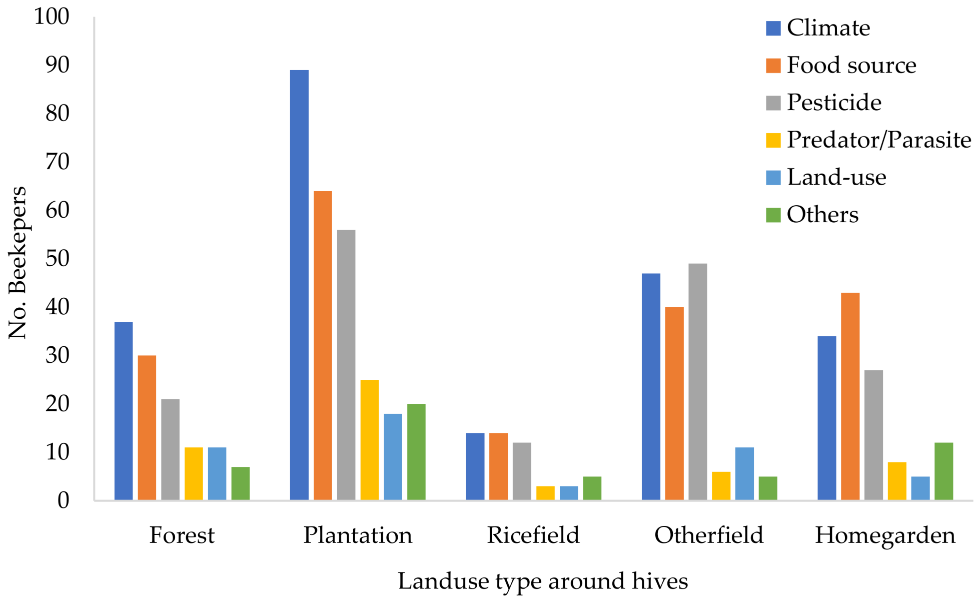


Figure 8. The knowledge of beekeepers on the factors affecting the death of forager bees based on the land-use types where the hives are placed.

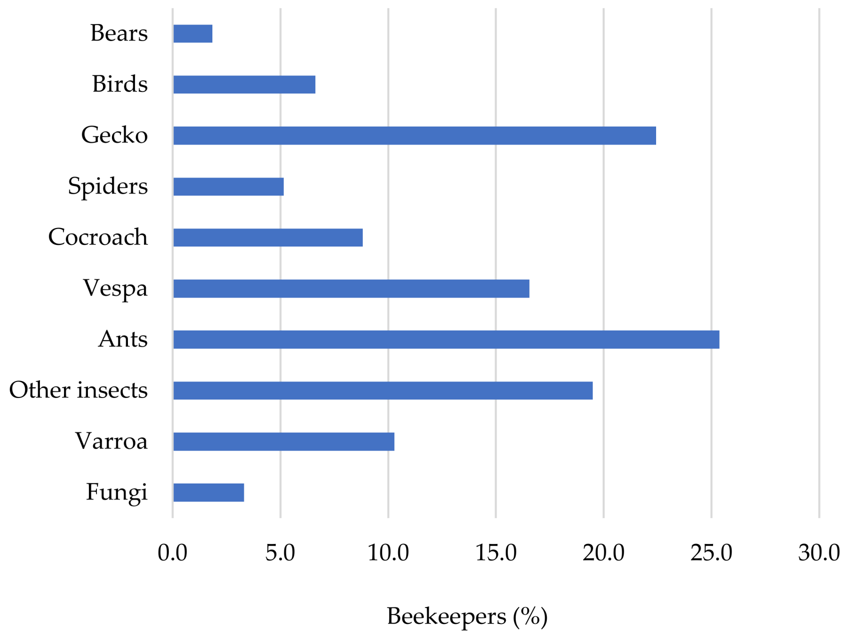


Figure 9. The list of bees predators based on beekeepers' knowledge.

4. Discussion

Based on our research, there is a wide variation in ages, experiences, business scales, and educational background of the beekeepers in Indonesia. It is interesting to note that it seems that there is no relationship between the educational background of beekeepers and the number of hives or business scale of beekeeping. Based on the interview, it seems that over time, the small-scale beekeeping tends to increase the numbers of their boxes or hives, while the large scale tends to stay constant. This indicates that the beekeeping business is promising at a large scale. Although education is an important factor for economic growth, there is strong evidence that cognitive skills are more important and complementary to the quality of economic institutions [40]. To run a successful beekeeping business, two sets of skills are needed, i.e., skills and experiences in beekeeping and skills/experiences the business itself. Nambiar et al. [41] mentioned that the working world is changing rapidly and that people need to be equipped with the skills to unlearn and relearn at every stage of their lives, and they need the ability to remain flexible, adaptive, up to date with workplace requirements, and resilient.

However, beekeeping is still considered to be the second class of farming in Indonesia, and therefore the beekeeping sector is still small. The national production of honey is considered part of forest production as a non-timber forest product [10]. In addition, the honey production in Indonesia is still low and has not met the domestic demand for honey. For instance, [42] estimated that honey production in the region of Kalimantan based on beekeeping with honey boards was between 53 kg and 267 kg per beekeeping family per year. It is estimated that domestic demand of honey needs 3750 ton per year, while the supply of honey is only 500–2000 ton per year [43]. According to the data on honey import and export, in 2018, Indonesia imported honey and sugar much higher than it exported, with USD 265 million worth of export sugar and honey but an import value is USD 2126 million [44]. Thus, this is a big opportunity for beekeeping business in Indonesia.

As one of the global hotspots of autochthonous *Apis* bee diversity, Indonesia faces an incoming threat from the western honey bee, *A. mellifera*. The local bees, such as the Asian honey bee *A. cerana*, have tended to decline due to competition with *A. mellifera* [45]. Although in this survey, the native honey bee, *A. cerana* is still the dominant species and is still managed by the beekeepers in Indonesia, in the near future, the biggest challenge for Indonesian honey production is to balance the beekeeping between *A. mellifera* and *A. cerana*.

Our survey also found that beekeepers in different islands of Indonesia have different preferences in beekeeping, especially in choosing the bee species. For instance, beekeepers in Java mostly prefer to rear *A. mellifera* and *A. cerana*. This is arguably due to the fact that in Java has many plantations and wild plants that flower in different places and times that are suitable for the moving beekeeping system, especially *A. mellifera* [46,47]. Many plants flower throughout the year, such as coconut (*Cocos nucifera*) and calliandra (*Calliandra calothyrsus*). Java formerly had a flowering calendar that gave guidance for the movement of *A. mellifera*, but it is no longer accurate because of the impacts of climate change [46].

Our survey did not cover all bees in Indonesia, which have been reported to include five species of native honey bees [5,6] and more than 46 species of stingless bees [3]. The most common *Apis* species in Indonesia is *A. cerana*, which is characterized by a smaller body size compared to the other two species of domesticated honey bees, *A. nigrocincta* and *A. koschevnikovi* [3]. This result is the same with the research by [48], who found *A. cerana* to be widespread on almost all islands in Indonesia. However, the populations of *A. cerana* in Indonesia are usually recognized as the subspecies *A. cerana indica*, which is distinct from other subspecies such as *A. cerana javana* [49]. The subspecies *A. cerana* are known to vary across Indonesia, mostly related with latitude and elevation [5].

Beekeepers in Java, Sumatera, Kalimantan, Sulawesi, and Bali still conduct traditional beekeeping of *A. cerana* in simple wooden boxes without frames or in the cavity of tree trunks [3]. They are also familiar with traditional stingless bee keeping methods that utilize the cavities of cut tree trunks, bamboo, or simple wooden boxes as the colonies nest and place the nests around houses to make it easy to manage and harvest. As the most dominant stingless bee in this survey, *T. laeviceps* also are farmed in human settlements of many places in Indonesia. *T. laeviceps* and other native stingless bee species also tend to be managed in the areas which are adjacent of forests in Indonesia so that the forest can be conserved as well as managed stingless bees [50].

Many studies reported showed the colony losses of honey bees with ranges 8–50% [19–32]. In contrast, [33] reported that 42% of monitored countries (27 countries) showed an increasing trend in genetic diversity of the honey bee population. Similarly to [33], the number of hives that were kept by beekeepers in Indonesia tend to increase significantly. It showed that the business of beekeepers tends to develop by increasing the numbers of bee colonies, particularly of stingless bees. However, their operation size is still smaller than the operation size of most beekeepers in other countries [19,28,29]. Most Indonesian beekeepers were stationary beekeepers with a low risk of loss of colonies than migratory beekeepers [30].

According to the beekeepers' perspective, the most important factor affecting the bee population is climate, along with food sources and pesticides. The perspective is the same as that of other research, which found that declines in bees have been linked to climate change, habitat fragmentation, and pesticide application [12,13]. The threat from insecticides such as neonicotinoid has been reported to increase the mortality in honey bees by impairing their homing ability [15]. Previous studies in Europe also detected residue pesticide in honey bees products in countries such as in Spain [35], Germany [36], Greece [37], and France [38], while in Indonesia, traces of residues were detected, albeit at very low concentrations [34].

In addition, predators and parasites are also considered to affect bee populations, especially ants, geckos, and *Vespa* sp. The result is similar to that of [3], who reported the common pests in captive beekeeping are *Varroa destructor*, the Galleria moth, the genus Vespa, and ants. The authors of [51] reported that ant, spider, and lizard were the main predators of the stingless bees *Lepidotrigona terminata*. The highest threat to honey bee population globally (29%) is pests, and *V. destructor* is seen as the main threat in Asia [33]. Gajger et al. [31] also showed that 16.12% mortality of colonies due to *V. destructor*. However, every location has its own local pests, such as monkeys and honey bears in Sumatera and Kalimantan. Different bees also have different protective behaviors. For example, feral nests of stingless bees are well protected by propolis [52–54]. Thus, only strong animals such as honey bears or mice are capable of occasionally damaging nests.

5. Conclusions

In this research, we confirmed that 22 species of bees, including 3 species of honey bees and 19 species of stingless bees, are reared by beekeepers in Indonesia. *A. cerana* and *T. laeviceps* are the most commonly chosen bee species that are reared by beekeepers. Based on beekeepers perspective, there has been a decrease in bees population, which is linked to climate as the main factor. However, food sources and pesticides are also important factors associated with the death of bee foragers. Although predators and parasites are not important factors, we recognized that the presence of ants and gecko could also affect bee populations in the hives.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d14010052/s1, Table S1: Questionnaire for direct interview and online.

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Data Availability Statement: Data available on request due to restrictions.

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