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Exploring the adoption of modern hives among stingless beekeeping in Sabah, Malaysia: The approach of diffusion of innovation theory

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Abstract. Stingless beekeeping is crucial for Malaysia's socio-economic development and environmental conservation, providing sustenance, materials, and income. Despite its potential, conventional practices such as obtaining stingless bee colonies through tree logging will disrupt ecosystems and threaten native pollinators. This study focuses on Sabah's stingless beekeepers, examining factors influencing the adoption of sustainable modern hives essential for boosting honey production and additional colony sales. However, current use of modern hives remains limited due to beekeepers' lack of interest. The Diffusion of Innovation Theory suggests the need for a sustainable approach. The results of this study show that most beekeepers use conventional hives such as log and honey box hives (87.7%), bamboo hives (59.6%), and single box hives (55.3%), while sustainable options like MARDI hives (55.3%), Mustafa hives (33.3%), and SIRIM ceramic hives (3.5%) are less common but align with guidelines for sustainable stingless beekeeping. The results discovered five latent factors that influence the respondents' to adopt modern hives which are Compatibility, Trialability, Observability, Relative Advantage and Complexity or Simplicity with 85.31% total cumulative variance explained. These findings highlight the importance of promoting sustainable hive adoption to bolster the industry's growth and environmental sustainability. By enhancing modern hive adoption, the stingless beekeeping industry can achieve ecological, economic, and social sustainability, contributing to Malaysia's conservation efforts and economic growth.

1. Introduction

Stingless bee farming can be considered as one of the potentially high-impact ventures in the agricultural industry in Malaysia [1]. In Malaysia, the current market price for a stingless bee colony range from MYR 500 to MYR 1,000, while the price of stingless bee honey is MYR 85 per 150 grams [6], [7], and [15]. A survey also indicates that 36% and 29% of stingless beekeepers generate additional income of RM 833 and RM 1666 respectively [13]. The stingless bee products and by-products industry is rapidly growing and increasingly popular among consumers due to their medicinal

and supplementary food properties. Therefore, encouraging early involvement in stingless bee farming in this industry is crucial. One strategy to increase yields in stingless bee farming is the multiplication of stingless bee colonies. According to the manual guidelines issued by [9], the process of multiplying stingless bee colonies requires beekeepers to provide several hives. Conventionally, stingless bee colonies are obtained by cutting the middle part of trees to obtain colonies, which are then transferred to bee farms ([13]. Thus, modern hives are the solution to replace conventional practices that negatively impact natural ecosystems. Various efforts have been undertaken by stakeholders to raise awareness among stingless beekeepers about applying and adopting modern hives with sustainable features to preserve the natural habitat ecosystem. For instance, the Department of Agriculture Malaysia promotes the Modular Stingless Bee Hives (SKM) with topping, MARDI box hives, Mustafa hives, and Sirim ceramic hives, which emphasize baiting, bridging, separating (splitting), and colony multiplication. However, many still use traditional hives such as bamboo and wooden logs. Modern hives play a crucial role in establishing sustainable stingless bee breeding because more colonies are needed to increase honey production and the valuable by-products; stingless bee colonies can also be sold to other beekeepers [5]. This approach supports the sustainable practices outlined in MyGAP A.M (2002), which state that hives must be made from materials that are not harmful to stingless bees, do not affect the quality of honey production, and do not harm the environment. The hives should also not be placed directly on the ground. In terms of design, the hives should be stingless bee-friendly to ensure the welfare of the bees is always prioritized. Therefore, utilizing modern hives equipped with innovation elements with the functions of baiting, bridging, separating (splitting), and multiplication of the colonies will boosts stingless bee honey production, thus advancing the stingless beekeeping industry to positively impact the nation's socio-economic status, species conservation, and long-term ecological preservation [13]. Various studies have explored hive designs with sustainable attributes, revealing that modern hives can enhance honey production, simplify colony inspection and honey harvesting, offer flexible transportation, support queen expansion, ensure high colony survival rates, be durable, and environmentally friendly [2], [3], [6], [7], [8], [9], [10], [11], [13], [14], [17]. However, many beekeepers in Malaysia have not fully engaged in sustainable stingless bee farming. As stated in the statistics of stingless beekeepers obtained from the Malaysian Good Agricultural Practices (Tribus Apini and Tribus Meliponini) or known as MyGAP A.M in 2021, only 101 out of 717 stingless beekeepers are registered under the Agricultural Department in Malaysia. Therefore, the findings of this study to explore the adoption of modern hives among stingless beekeeping in Sabah, Malaysia on the approach of Diffusion of Innovation Theory.

2. Materials and Methods

2.1. Sample and questionnaire

For this study, a systematic stratified random sampling method was utilized, involving 114 respondents who completed the questionnaire. The structured questionnaire covered socio-economic and demographic profiles, knowledge, and awareness, divided into three sections (Section A, B, and C), guided by the Diffusion of Innovation Theory.

The research was conducted among all stingless beekeepers who owned stingless bee hives on their farms in the state of Sabah. Data was obtained from the Department of Agriculture Malaysia and the *Gabungan Persatuan Usahawan Lebah Kelulut*, also known as the Combined Association of Stingless Beekeepers in Malaysia. The target population consisted of stingless beekeepers from Sabah, with data collected from these two sources.

The questionnaire, employing a 7-point Likert scale and open-ended questions, comprised three sections. Section A addressed socio-demographic information such as gender, age, education, income, and types of hives used by the stingless beekeepers. Section B delved into beekeepers' perceptions and awareness of modern hive usage, along with the prevalent types of hives. While section C focused on the adopt modern hives in their stingless bee farm. Identifying the types of hives used by respondents

offered initial insights into whether they had transitioned to modern hives or were still using conventional materials like logs, bamboo, and ceramic.

The Theory of Diffusion of Innovation (DOI) [16] is used as the conceptual framework to explain the stingless beekeepers' intention to adopt modern hive in their farm. [16] identified five general attributes of innovation: relative advantage, compatibility, complexity, observability, and triability. The attributes of DOI theory, relative advantage, compatibility, complexity, observability, and triability [16], will be tailored to align with the study's objectives (Figure 1).

1. Relative advantage – the degree to which innovation of sustainable new modern hives is perceived as being better than its precursor
2. Compatibility – the degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of the stingless beekeeping using the conventional hives.
3. Complexity – the degree to which innovation is perceived as difficult because it is normal practice to obtain conventional hives by cutting down trees and so on.
4. Observability – the degree to which the results of an innovation are observable by all stakeholders in the industries, such as the Ministry of Agriculture and Food Industries (Malaysia) with MyGAP (tribus Apini, tribus Meliponini) guidelines.
5. Triability – the degree to which an innovation may be experimented with before adoption

2.2 Method of analysis

In order to accomplish the objectives of this study, descriptive analysis and factor analysis were used to analyse information gathered from the questionnaires. Descriptive analysis was used to summarise the data for each sections. While, Factor analysis was used to reduce the data and categorise the variables into a small number of factors.

3. Results and Discussion

3.1 Socio-demographic profile of respondents

A total of 114 respondents completed the distributed questionnaire. Out of these, 61.4% were male and only 38.6% were female. The highest age group was in the category of 20 to 25 years old (57.2%), while only 5.4% of the respondents were aged 50 years and above. In terms of education level, the findings showed that 4.4% of the respondents had education up to primary school, 17.5% attended secondary school, and 78.1% had qualifications from any university or college in Malaysia or abroad. The estimated annual sales of respondents ranged from the highest, reaching RM200,000.00, to as low as RM2000.00 and below. Most beekeepers in this study reported annual sales of around RM10,000.00. The findings also indicated that most of these stingless beekeepers had less than five years of beekeeping experience. Figure 1 below shows the percentage of hive usage based on types of hives such as MARDI box hives, Mustafa box hives, SIRIM ceramic hives, flowerpot or ceramic hives, bamboo hives, log with honey box hives, single box hives, and self-designed hives produced by respondents. The highest percentage of hive usage by respondents was for log hives and honey box hives, at 87.7%, followed by bamboo hives at 59.6%, and single box hives at 55.3%. These three types of hives are conventional ones still commonly used among respondents. However, 55.3% used MARDI hives, 33.3% used Mustafa hives, and 3.5% used SIRIM ceramic hives, which are characterized as sustainable hives. These hives comply with the guidelines recommended by [9], specifically the Modular Stingless Beehive (SKM) with a topping.

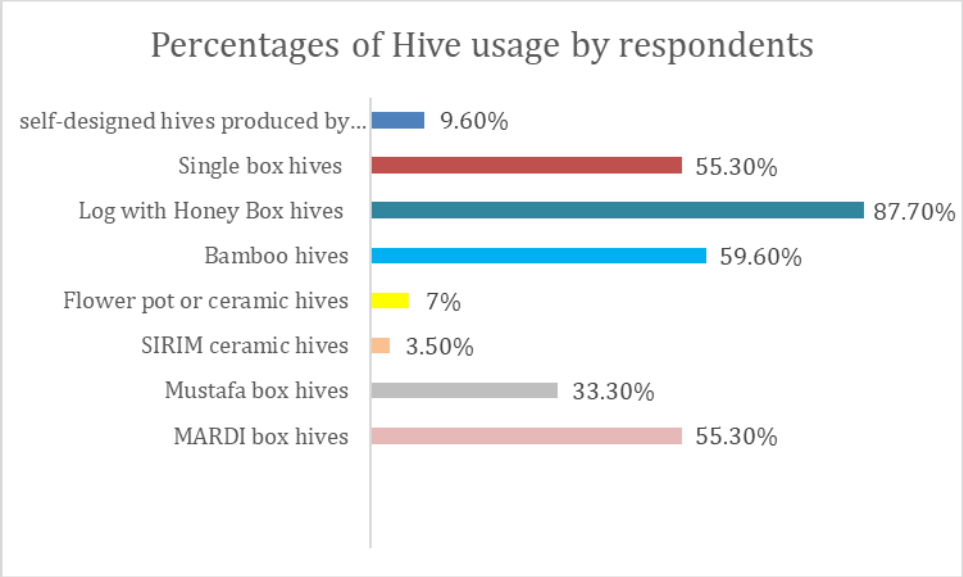

Figure 1. The types of hives used by respondents and the percentage of usage.

3.2 Exploratory Factor Analysis (EFA)

In this study, EFA was used to identify the critical factors influencing respondents' intention to adopt modern hives in stingless bee farming industry. The EFA, KMO and Bartlett's Test were employed to measure sampling adequacy and the presence of correlations among variables on the Likert Scale questions. Table 1 reveals that the KMO score was 0.905, indicating inter-correlations between the factors, whereas Bartlett's Test of the Sphericity significant level of $p<0.01$ in this study implies that it is appropriate to run the factor analysis. KMO values between 0.8 and 0.9 are considered high.

Table 1. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure Sampling of Adequacy		0.905
Bartlett's Test of Sphericity	Approx. Chi-square	987.219
	Df	21
	Significance	0.001

Table 2 presented the factor loadings from principal component factor analysis, using a varimax rotation of the respondents' responses to the 32 questions relating their intention to adopt modern hives in stingless bee farming. The results discovered five latent factors that influence the respondents' intention to adopt modern hives. The total cumulative variance explained from the exploratory factor analysis in this study was 85.31%, represented by four underlying factors. Thus, the value of 85.31% of the respondents' total variation suggested that they are likely to have the intention to adopt modern hives.

Table 2. Respondent's adoption of modern hives.

Items	Factor Loading				
	F1	**F2**	**F3**	**F4**	**F5**
Compatibility towards the adoption of modern hives					
Modern hive offers me real advantages over the way I usually using Conventional log	0.736				
Modern hive would be compatible with sustainable practices of Meliponiculture.	0.818				
Using modern hive is compatible with all aspect of my work	0.821				
Using modern hive is completely compatible with my current situation.	0.764				
I think sustainable practice of meliponiculture should use modern hive.	0.723				
The use of modern hive help me to learn more about technology while also learning about sustainable practice.	0.722				
I will be able to use modern hive for meliponiculture purposes, without significantly changing the structure of my business.	0.770				
Variance (Percent of explained)	**26.781**				
Trialability towards the adoption of modern hives					
I want to be able to use modern hive on a trial basis.		0.730			
I want to be able to properly try out modern hive.		0.764			
I want to use modern hives as a long -term trial to see the capabilities		0.766			
The ability to try modern hives is crucial in my decision to use them		0.733			
I like being able to try out modern hive before deciding whether I like it or not.		0.713			
Variance (Percent of explained)		**19.052**			
Observability towards the adoption of modern hives					
I will use modern hives when many use it			0.886		
I will use modern hives when I have seen others use it			0.895		
I will wait until the other stingless beekeeper start to use modern hives			0.878		
I will use modern hives when other people have successful experience of using it			0.813		
Variance (Percent of explained)			**13.520**		
Relative Advantage towards the adoption of modern hives					
Modern hive would improve the quality of meliponiculture				0.608	
Modern hive would enhance my effectiveness on meliponiculture.				0.619	
Modern hive makes it easier for me to conduct honey harvesting.				0.682	
Using modern hive made meliponiculture activity more sustainable.				0.606	
Modern hive offer me real advantage over the way I usually using conventional log				0.615	
Variance (Percent of explained)				**13.177**	
Complexity or Simplicity towards the adoption of modern hives					
I had no difficulty understanding how to use modern hive.					0.690
I had no difficulty understanding how modern hive technically work.					0.608
It would be easy for me to become skillful at using modern hive					0.715
I believe that modern hives are easily accessible and easy to handle.					0.690
Variance (Percent of explained)					**12.775**
Total Percentage of Variance					**85.30**

The compatibility towards the adoption of modern hives is determined as the first factor. This factor has seven sub-variables, with a total variance of 26.781%. The seven sub-variables are: "Modern hive offers me real advantages over the way I usually use Conventional log" (0.736), "Modern hive would be compatible with sustainable practices of Meliponiculture" (0.818), "Using modern hive is compatible with all aspects of my work" (0.821), "Using modern hive is completely compatible with my current situation" (0.764), "I think sustainable practice of meliponiculture should use modern hive" (0.723), "The use of modern hive helps me to learn more about technology while also learning about sustainable practice" (0.722), and "I will be able to use modern hive for meliponiculture purposes, without significantly changing the structure of my business" (0.770). According to Basrawi et al. (2017), the adoption of modern hives is crucial for the sustainable development of stingless beekeeping practices.

Trialability towards the adoption of modern hives is the second factor, with five sub-variables contributing to a total variance of 19.052%. Trialability reflects the extent to which an innovation can be experimented with on a limited basis (Rogers, 1995).

Observability towards the adoption of modern hives is the third factor, with a total variance of 13.520%. It comprises four sub-variables: "I will use modern hives when many use it" (0.886), "I will use modern hives when I have seen others use it" (0.895), "I will wait until other stingless beekeepers start to use modern hives" (0.878), and "I will use modern hives when other people have successful experiences using it" (0.813). Observability indicates the degree to which the results of an innovation are visible to others, which significantly influences the adoption decision (Rogers, 1995).

The relative advantage towards the adoption of modern hives is identified as the fourth factor, accounting for a total variance of 13.177%. There are five sub-variables under this factor. This factor indicates that stingless beekeepers intend to adopt modern hives by considering the relative advantages they perceive. Studies such as Jaffe et al. (2015) suggest that relative advantage is a key determinant in the adoption of agricultural innovations.

Finally, complexity or simplicity towards the adoption of modern hives is determined as the fifth factor, with four sub-variables and a total variance of 12.775%. Complexity refers to how difficult the innovation is to understand and use, which can hinder its adoption (Rogers, 1995).

According to Gliem and Gliem (2003), Cronbach's Alpha serves as a tool to assess the internal consistency reliability across participants in research studies. In this study, Cronbach's Alpha was employed to gauge the reliability of 32 relevant variables utilized in the exploratory factor analysis. This study identifies five latent factors with reliable internal consistency, as evidenced by the Cronbach's Alpha scores listed in Table 3: compatibility with the adoption of modern hives (0.974), trialability with the adoption of modern hives (0.941), observability with the adoption of modern hives (0.906), relative advantage in the adoption of modern hives (0.958), and complexity or simplicity in the adoption of modern hives (0.941).

Table 3. Result of Reliability Test (Exploratory Analysis)

	Number of Items	Cronbach's Alpha
Compatibility towards the adoption of modern hives	7	0.974
Trialability towards the adoption of modern hives	5	0.941
Observability towards the adoption of modern hives	4	0.906
Relative Advantage towards the adoption of modern hives	5	0.958
Complexity or Simplicity towards the adoption of modern hives	4	0.941

The study's findings are based on a specific group of stingless beekeepers, which may limit the generalizability of the results. Future research should include a larger and more diverse sample to enhance the representativeness and applicability of the findings across different regions and demographic groups. Additionally, future studies should consider external factors such as governmental policies, market conditions, and environmental changes that may impact the adoption of

modern hives. Understanding these influences can help develop more comprehensive strategies to promote sustainable beekeeping practices.

4. Conclusion

Conventional hive types, such as log hives with honey boxes, were the most used among respondents, followed by bamboo hives and single box hives. However, there was a notable adoption of sustainable hives, such as MARDI hives, Mustafa hives, and SIRIM ceramic hives, indicating a shift towards modern and sustainable practices in beekeeping.

The study identified five latent factors that influence the respondents' adoption of modern hives:

i. Compatibility, this factor, with a total variance of 26.781%, includes sub-variables like the real advantages offered by modern hives, compatibility with sustainable practices, and the ability to use modern hives without significantly changing the business structure.
ii. Trialability, accounting for 19.052% of the total variance, this factor reflects the extent to which modern hives can be experimented with on a limited basis.
iii. Observability, with a total variance of 13.520%, this factor comprises sub-variables related to the visibility of the benefits of modern hives, such as seeing others use them successfully.
iv. Relative Advantage, this factor has a total variance of 13.177% and indicates that stingless beekeepers consider the perceived benefits of modern hives.
v. Complexity or Simplicity, accounting for 12.775% of the variance, this factor refers to the ease of understanding and using modern hives.

These findings demonstrate a growing interest and potential for the adoption of modern hives among stingless beekeepers. To capitalize on this opportunity and promote sustainable beekeeping practices, several recommendations can enhance the use of modern hives in the stingless beekeeping industry in Malaysia. Firstly, implementing training programs and educational initiatives targeting beekeepers is essential. These programs should focus on the benefits and best practices associated with modern hive adoption, enhancing awareness and understanding among beekeepers, thereby encouraging their willingness to transition towards modern hive technologies.

Next, collaboration between policymakers and stakeholders is crucial for advancing the adoption of modern hives among beekeepers. By fostering partnerships and aligning efforts, they can create a conducive environment for beekeepers to transition towards modern hive technologies. Supportive policies and regulatory frameworks play a pivotal role in incentivizing this transition, offering financial incentives or subsidies to beekeepers investing in modern hive equipment.

Furthermore, capacity-building initiatives are essential to ensure beekeepers have the necessary skills and knowledge to effectively manage modern hives. Training programs, workshops, and educational materials can empower beekeepers with the latest techniques and best practices in hive management and sustainable beekeeping.

Investing in research and innovation is equally important to drive continuous improvement in hive technology. By funding research projects and fostering innovation partnerships, policymakers and stakeholders can support the development of more efficient, durable, and user-friendly modern hive designs. This not only enhances the adoption of modern hives among beekeepers but also contributes to the overall sustainability and resilience of the beekeeping industry. In summary, collaboration, supportive policies, capacity building, and research and innovation are integral components of a holistic approach to promoting the adoption of modern hives among beekeepers. By prioritizing these efforts, policymakers and stakeholders can catalyze positive change within the beekeeping sector, ultimately benefiting both beekeepers and the environment.

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