TECHNO-ECONOMIC AND ENVIRONMENTAL ANALYSIS OF MELIPONICULTURE IN BUKIT SANDY, BANDUNG

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ABSTRACT: Propolis produced by stingless bees has a high economic value in Indonesia. Bukit Sandy is a plantation area in Cimenyan, Bandung which is famous for citrus picking tourism and has the potential to be developed for meliponiculture. Currently, there are stingless bee colonies in Bukit Sandy, but the colonies are not growing well. This research aimed to examine environmental conditions and techno-economic analysis of meliponiculture in Bukit Sandy. This research used descriptive analysis, vegetation analysis, colony carrying capacity analysis, and techno-economic analysis methods. The results show that environmental conditions in Bukit Sandy are suitable for meliponiculture. Dominant forage vegetation potential for stingless bees in Bukit Sandy are mahogany (tree), pine (pole), lemon (sapling), and paspalum (seedling). The estimated potential for production of honey in Bukit Sandy ranges from 2.25-30.21 kg/month and the carrying capacity of stingless bee colonies in Bukit Sandy is 4-54 colonies. This study proposed several scenarios for techno-economic analysis for cultivation of *Heterotrigona itama*; i) 4 colonies with raw propolis and honey as products, ii) 4 colonies with propolis extract, honey and propolis residue as products, iii) 54 colonies with propolis extract, honey and propolis residue as products. Based on the techno-economic analysis, meliponiculturein Bukit Sandy is technically feasible and profitable for scenario 2 and 3, while scenario 1 is not profitable. Scenatio 2 is proposed for early stages of meliponiculture in Bukit Sandy and later transformed to scenario 3 for higher profit and benefits to the society.

KEY WORDS: *Colony carrying capacity, Heterotrigona itama, Meliponiculture, Techno-economic analysis, Vegetation analysis.*

1. INTRODUCTION

Propolis is one of non-timber forest product that has a high economic value derived from bees. Propolis has many beneficial properties such as antibacterial, antifungal, antiviral, anti-inflammatory, antioxidant [1], fungicide [2], anti-protozoa, anti-cancer, anti-tumor, and hepatoprotective [3] and can be used as an ingredient in cosmetics, food, and medicine [4,5]. Stingless bees are one of the bees that produce propolis. These bees produce more propolis but produce less honey than *Apis* bees [6,7]. The propolis produced by stingless bees has been reported to contain a higher economic value because of a higher bioactive content compared to the propols produced by *Apis* bees [8].

Stingless bees can be cultivated like honeybees. The advantages of meliponiculture are that it does not need to be maintained intensively, it does not sting, it does not need special equipment, relatively resistant to pests and diseases, and it does not have famine periods [9]. In addition, stingless bees can increase the productivity of plantations because they are pollinating insects [10,11]. However, meliponiculture is less desirable because of low honey productivity but recently, meliponiculture has begun to be considered for development because the honey produed by stingless bees has abetter quality than produced by honeybees. In addition, stingless bees also produce other pdocucts particularly propolis and pollen [9].

Bukit Sandy is a plantation area in Cimenyan, Bandung which is famous for citrus picking tourism and has the potential to be developed for meliponiculture. The area has many varieties of plants besides citrus such as butter avocados, lemon, guava, and many more [12]. The vegetation diversity is one of the potentials for meliponiculture in Bukit Sandy. Moreover, the presence of several colnies of stingless bees in Bukit Sandy can help pollinate the plants in that area and the products from meliponiculture can also be profitable for Bukit Sandy. However, the colonies are not growing well under current conditions in Bukit Sandy.

Previous studies conducted by Ichwan et al. [13] and Yanto et al. [14] showed that suitable environmental conditions for stingless bee colonies are very important for survival. Carrying capacity of the colony is alse another important factor that need to be considered to ensure availability of sufficient nutrients for stingless bee colnies to grow well [15,16]. If the factors are managed well, meliponiculture is technically and economically feasible as previously investigated by Adam et al. [17]. Systematic studies that investigate environmental and techno-economic analysis of meliponiculture are still very scarce. Therefore, this study aimed to analyze environmental conditions, carrying capacity of stingless bee colonies, and techno-economic analysis of meliponiculture in Bukit Sandy.

2. METHODS

This study was conducted in the Bukit Sandy located at Ciharalang Kulon No.9, Mekarsaluyu Village, Cimeyan District, Bandung Regency, West Java. Geographically, Mekarsaluyu Village is located at 900 – 1100 m above sea level (masl) altitude that is categorized as highland with an average air temperature of 26˚C-29˚C and rainfall of 1,500 mm/year [18]. The total area of Bukit Sandy is ± 9 Ha but only approximately ± 7 Ha that can be easily accessed in this study. The selection of sampling plots in this study was done purposively and carried out from May 2021 to June 2021.

2.1 Sampling and Data Collection Methods

The sampling methods used in this study were purposive sampling and intensity sampling. Purposive sampling was used to collect data interview from the Bukit Sandy management as respondents while the intensity sampling was used to collect vegetation data (5%) from Bukit Sandy area based on Hadjar et al. [19]. The sample plots were shown in Fig.1 with a size criterion of 20 x 20 m for the tree level, 10 x 10 m for poles, 5 x 5 m for saplings and shrubs, and 2 x 2 m for seedlings and herbs and the placement of sample plots as shown in Fig. 2 in the foraging range of 200 m from the point of the colony [20].

Measurement of temperature and humidity were carried out using data loggers. Other data collection was carried out throughout observations, interviews, inventory, Google imagery, GPS trackers, and literature study. Field observations and interviews with employees and management of Bukit Sandy were carried out in March 2021 to gather information about Bukit Sandy's environmental conditions. Inventory of vegetation was used to collect species identity, density, frequency, and diameter at breast height to describe the vegetation in Bukit Sandy. Google imagery and GPS tracker were used for mapping the plantation areas in Bukit Sandy.

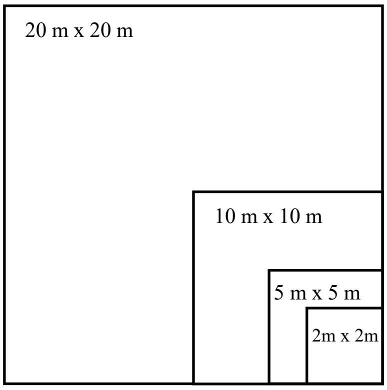

Fig.1.Sample plots for vegetation analysis in Bukit Sandy

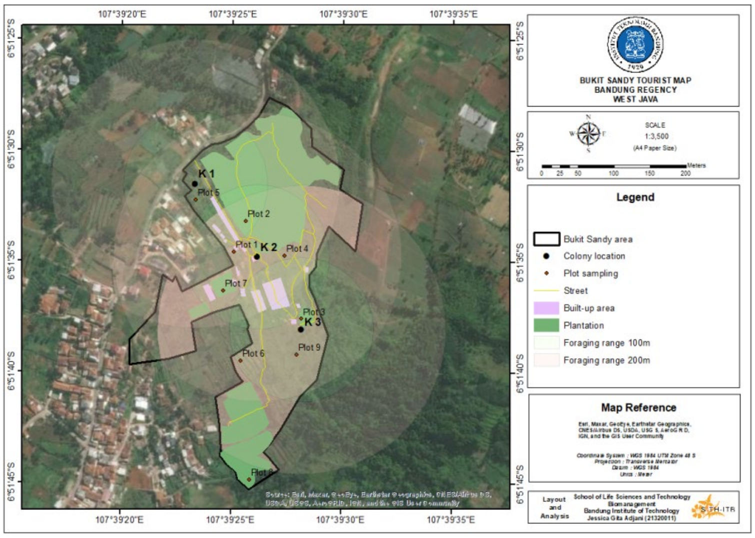

Fig.2.Location of stingles bee colnonies and sample plots in Bukit Sandy

2.2 Methods Analysis

2.2.1 Vegetation Analysis

Plants that have been inventoried from each sample plot were matched with the literature suitable for vegetation of stingless bees. After that, the data was tabulated to calculate the importance value index (IVI) based on relative density (RD), relative frequency (RF), and relative dominance (Rdom) for the level of trees and poles using Eq. (1) to (4) [21] and Eq. (5) for sapling and seedling levels [22].The values of IVI can be used to express the level of dominance of species of a plant community in Bukit Sandy.

$$RD\ (\%) = \frac{species\ density}{total\ species\ density} \times 100\% \tag{1}$$

$$RF\ (\%) = \frac{species\ frequency}{total\ species\ frequency} \times 100\% \tag{2}$$

$$Rdom\ (\%) = \frac{species\ dominance}{total\ species\ dominance} \times 100\% \tag{3}$$

$$IVI\ (\%)_{tree\ and\ pole} = RD + RF + Rdom \tag{4}$$

$$IVI\ (\%)_{sappling\ and\ seedling} = RD + RF \tag{5}$$

2.2.2 Colony Carrying Capacity Analysis

Calculation of feed availability was based on the nectar availability in Bukit Sandy. Amulen et al. [23] estimated the potential of beekeeping based on the nectar availability sources. The calculation model requires data on number of flowers per plant, nectar volume per plant, and sugar concentration. The data of sugar concentration obtained from the literature was then converted to total sugar using the equation suggested by Chamberlain and Rajaselvam [24]. Honey production potential (HPP) and modified colony carrying capacity (CCC) can be calculated based using Eq. (6) and Eq. (7) as suggested by Bareke et al. [25] where f is the average number of flowers per plant, s is the average amount of sugar per flower, t is the time of flowers secrete nectar (days), c is bee consumption, and p is the productivity of harvested honey.

$$HPP\ (kg\ sugar/plant) = f * s * t \tag{6}$$

$$CCC\ (colony) = \frac{HPP}{c\ +\ p} \tag{7}$$

2.2.3 Techno-economy Analysis

Technical analysis for meliponiculture in Bukit Sandy was carried out based on the availability of vegetation of stingless bees to produce various products particularly honey, raw propolis, propolis extract, and propolis residue. Meanwhile, the economical analysis in this study includes calculation of Total Capital Invetsment (TCI), Total Production Cost (TPC), total revenue, Break Even Point (BEP) unit with FC as fixed costs, p as price per unit, and v as variable cost per unit; BEP price; Net Present Value (NPV) with r as an interest rate of return; Internal Rate of Return (IRR) with i as interest rate, Benefit-Cost Ratio (BCR); and Payback Period (PP) where n as the last year of cash flows has not covered the investment, a as the amount of investment, b as cumulative cash flows in the n year, and c as cumulative cash flows in the n+1 year [26-28]. The value of money and interest rates used in this study were based on the values during the investigated period.

$$BEP\ (kg) = \frac{FC}{p - v} \tag{8}$$

$$BEP\ (US\$) = \frac{FC}{1 - \left[\frac{v}{p}\right]} \tag{9}$$

$$NPV\ (US\$) = \frac{net\ cash\ flow\ 1}{(1+r)} + \frac{net\ cash\ flow\ 2}{(1+r)^2} + \cdots - Invesment \tag{10}$$

$$IRR\ (\%) = i_1 + \frac{NPV_1}{NPV_1 - NPV_2} \times (i_2 - i_1) \tag{11}$$

$$BCR\ (\%) = \frac{\sum PV\ net\ cash\ flow}{\sum PV\ invesment} \times 100\% \tag{12}$$

$$PP\ (year) = n + \frac{(a-b)}{(c-b)} \times 1\ year \tag{13}$$

3. RESULTS AND DISCUSSION

3.1 Environmental Conditions in Bukit Sandy

During the investigation period, there were 18 colonies of *Tetragonula laeviceps* producing a limited amount of honey and propolis. Based on the interviews and observations, the condition of 15 colonies did not develop properly while 3 colonies had bee fleas within the hive with 1 colony full of stingless bees but no honey meanwhile the other colonies were almost abandoned by the colony. Only 16 colonies can be saved for further survival.

Bukit Sandy is topographically categorized as a hilly area with different slopes and altitudes. Research from Sabila [11] shows that the slope in Bukit Sandy is dominated by the steep category with range of 25-45% and several areas that have extremely steep slopes (> 45%) because Bukit Sandy management wants to maintain in the natural state of that location. Beside that, Bukit Sandy is 987.5 – 1125 masl altitude which is categorized as highlands. The altitude will affect the types of plants that grow in that area which impacts the availability of feed for stingless bees [29].

Bukit Sandy area is not only used for tourism but also for plantations of local commodities and academic research. Based on the observation results, pesticides were applied at nearby asparagus plantation area rented by local farmers within Bukit Sandy. This condition does not meet the requirements for meliponiculture which prohibits the use of pesticide within the areas of stingless bee clonies because it can cause decrease growth and may even lead to death for the colonies [9].

According to Kwapong et al. [30], meliponiculture near pesticide areas can be overcome by coordinating with local farmers regarding the timing of pesticide spraying so that the Bukit Sandy manager can close the hives of stingless bee colonies before the spraying begins. Furthermore, there is ascreen house dedicated for cultivation *Hermetia illucens* (Black Soldier Fly, BSF) within the area of Bukit Sandy. The BSF is known asa predator for stingless bees, so meliponiculture needs to be far from the secreen house [31]. The minimal exposure to pesticide and predator is the foraging range from the point of the colonies.

The mapping of land area in Bukit Sndy from Google imagery is shown in Fig. 3 and Table 1. Total area in Bukit Sandy is 7.60 Ha. The built-up area and plantation in Bukit Sandy are 3.27% and 37.96%, respectively. Land potential in Bukit Sandy is around 58.77% which indicates that there is still a large area for meliponiculture. According to Ichwan [13], meliponiculture does not require a large area of land. Large areas of land can be used to provide necessary vegetations for stingless bees.

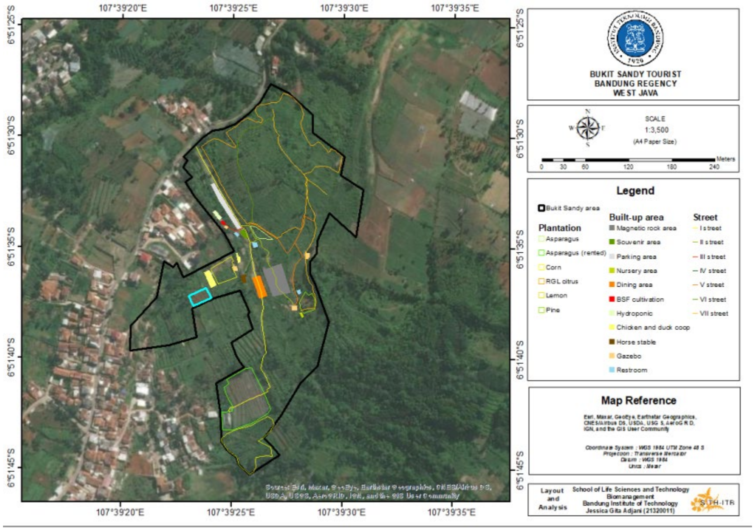

Fig.3.Mapping of built-up and plantation ares in Bukit Sandy

Table 1: Recapitulation of land area in Bukit Sandy

Name	Area (Ha)	Percentage (%)
Bukit Sandy	7.60	100
Plantation	2.89	37.96
Built-up area	0.25	3.27
Potential land	**4.47**	**58.77**

Microclimate is one of the requirements for stingless bees to develop properly [13]. Based on the observation results, the air temperature in July 2021was around 18-27˚C with 70-95% humidity in Bukit Sandy. Stingless bees can live and develop at temperatures of 23-30˚C and relative humidity of 77-94% [32]. Other research mentions that *Tetragonula sp.* can live at 22-28˚C temperatures with 55-88% humidity [33]. The results shows that the microclimate at Bukit Sandy is still within range that is suitable for meliponiculture.

3.2 Vegetation Analysis

Availability of feed is the key to the success of stingless beekeeping [34]. Based on interview results, Bukit Sandy has many types of plants besides citrus variety Rimau Gerga Lebong (RGL) such as lemon, buddha's hand lemon, avocado, passion fruit, jackfruit, sunflower, lemongrass, cogon grass, pine, lantana, asparagus, and may more. The natural disaster which occurred for the first time at Bukit Sandy in 2020 is a tornado. This disaster caused some of those plants and some areas in Bukit Sandy extreamly damaged.

Based on the vegetation analysis, 31 types of plants were identified, and the results were shown in Table 2 and Table 3. Plants that have the potential as feed for stingless bee were around 67.74%. Five plants are identified as tree level, three plants as pole level, eight plants as sapling level, and seventeen plants as seedling level (herbs and liana). Plants at pole level are tree except pine and at sapling level are shrubs except mangoes. Highest IVI for each level is suren, pine, lemon, and cogon grass, respectively. Suren from tree level and cogon grass from seedling level not categorized as stingless bee feed. Therefore, the highest IVI for tree and seedling level as stingless be feed is Mahogany and paspalum, respectively. Mahogany as stingless feed can provide nectar and resin [29,35], pine (the only shrub at pole level) provide resin [36], lemon provide nectar and pollen [37], and paspalum provide pollen [38].

Table 2: Vegetation analysis in Bukit Sandy

No	Name	Scientific name	RD (%)	RF (%)	Rdom (%)	IVI (%)	Feed
Tree							
1	Avocado	*Persea americana*	11.11	16.67	4.93	32.71	√
2	Suren	*Toona sureni*	33.33	33.33	46.27	112.93	-
3	Mahogany	*Swietania macrophylla*	33.33	16.67	12.77	62.77	√
4	Rambutan	*Nephelium lappaceum*	11.11	16.67	15.17	42.95	√
Pole							
1	Matoa	*Pometia pinnata*	14.29	33.33	10.34	57.96	√
2	Pine	*Pinus merkusii*	71.43	33.33	62.76	167.52	√
3	Suren	*Toona sureni*	14.29	33.33	26.90	74.52	-
Sapling							
1	Lemon	*Citrus limon*	31.43	25.00	-	56.43	√
2	RGL citrus	*Citrus reticulate var RGL*	28.57	18.75	-	47.32	√
3	Caliandra	*Calliandra calothyrsus*	5.71	6,25	-	11.96	√
4	Lantana	*Lantana camara*	22.86	25.00	-	47.86	√
Seedling							
1	Touch-me-not	*Mimosa pudica*	6.17	10.81	-	16.98	√
2	Cogon grass	*Imperata cylindrica*	52.77	21.62	-	74.39	-
3	Paspalum	*Paspalum sp.*	29.87	21.62	-	51.49	√
4	Redflower ragleaf	*Crassocephalum crepidioides*	3.94	8.11	-	12.05	-

Table 3: The floral calender and type of vegetation feed in Bukit Sandy

No	Name	Type of feed			Month											
		N	P	R	1	2	3	4	5	6	7	8	9	10	11	12
1	Avocado	√	√													
2	Pine			√												
3	Mahogany	√		√												
4	Mangoes	√	√	√												
5	Matoa	√														
6	Rambutan	√	√	√												
7	Lemon	√	√													
8	Water apple	√	√													
9	RGL citrus	√	√													
10	Caliandra	√	√													
11	Lantana	√	√													
12	Cassava	√	√	√												
13	Touch-me-not	√	√													
14	Paspalum		√													
15	Corn		√													
16	Sweet potato	√														
17	Goat weed	√	√													
18	Snakeweed		√													
19	Clidemia		√													
20	Orosne		√													
21	Kirinyuh	√	√													

Feed availability compositions based on the plant type in Bukit Sandy are 76.2% nectar (N), 81.0% pollen (P), and 23.8% resin (R). Bees use nectar as source of energy while pollen as source of protein [39]. Lack of nectar sources will affect the hygiene behavior of the bees which affects the growth of the colony and make the bees want to look for pollen [40]. The composition of nectar and pollen is slightly different, but the ratio of nectar and pollen is almost equal. Feed distribution based on plant type was highest in March and lowest in February and November (Fig.4). The average distribution of feed per month is 8.33% ± 1.20%.

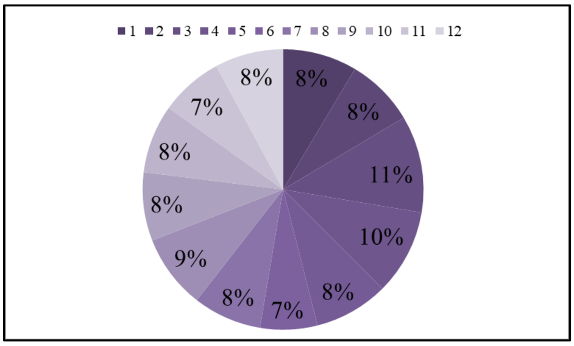

Fig. 4. Feed distribution permonth available for stingless bees in Bukit Sandy

3.3 Carrying Capacity of Stingless BeeColonies in Bukit Sandy

K3 is a meliponiculture location in Bukit Sandy that meets the requirements based on the environmental description. Estimation of feed availability uses the honey production potential (HPP) approach with total sugar content units in plants [23, 25]. However, there are competitors with other insects such as butterflies, ants, bees, etc. so the HPP decreased by 40% [23]. To convert total sugar mass into honey, it was assumed that the acceptability of honey on the market is 18% water content so 82% total dissolved sugar of 82% is obtained from 1 kg of honey [25]. Stingless honey has a water content of 28.60% so the dissolved sugar of stingless honey is 71.40% [41]. The results of HPP per month are shown in Table 4.

Table 4: Honey production potential and colony carrying capacity per month in Bukit Sandy

Month	HPP (kg)	HPP after competiton (kg)	Sugar to honey (kg)	CCC
January	6.28	3.77	5.28	10
February	6.28	3.77	5.28	10
March	35.95	21.57	30.21	54
April	32.27	19.36	27.11	48
May	27.61	16.57	23.21	42
June	2.69	1.61	2.25	4
July	2.69	1.61	2.25	4
August	2.69	1.61	2.25	4
September	25.85	15.51	21.72	39
October	25.85	15.51	21.72	39
November	25.85	15.51	21.72	39
December	6.28	3.77	5.28	10

The calculation of colony carrying capacity (CCC) assumed that the stingless bees collect 16 mg nectar per day with a sugar content of 0.4 mg sugar/mg nectar [42] and the number of individual stingless bees in the colony is 2000 [1] so 1 colony needs 0, 96 kg of nectar/month or equivalent to 0.38 kg of sugar/month or 0.54 kg of honey/month. Honey productivity varies between 49.2-66.6 ml per 2 months [43], 200 ml/colony/year [44], 0.3-

0.4 kg/colony/year [45], and 600-700 gr/colony/year [46]. Hence, it can be inferred that stingless bees produce less than 1 kg and the honey productivity used in this study was estimated at 300 g/colony/year or 25 g/colony/month.

Based on the analysis, the carrying capacity of stingless bee colonies in the K3 location varies from 4 to 54 colonies each month (Table 4). The minimum carrying capacity of stingless bee colonies in the K3 location makes the feed sufficient every month. If Bukit Sandy manager wants to maximize the carrying capacity of stingless bee colonies, it is necessary to provide additional feed support and requires good feed management for the survival of colomies.

3.4 Techno-economy Analysis

The techno-economic analysis carried out in this study was based on the estimation of the carrying capacity of stingless bee colonies in Bukit Sandy. The main product of the meliponiculture is propolis. Hakim and Abduh [47] reported that *Tetragonula laeviceps*can produce 2-2.4 g/week/colony propolis while Pribadi [48] reported that *Heterotrigona itama* can produce 34.97-37.20 g/colony/month. As such indicates that *H. itama* can produce more propolis than *T. laeviceps*. Moreover, the microclimate conditions in Bukit Sandy are more suitable *H. itama* with average temperature and humidity of 28.81°C and 83.06%, respectively [49]. Hence, this study investigates a techno-economic analysis for meliponiculture in Bukit Sandy using *H. itama* with three proposed scenarios:

1. Scenario 1 (SC 1): meliponiculture based on minimum CCC (4 colonies) with raw propolis and honey as products.
2. Scenario 2 (SC 2): meliponiculture based on minimum CCC (4 colonies) with propolis extract, honey and propolis residue as products.
3. Scenario 3 (SC 3): meliponiculture based on maximum CCC (54 colonies) with propolis extract, honey and propolis residue as products.

3.4.1 Technical Analysis

The calculation of production capacity uses the estimated productivity of raw propolis and honey that have been calculated. The productivity of the raw propolis used in this study is 0.42 kg/colony/year [48] and 0.30 kg/colony/year for honey [45]. The estimated production capacity for scenarios 1 and 2 is 1.68 kg raw propolis/year and 1.2 kg honey/year. Meanwhile, the production capacity for raw propolis is 22.66 kg/year and 16.20 kg/year honey for scenario 3.

The production process started with meliponiculture using MOTIVE (Modular Tetragonula Hive) made of wooden boxes with dimensions 20 cm x 18 cm x 18 cm [47,48], to production of meliponiculture products in Bukit Sandy. The overall process was divided into two types of process such as the production process of raw propolis and honey for scenario 1 and the production process of propolis extract, honey, and propolis residue for scenarios 2 and 3 as shown in Fig. 5.

The implementation of meliponiculture for scenarios 1 and 2 needs to reduce the current number of colonies on Bukit Sandy because it exceeds the estimated CCC. In contrast to scenario 3 that needs to increase the number of colonies to maximize the CCC of the existing colonies. It is aligned with increasing the amount of feed and good feed management for stingless bees. The additional feed used for scenario 3 is sunflower [50] and coral vine [51] because of stingless bees like both flowers. Both flower plants produce nectar and pollen [50].

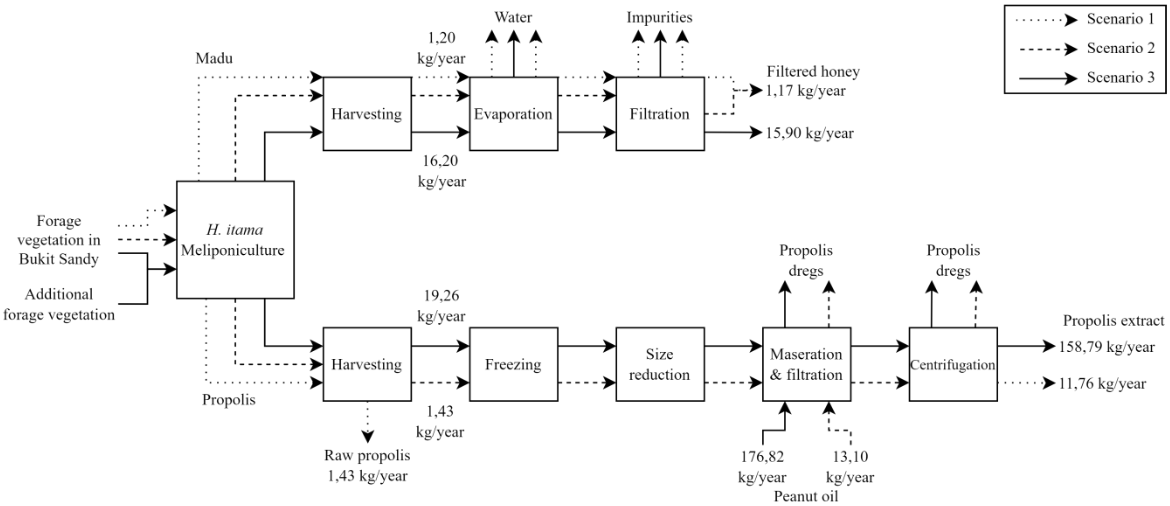

Fig. 5. Block flow diagram and mass balance for scenario 1,2, and 3

The honey production process started from the harvesting process. It was assumed that honey from *H. itama* meliponiculture in Bukit Sandy could be harvested 4 times per year [8]. The next process was to filter honey to separate impurities from the honey and evaporated the honey to reduce the moisture content of honey for all scenarios [17]. The final target of the expected moisture content in *H. itama* honey was 27% according to the criteria of SNI 2018 [52] and the Department of Malaysian Standards [53] while the targeted impurities were 0.7% [52]. The process of reducing the moisture content of *H. itama* honey uses a simple tool with the dehumidification method [54,55]. The dehumidification process was set at 40˚C for 1 hour 30 minutes.

The propolis production process started with harvesting of raw propolis once a month [48]. It was assumed that 85% of raw propolis that could be separated from the propolis frame [1]. Raw propolis from scenario 1 could be packed immediately while for scenarios 2 and 3, were stored in the refrigerator for 24 hours [56] to make it easier for size reduction [57]. The next processes were the extraction process by maceration and the purification process by filtration and centrifugation. Peanut oil was chosen as the solvent because there are additional benefits from the oil and have prospects in the field of health and halal food supplements [4,57]. The ratio between raw propolis and peanut oil was as suggested by Firmansyah et al. [57] particularly 1:10 w/v and the maceration process was carried out for 7 days to obtain a high content of antioxidant compounds with an estimated yieldof 89.98%. Purication was carried out using centrifugation with to produce propolis extract as the main product and propolis residue as the co-product.

3.4.2 Economical Analysis

The investment cost for meliponiculture of *H. itama*in Bukit Sandy is shown in Table 5 which comprises of *H. itama* colonies, total cost of equipment, distribution and electrical installation, water installation, land and building costs, and unexpected costs [1]. The total investment cost for scenario 3 is much higher than the other 2 scenarios due to higher amount of colonies and consequently more investment is needed. The total production cost of proproplis for all scenarios are shown in Table 6. The total production cost consists of fixed costs (FC) and variable costs (VC). Fixed costs are costs that are relatively fixed and are not affected by the amount of production. Fixed costs for *H. itama* meliponiculture include labor salaries, equipment depreciation, electricity utilities, internet, equipment maintenance, and marketing costs. Variable costs are costs that will change according to the amount of production and can be affected by changes in the market. Variable costs include raw materials for production and packaging.

Table 5: Total capital investment for meliponiculture of *H. itama* in Bukit Sandy

Component	**Cost (US$)**		
	Scenario 1	**Scenario 2**	**Scenario 3**
***Direct Cost* (DC)**			
H. itama colonies	41.26	41.26	556.99
Total cost of equipment	148.60	939.39	3.727.92
Distribution and electrical installation	0	127.21	433.22
Water installation	0	0	398.83
Land and building	0	687.64	3,060.02
Total DC	189.86	1,795.51	8,176.98
***Indirect Cost* (IC)**			
Unexpected costs (0,05 DC)	9.49	89.78	408.85
Total IC	9.49	89.78	408.85
***Total Capital Investment* (TCI)**			
TCI = DC + IC	199.35	1,885.28	8,585.83

Table 6: Total annual production cost of propolis for meliponicultre of *H. itama* in Bukit Sandy

Parameter	**Cost (US$)**		
	Scenario 1	**Scenario 2**	**Scenario 3**
Total Fixed Cost (TFC)	1,538.28	5,961.22	26,450.65
Total Variabel Cost (TVC)	7.23	691.79	9,782.38
Total Co-credit (CC)	51.00	136.00	1,838.00
Total Production Cost (TPC)			
TPC = FC+VC	1,545.51	6,653.02	36,233.03
TPC/kg propolis	1,080.77	565.73	228.18
TPC - CC	1,494.51	6,517.02	34,395.03
(TPC-CC)/kg propolis	1,045.11	554.17	216.61

From Table 6, it can be obserbed that TPC per kg of propolis for each scenario decreases when the sales of co-products such as honey and propolis residue were considered. The TPC-CC per kg for scenarios 2 and 3 are still acceptable for the Indonesian and international markets that still allow for a profit margin [58,59] whereas for scenario 1, the TPC-CC per kg is too high for commercial sales. Therefore, scenario 1 was not analyzed further. The Break-even point (BEP) for scenarios 2 and 3 are 7.72 kg (US$ 6.415,19) and 100.45 kg (US$ 32.639,18), respectively as illustrated in Fig. 6 and Fig. 7.

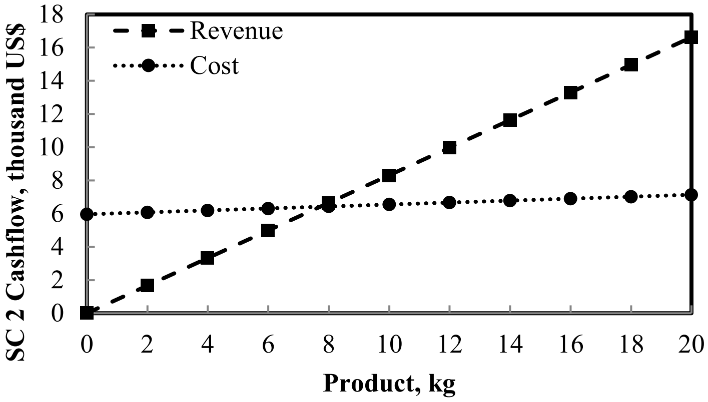

Fig. 6. BEP of scenario 2 for meliponiculture of*H. itama*in Bukit Sandy

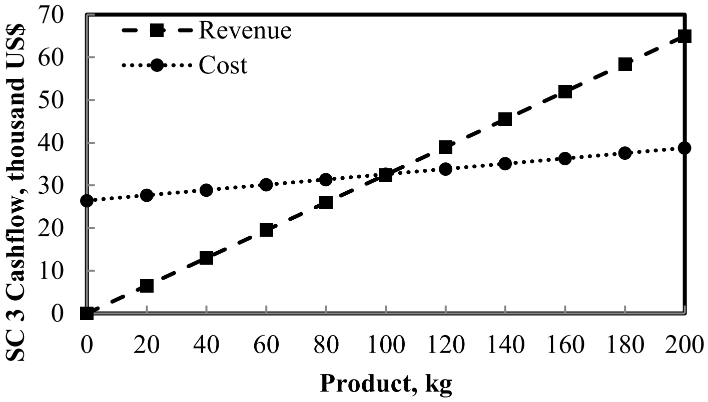

Fig. 7. BEP of scenario 3for meliponiculture of*H. itama* in Bukit Sandy

The cumulative cash flows for scenarios 2 and 3 are shown in Fig. 8. The preparation process for meliponiculture at Bukit Sandy was estimated around 6 months. In addition, the sales of propolis for scenarios 2 and 3 in the 1st year were assumed 85% and will increase by 3.5% [1] in the 2nd - 5th year and reached 100% in the 6th year. Sales of honey for scenario 2 were assumed to be 100% annually while for scenario 3 was 85% in the 1styear and will increase by 6.5% [1] in the 2nd - 3rdyear and reached 100% in the 4th year. The production capacity of the products was assumed to remain the same. Income tax for scenario 2 was subjected to a 0% rate while for scenario 3 was 0.5% based on Indonesian regulation No. 7 year 2021. The discount rate was assumed to be 15% [60].

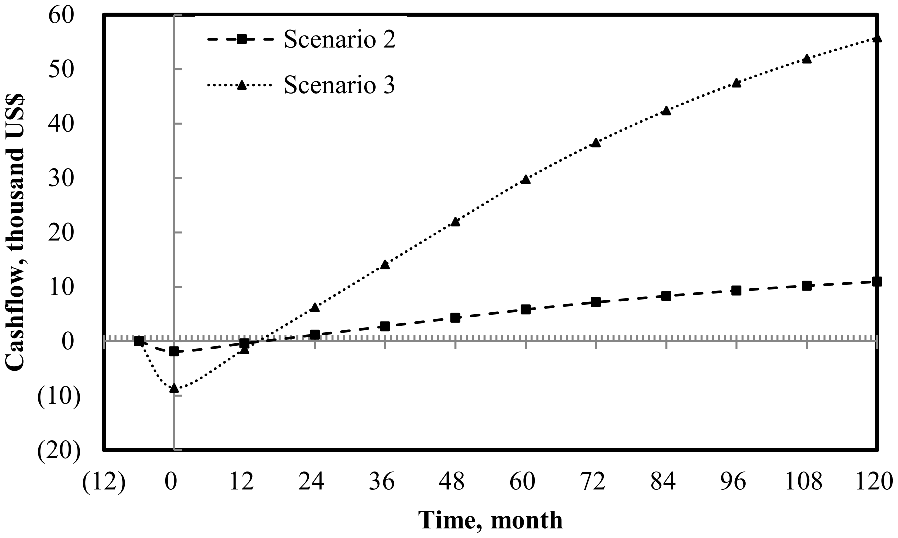

Fig. 8. Cumulative cash flow for *H. itama* meliponiculture in Bukit Sandy

Table 7: The investment criteria of meliponiculture in Bukit Sandy

Criteria	Scenario 2	Scenario 3
NPV	US$10.909,85	US$116.208,62
IRR	105.19%	121.15%
PP	1.3 years	1 year
BCR	4.02	4.49

The recapitulation of the investment criteria is shown in Table 7. The investment is considered feasible if the NPV > 0, IRR > 3.75% (Bank of Indonesia reference rate), BCR > 1, PP is faster than the project lifetime, BEP unit < production unit [61]. Based on that criteria, scenarios 2 and 3 maybe considered feasible with is scenario 3 is more profitable as compared to scenario 2. However, scenario 2 maybe a good option for early stages of meliponiculture in Bukit Sandy due to easier operation for managing only 4 colonies of *H. itama* and yet to achieve a PP after 1.3 years. After the establishment of meliponiculture in Bukit Sandy, the number of colonies can be increased up to 54 colonies of *H. itama* for higher profit and benefits to the society.

4. CONCLUSION

This study has investigated the environmental conditions, carrying capacity of stingless bee colonies, and techno-economic analysis of meliponiculture in Bukit Sandy. The findings suggest that environmental conditions in Bukit Sandy are suitable for stingless beekeeping with dominant forage vegetation potential for stingless bees in Bukit Sandy are mahogany, pine, lemon, and paspalum. The estimated potential for production of honey in Bukit Sandy ranges from 2.25-30.21 kg/month and the carrying capacity of stingless bee colonies in Bukit Sandy is 4-54 colonies. Meliponiclture based on minimum carrying capacity (4 colonies) with propolis extract, honey and propolis residue as products is proposed for early stages implementation in Bukit Sandy and gradually transformed to meliponiculture based on maximum carrying capacity (54 colonies) with propolis extract, honey and propolis residue as products for higher profit and benefits to the society.

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