Potential growth of meliponomiculture in West Halmahera, Indonesia

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Abstract. Meliponiculture is stingless bee’s beekeeping, developed in many countries, also Indonesia. Stingless bee produced honey with high value, wax, and propolis that used by humans, also to pollinate crops. West Halmahera, North Moluccas Province, Indonesia has potencies for the growth of meliponiculture, supported by natural resources that produced nectars and pollens to feed them, as well as resins for the nest and defenses. Land suitability has been considered in beekeeping. This research was conducted in West Halmahera. This paper aims to evaluate the land suitability for the growth of meliponiculture in West Halmahera. The method used was Multi-Criteria Decision Making. There are four (4) criteria used, which are: elevation, temperature, bee forage potency, and land use. These criteria were weighted by Analytical Hierarchy Process. The criteria’s weights, as well as sub-criteria scores resulted, were used to delineate areas that are suitable for bee in a model by using Geographic Information System. The result of the analysis showed that West Halmahera has 99% potencies for the growth of meliponiculture in various levels of suitability. The highly suitable (S1) area for meliponiculture is 26.46%, suitable (S2) is 59.46% and marginally suitable (S3) is 13.18%.

Keywords: Geographic Information System, Land Suitability, Stingless Bee, Multi-Criteria Decision Making, West Halmahera

1. Introduction
Meliponiculture is stingless bee’s beekeeping that developed in Central and North America [1]. Generally, this activity traditionally doing by community-based on region and their culture [2]. Stingless bee produces honey and wax. Even it produce less honey, but stingless bee produce honey with higher value than honey bee [1]. Honey used as nutrition supplement, cosmetic, pharmacy and drugs [3]. Resin from stingless bees also used by humans, besides that stingless bees also used as pollinator [2].

Stingless bees live in nature and spread through tropic and sub-tropic area [4], including Indonesia. Stingless bee is a local bee, and there are 46 species in Indonesia [5,6]. Meliponicuture is developed,
including Indonesia and the community used the product from stingless bee [6]. Sustainability of meliponiculture supported by availabilities of various plants and flowering season [7,8]. Meliponiculture in Indonesia is ideal because it works in various types of environment. The development in Indonesia was significant in many areas related to distribution, increasing honey production, raw propolis, and derivative products [6].

Availability of plants producing nectar and pollen in Indonesia supported beekeeping. It spread through all types of vegetation, i.e. agriculture, plantation, forestry, also shrub vegetation [9]. The population development of bees and the success of beekeeping influenced by nectar and pollen availabilities [10].

Bees feed resource in Indonesia supported by natural and artificial environment [6]. West Halmahera is one regency of North Moluccas Province, has a wide area with fertile soil, that about 40 percent of civil working in agriculture. Agriculture is the superior sector, produced various plants as food, crops, and forest [11]. Business opportunities to develop meliponiculture in West Halmahera is potential because it supported by natural resources.

Habitat suitability has to be considered in beekeeping based on ecological environment and land suitability as feed resources [12]. Geographic Information System is a technology with ability in land suitability modeling [13]. Model of land suitability construct by approach of multi-criteria decision making (MCDM) based on expert opinion [14,15]. Model of land suitability also been used to determine bees habitat in a few research [12,16,17]. The objective of this paper is to show the results of an evaluation of the land suitability for the growth of meliponiculture in West Halmahera.

2. Methodology

2.1. Study Area
This research was done in West Halmahera Regency, North Moluccas Province in 2019 (figure 1). West Halmahera has 2,361.56 km² of land area, located between 00° 48’ north latitude until 10° 48’ north latitude and between 127° 16’ 00” east longitude until 127° 16’ 01” east longitude.

The highest temperature occurs be spread evenly each month in 2017 in the amount of 31 °C, and the minimum temperature was in June and September, 24 °C, with the highest light intensity, was in October. West Halmahera is dominated by steep ground which reached 61.99% [11].

![Map of West Halmahera Regency](image)

**Figure 1.** Research area of West Halmahera Regency, North Moluccas, Indonesia
2.2. Data

The data used are interview results with experts and the general state of research location from BPS-Statistic of West Halmahera. Digital Elevation Model (DEM) Map from www.eartexplorer.usgs.gov used to generate altitude and temperature maps by ArcGIS 10.3. Land Use map was done by Directorate General of Forestry and Environmental Planning. Direction of Agriculture Suitability map in small scale (1:250,000) obtained from Development Planning Agency at Sub-National Level, West Halmahera Regency to have the species of feed plants and resin producer that use for developed of meliponiculture.

2.3. Analysis

Analysis of land suitability to develop meliponiculture in West Halmahera used Multi-Criteria Decision Making (MCDM) method. The first step is to use the Analytical Hierarchy Process (AHP) by weighted the criteria of land suitability [14]; [15]. Criteria of land suitability consists of 2 (two) groups of parameters: 1). Land Physic, and 2). Growth Potency. Parameters group of land physics consists of 2 (two) parameters, which are altitude and temperature, while parameters group of growth potency are parameter of plants of bees feed and resin producer, also parameter of land use. Each criteria consist of sub-criteria and have to scored. Spatial data for criteria and sub-criteria shown in figure 2, while the spread of quantitative data shown in table 1 (column d-e). Criteria weighted by AHP was done by 2 (two) expert, by pairwise comparison of Saaty. Pairwise comparison was assessed from 1 to 9 based on their importance level (table 2). Consistency ratio (CR) less than 10% shown that the weighting process is valid [18].
Table 1. Distribution of criteria and sub-criteria in the study area.

| Parameter       | Criteria          | Sub Criteria          | Area (d) | % (e) | Score (f) |
|-----------------|-------------------|-----------------------|----------|-------|-----------|
| Land Physic     |                   |                       |          |       |           |
| Altitude        |                   | 0 – 500 m asl         | 187,943.7| 87.0  | 10        |
|                 |                   | 500 – 1,000 m asl     | 26,388.5 | 12.2  | 8         |
|                 |                   | 1,000 – 1,500 m asl   | 1,644.7  | 0.8   | 6         |
|                 |                   | 1,500 – 2,000 m asl   | 15.2     | 0.0   | 2         |
| Temperature     |                   | 23 – 25 C             | 11,517.8 | 5.3   | 4         |
|                 |                   | 26 – 28 C             | 45,577.1 | 21.1  | 10        |
|                 |                   | 29 – 31 C             | 81,363.7 | 37.7  | 10        |
|                 |                   | 32 – 34 C             | 77,533.5 | 35.9  | 4         |
|                 |                   | Agathis               | 54,179.5 | 25.1  | 4         |
|                 |                   | Acacia                | 36,282.7 | 16.8  | 4         |
|                 |                   | Mangrove forest       | 4,338.6  | 2.0   | 2         |
|                 |                   | Zea Mayz              | 15,202.8 | 7.0   | 6         |
| Growth Potency  | Bees Forage Potency | Hevea brasiliensis    | 3,828.9  | 1.8   | 2         |
|                 |                   | Eucalyptus spp.       | 4,723.7  | 2.2   | 2         |
|                 |                   | Cocos nucifera        | 16,885.6 | 7.8   | 6         |
|                 |                   | Coffea canephora      | 28,583.0 | 13.2  | 6         |
|                 |                   | Swietenia mahagoni    | 40,841.0 | 18.9  | 4         |
|                 |                   | Myristica fragrans    | 8,278.0  | 3.8   | 2         |
|                 |                   | Vanilla planifolia    | 2,848.3  | 1.3   | 2         |
|                 |                   | Water Bodies          | 224.8    | 0.1   | 2         |

Figure 2. Spatial Distribution of: A. Altitude; B. Temperature; C. Bee Forage; D. Land Use.
Parameter | Criteria | Sub Criteria | Area ha | Score % | Score
---|---|---|---|---|---
(a) | (b) | (c) | (d) | (e) | (f)

| | | | | | |
|---|---|---|---|---|---|
| Shrub | 7,095.7 | 3.3 | 8 |
| Swamp bushes | 13.5 | 0.0 | 3 |
| Mangrove forest | 2,898.3 | 1.3 | 6 |
| Secondary of Mangrove Forest | 707.8 | 0.3 | 4 |
| Primary Forest | 14,561.4 | 6.7 | 2 |
| Secondary Forest | 98,856.5 | 45.8 | 8 |
| Open Spaces | 316.6 | 0.2 | 0 |
| Residential | 1,988.0 | 0.9 | 10 |
| Agriculture on dry land | 4,411.4 | 2.0 | 7 |
| Agriculture on dry land with shrubs | 84,776.0 | 39.3 | 8 |
| Fishpond | 35.3 | 0.0 | 0 |
| Transmigration area | 106.8 | 0.1 | 2 |
| **Total** | **215,992.1** | **100** | |

Table 2. Rating for pairwise comparison according to Saaty (2008).

| | 1/9 | 1/7 | 1/5 | 1/3 | 1 | 3 | 5 | 7 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| Extremely Less Important | Very Strongly Less Important | Strongly Less Important | Moderately Less Important | Equally Less Important | Moderately More Important | Strongly More Important | Very Strongly More Important | Extremely More Important |

Each criteria consist of sub-criteria were scored, which given by expert consideration. The score given start from 0 – 10 [14,15], based on the contribution to develop meliponiculture. The score given to the sub-criteria shown in table 1 (column f). the Altitude 0 – 500 m asl, the score given is 10, 500 – 1,000 m asl is 8, 1,000 – 1,500 m asl is 6, while 1,500 – 2,000 m asl is 2. The highest score of temperature were given to 26 – 28 °C and 29 – 31 °C, because it was the best temperature as habitat of stingless bee. Zea mayz, Cocos nucifera, and Coffea canephora were the best plants to meliponiculture based on the map of Direction of Agriculture Suitability, while Agathis, Acacia, Swietenia mahagoni, Mangrove Forest, Hevea brasiliensis, Eucalyptus spp., Myristica fragrans, and Vanilla planifolia stiil used as bees fee and resin producer. Residential is the best location for meliponiculture. Stingless bees can also manage in shrubs, secondary forest, agriculture on dry land with shrubs, agriculture on dry land, mangrove forest. Secondary of mangrove forest, swamp bushes, and transmigration area had the lowest score, while open spaces and fishpond cannot be used for meliponiculture.

2.4. Spatial Treatment

Map of altitude was obtained from reclassify of DEM map, consist of four class: 0 – 500 m asl, 500 – 1,000 m asl, 1,000 – 1,500 m asl and 1,500 – 2,000 m asl. Map of temperature obtained from the DEM map by estimating based on altitude of place with Braak formula:

\[
\text{Temperature} = \text{Average of temperature} - (0.01 \times \text{altitude} \times 0.6)
\]  

Map of bee forage direction used 11 species of plants from map of Direction of Agriculture Suitability in West Halmahera. Map of land use showed that there are 13 classes of land use in West Halmahera Regency.

Map of Land Suitability for meliponiculture created by multiplying the weight of criteria and score of sub-criteria. Land suitability divided into 4 (four) class: Highly Suitable (S1), Suitable (S2), Marginally Suitable (S3) and Not Suitable (N) by the equation [19]: [20], [14]:

5
Where: $S = \text{Land Suitability}; w_i = \text{weight of land suitability}; x_i = \text{score of sub-criteria i}; n = \text{number of land suitability criteria.}$

3. Result and discussion

Pairwise comparison of various criteria for growth potencies of meliponiculture in West Halmahera regency shown in table 3. The consistency ratio (CR) is 0.04 so that the result analysis is valid. AHP analysis is valid if CR less than 0.1. it is shown that the decision from expert is not subjective [18].

| Table 3. Weight of parameter resulting from pairwise comparison of criteria. |
|-----------------------------|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                            | Altitude | Temperature | Bee Forage Potency | Land Use | Weight    |
| Altitude                    | 1        | 1/4         | 1/8              | 1/8   | 0.2582    |
| Temperature                 | 3 7/8    | 1           | 1/5              | 1/4   | 1.0000    |
| Bee Forage Potency          | 8        | 5 1/5       | 1                | 1 3/4 | 5.1962    |
| Land Use                    | 8        | 3 7/8       | 4/7              | 1     | 3.8730    |

Konsistensi Vektor: 4.103689; n = 4; Konsistensi Index (Ci) = 0.034563; Random Index (Ri) = 0.90; Konsistensi Rasio (Cr) = 0.028403

The weight result of criteria of land suitability for meliponiculture showed that bee forage is the main factor, followed by land use and temperature, while altitude is the factor with the lowest weight. The result of this research supported by the researcher before reported that vegetation is the main factor in beekeeping, including the composition of plants, flowering season and the ability to attract the bees to visit flower [21]. Beekeeping depends on plants as bee forage to produce honey. Plants diversity supported business development and carrying capacity of beekeeping [22]. Stingless bee collect nectar, pollen, and resin from nature to survive. Nectar and pollen collect from flower contains carbohydrate and protein for their life necessities [23].

Land use is one of the important factors to determine the suitability of stingless bees’ habitat because it supported bee forage availability. Residential is the priority for meliponiculture. This result supported by other researcher stated that the beekeepers placed nest around houses. It makes them easy to care and harvesting [6]. Other researchers stated, that priority beekeeping location is agriculture area, non-agriculture areas like plantation, rice fields irrigation, rainfed rice field, moor, shrubs or residential [17].

The results show that temperature also one of the important factors on meliponiculture. It supported by the previous researcher, that the flight activity was relatively constant in a wide range of temperatures, from 22 °C to 34 °C. Rising of temperature will increase flight activity [24], but increase at higher temperature [25]. Low temperature will increased the mortality rate of adults and pupae in stingless bees. Water consumption has a significant positive correlation with high temperature [26].

Altitude is the last factor to determine the location for meliponiculture, but it correlates with temperature. Braak formula in previous research showed, that every 100 m increase above sea level, temperature decrease 0.5 °C [17]. Spread of plant species and microclimate (temperature, light intensity, and humidity) on the area has the relation with altitude. Altitude also affected the topography of the area, while in the highest altitude, the slope is extreme [27].

Map of land suitability for development of meliponiculture in West Halmahera shown in figure 3, showed that almost all areas are potential for meliponiculture. This result supported by table 4, that showed 99% of areas in West Halmahera are potential to develop meliponiculture, amount of 128,422.70 ha (59.46%) is moderately suitable (S2).
Figure 3. Map of land suitability for meliponiculture in West Halmahera

Table 4. Summary of suitability for meliponiculture in West.

| Class                        | Suitability | Ha     | %   |
|------------------------------|-------------|--------|-----|
| N (Not Suitable)             |             | 2,155.9| 1.00|
| S1 (Highly Suitable)        |             | 56,943.0| 26.36|
| S2 (Suitable)               |             | 128,422.7| 59.46|
| S3 (Marginally Suitable)    |             | 28,470.5| 13.18|
| Total                        |             | 215,992.1| 100 |

4. Conclusion
Analysis of land suitability for development of meliponiculture in West Halmahera Regency by multi-criteria decision making with two parameters, consist of various criteria. The criteria are temperature, potency of bee forage, and land use. The result of the analysis showed that about 213,836.20 ha (99%) areas in West Halmahera Regency potential to develop meliponiculture with various suitability.

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