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*Article*

# Modeling suitable habitats of stingless bee klanceng (*Tetragonula laeviceps*) in Merbabu Mountain areas related to elevation, temperature, and humidity variables

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**Abstract.** Klanceng is one of the stingless bee species in Indonesia with the scientific name *Tetragonula laeviceps*. This bee species has sustainable economic values since it has a role as a pollinator. This species is also common in mountainous areas, including Merbabu Mountain, Central Java. Despite this bee being very common, information about potential distributions of this bee is very limited, and this information is needed for its management. This study aimed to model the potential habitat for *T. laeviceps* using species distribution modeling (SDM) with elevation, temperature, and humidity as predictors. The model was built based on the *T. laeviceps* occurrence points gained through field surveys, with a total of 23 sampling points. According to the model, most of the west parts of Merbabu Mountain were considered not suitable for *T. laeviceps*. This suitability is also similar to the north and south parts. This condition is in contrast to the areas that bordered with the Merbabu Mountain directly. Most areas adjacent to the Merbabu Mountain were having high and very high suitability for *T. laeviceps*. Regarding altitudinal distribution, *T. laeviceps* was limited at elevations of 1000 m.

**Keywords:** Stingless bee, elevation, humidity, SDM, temperature

## INTRODUCTION

Genus Tetragonula is known as a tropical stingless bee widely distributed in the Indomalayan regions. This genus is also known as one of the most critical keystone bee pollinators across its range. This genus is predicted to have existed since the last glacial maximum and previous interglacial periods, as reported by Ghassemi-Khademi et al. (2023). According to climatic regions, Genus Tetragonula is widely distributed across subtropical and tropical regions (Wongsa et al., 2023). This genus was distributed from northern India to south east Asia. One of the Tetragonula species is inhabiting Indonesia.

In Indonesia, Klanceng is the Javanese term for a stingless bee from the order Hymenoptera, tribe Meliponini (Efin et al., 2018) with scientifical name of *Tetragonula laeviceps*. Indonesia has 52 species of Klanceng (Trianto et al., 2023) and plays an important role as a pollinator on various types of plantation crops (Kahono & Erniwati, 2014). The *T. laeviceps* has been found in various conservation areas in Java, including; Mount Halimun Salak National Park (Pratama et al., 2023), Baluran National Park (Rachmawati et al., 2022), and Forest Reserve Petungkriyono (Alfian, 2022).

Despite growing studies about *T. laeviceps*, the information about potential distributions of this stingless bee species is still very limited in particular Merbabu Mountain and nearby Mount Merbabu National Park (TNGMb) areas. This location can be potential habitats due to diverse plant species (Wahyudi, 2019) that might be correlated with the diversity of insects (Zhang et al., 2016), including *T. laeviceps*. The novelty of this research is aiming in using species distribution modeling with environmental variables including elevation, temperature, and humidity as predictors. As a result, a model that can be used and contribute to the sustainable management of this Klanceng stingless bee species.

## MATERIAL AND METHODS

### Study Period, Site, and Species

The method used in this study is a combination of field survey, the use of geographic information system (GIS) and modeling approach. Field survey activities aimed to collect and record the presences of *T. laeviceps* with its environmental variables including elevation, temperature, and humidity. While the use of GIS aiming to model the suitable habitats of *T. laeviceps*.

### Study Locations

The study area was located at areas bordered by Merbabu Mountain and Merbabu National Park, Central Java on the east side and bordered with Magelang District at west side, Temanggung District at north side, and the south side was bordered with Sleman District. According to Fig. 1, the precise location of study area was at 110.2540°- 110.3440°E (East Longitude) and 7.381°- 7.514°S (South Latitude). The study area was divided into three sampling stations, namely station A, B, and C. Station A was located at north side comprising of four sampling points, station B was located at west side comprising of seven sampling points, and station C was located at east side comprising of 12 sampling points, with a total of 23 sampling points. Station A and C was nearby the Merbabu Mountain and Merbabu National Park at Traditional Zone following Merbabu National Park zonation map available at https://www.google.com/maps/d/u/0/viewer?mid=1QFM_AbcV-nSl-phadBSw-3IlfeN1Tig&femb=1&ll=-7.440705140820734%2C110.403918499.

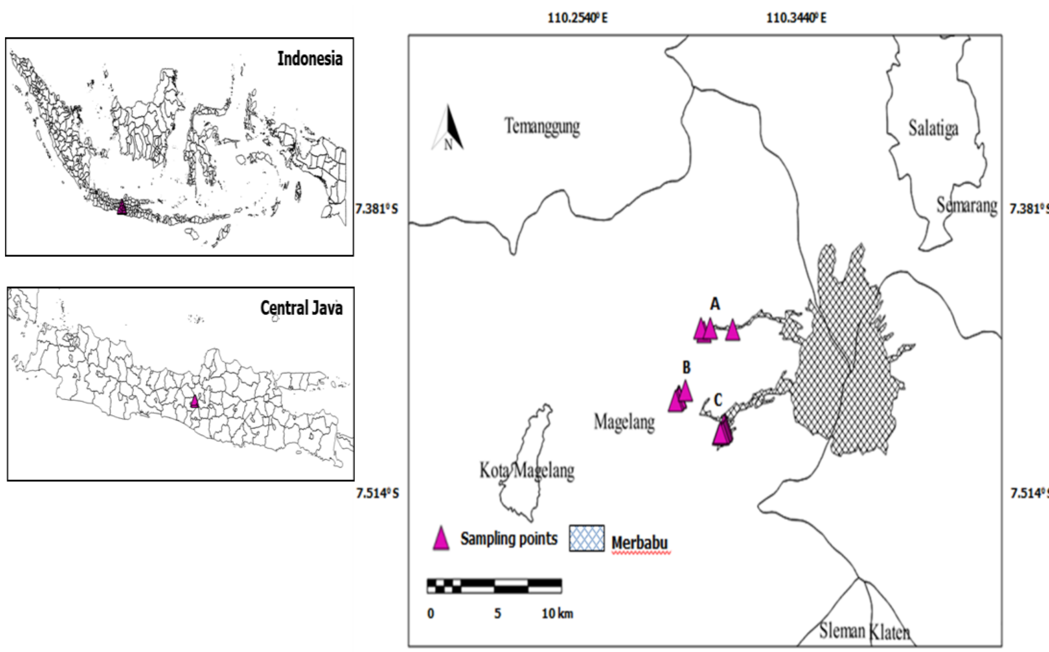


**Figure 1**. Study locations and sampling points in Merbabu, Central Java, Indonesia

### *Tetragonula laeviceps* Occurrence Surveys

The *T. laeviceps* occurrence in the Merbabu was recorded and assessed through field surveys. The survey techniques used included visual encounter surveys and multiple surveys through random visits on designated sampling points. The surveys were conducted in May, June, and September 2023 and carried out at 07.00–11.00 and continued at 14.00–16.00 following activity times of *T. laeviceps*. The bees were captured using sweep net and preserved using alcohol 95%, stored in the vial tube, the transported to the laboratory for further identifications. The identification of *T. laeviceps* was based on identification keys (Jalil & Shuib, 2012) and species descriptions following Trianto and Purwanto (2020). The presence and occurrence points of *T. laeviceps* were recorded using hand held Global Positioning System (GPS) then tabulated into a Geographical Information System (GIS) to be mapped and used as reference points for modeling.

### Data Analysis

Data analysis includes the modeling of *T. laeviceps* suitable habitats known as Species Distribution Modelling (SDM) (Fig. 2). The modeling was based on elevation, temperature and humidity predictors.

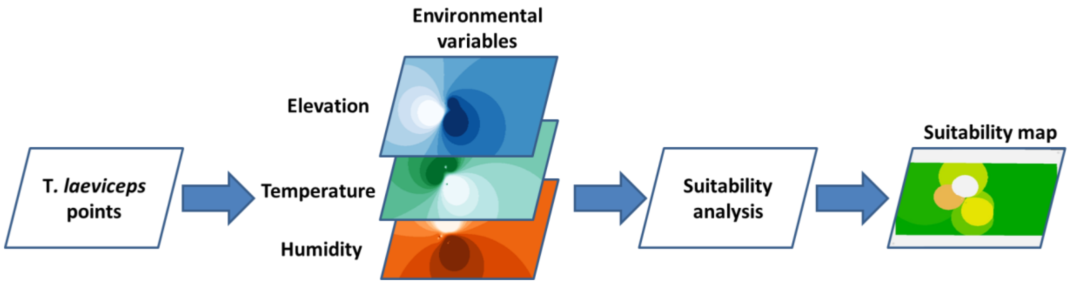


**Figure 2.** Flowchart of SDM

### Environmental Variables

Environmental variables recorded in this study and used as predictors for modeling including elevation, temperature, and humidity. Environmental variables recording was done simultaneously with *T. laeviceps* occurrence surveys. Elevation data were retrieved using GPS, while temperature data was recorded using digital thermometer and digital hygrometer for humidity.

### Suitability Analysis

This suitability analysis employed Species Distribution Modelling (SDM) analysis using R platform version 3.6.3 (Mao et al., 2022) (Fig. 2) to generate predicted suitability maps of *T. laeviceps* across Merbabu Mountain landscapes. Several R packages required to develop the suitability maps include library ("sp"), library ("dismo") (Khan et al., 2022), library ("maptools"), library ("rgdal") (Bivand, 2022), and library ("raster") (Lemenkova, 2020). The inputs for SDM included elevation, temperature and humidity variables. This variable was selected since there were correlation between the presences of *T. laeviceps* with elevation, temperature and humidity (Gonzalez et al., 2022). The results of SDM were suitable habitats that were classified into five classes including very low, low, moderate, high, and very high suitable. The *T. laeviceps* percentage of occurrences is calculated as:

$$\frac{Numbers\ of\ sampling\ points\ with\ T.laeviceps\ individuals\ overlapped\ with\ suitable\ habitats}{Total\ numbers\ of\ sampling\ points\ with\ T.laeviceps\ individuals}\ x\ 100\%$$

## RESULTS

This study is the first attempt to model *T. laeviceps* on Central Java, in particular Merbabu Mountain areas. This study used elevation, temperature, and humidity as predictors to project the suitable habitat for *T. laeviceps*. The result section will be divided into several sections, including the environmental variable elaborations and model analysis.

### Elevation Variables

The elevation variables related to the occurrences of *T. laeviceps* can be seen in Fig. 3. The elevation was ranging from 737 m to 1084 m. The areas near the Merbabu were higher than other areas. The lowest areas or the flat terrain were observed at the western sides near Magelang. Around 56.25% of *T. laeviceps* individual occurrences were observed at high elevation and 3.04% were observed at low elevation. Occurrences at high elevation were near the Merbabu Mountain.

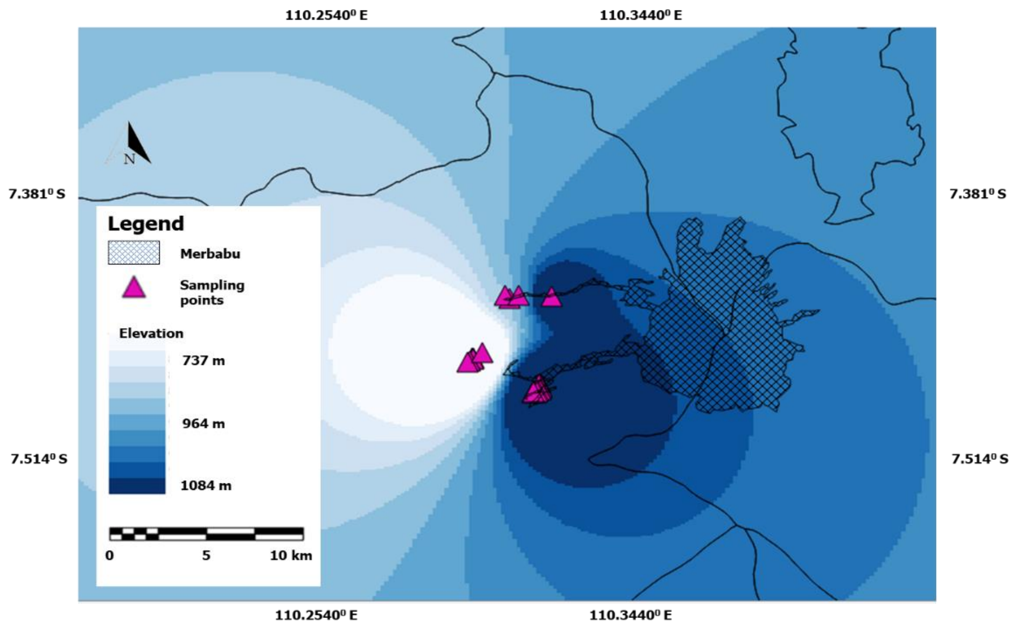


**Figure 3**. Elevation variables

### Temperature Variables

The temperature variables related to the occurrences of *T. laeviceps* can be seen in Fig. 4. The temperature was ranging from 19.8 0G °C to 31.8 °0C. The areas near the Merbabu were characterized by colder temperature than other areas as low as 19.8 °0C. The warm areas as low as 31.8 °0C were observed at the western sides near Magelang. Around 52.17% of *T. laeviceps* occurrences were observed at low temperature. While, 47.82% inhabiting warmer areas.

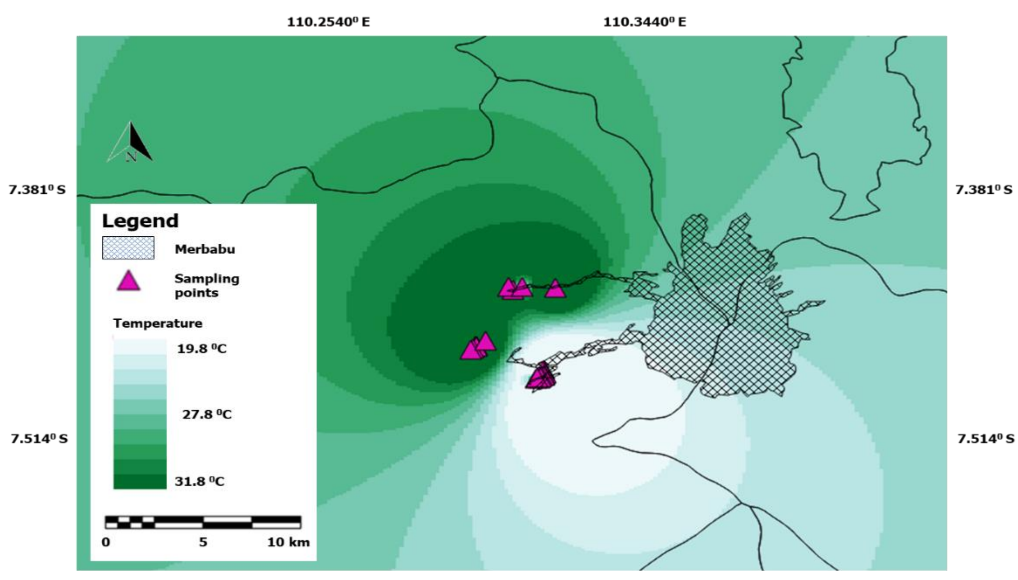


**Figure 4**. Temperature variables

**Humidity Variables**

The humidity variables related to the occurrences of *T. laeviceps* can be seen in Fig. 5. The humidity was ranging from 46% to 97%. The northern areas near the Merbabu were characterized by low humidity and high humidity in the southern areas of Merbabu. Around 52.17% of *T. laeviceps* occurrences were observed at areas with high humidity. While, 17.39% inhabiting areas with low humidity.

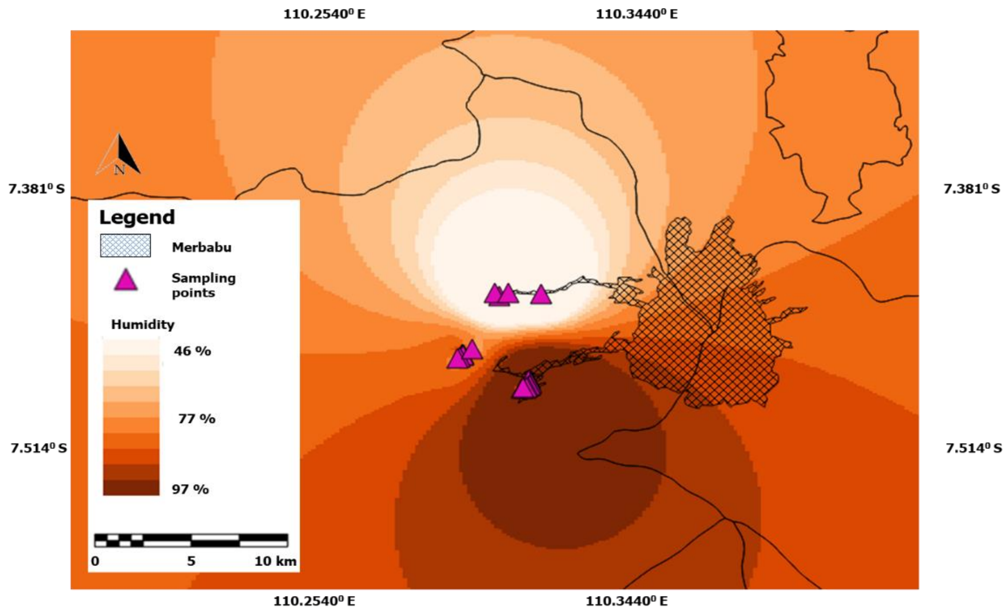


**Figure 5.** Humidity variables

**Suitable Habitats**

In this study, suitable habitats of *T. laeviceps* were modeled by using predictors and the *T. laeviceps* occurrence points. The result of suitable habitat modeling was available in Fig. 6. According to the model, most of the west parts bordered with the Magelang were considered not suitable for *T. laeviceps*. This suitability is also similar to north and south parts. This condition is contrast to the east parts that bordered with the Merbabu Mountain. Most areas adjacent to the Merbabu Mountain were having high and very high suitability for *T. laeviceps*.

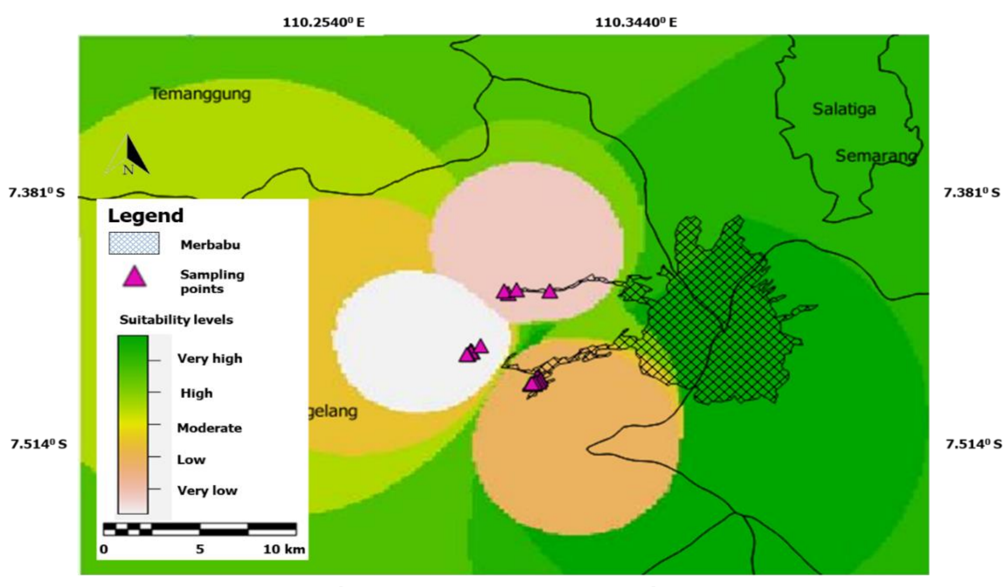


**Figure 6.** Suitable habitat model of *T. laeviceps* in Merbabu, Central Java, Indonesia

## DISCUSSION

SDM is one approach that has been widely used recently as a versatile tool to model the suitable habitats of certain species, including insects. Recently, many studies have modeled the insect species, including bees as studied by Patel et al. (2023) and bee distribution at global scale by Hosni et al. (2022). While sustainable habitat model studies for stingless bees, including Klanceng, are still very limited. Then, to the best of our knowledge, this study is the first to have modeled the stingless bee-suitable habitats in particular south east Asia regions.

The model confirms that the most suitable areas were observed in the Merbabu Mountain and this indicating the preferences of *T. laeviceps* on the mountainous areas. This preference is related to the altitudinal movement capacity of insect that has been reported previously. Some bee species even can reach the cloud forest at high elevation. This capacity belongs to a wide altitudinal and potential distribution regulated with high plasticity in the habitat selected for nesting. As a result, a bee specie can have wide distribution and this including reaching mountainous areas as reported by Rojas-Arias et al. (2023).

A mountainous area becomes suitable for *T. laeviceps* is related to the availability of resources. Bees are depending on the presence of tree stands (Rachmawati et al., 2022) that are limited in the forest for nesting and foraging, especially the flowering vegetation. Since mountainous areas within Merbabu Mountain are areas that still have tree stands, this explains the suitability of these areas for *T. laeviceps*.

In this study, the suitable habitats of *T. laeviceps* were observed in the areas with low temperature and this species avoid warm temperature. This finding is in contradiction with previous study. Al-Khalaf (2021), observed that bees were prefer and adapt to the warm areas even the areas were having extreme hot temperature like in the desert.

Most of the modeled suitable habitats in Merbabu are located in the areas that have high humidity. This indicates that the humidity favors *T. laeviceps* and corroborates previous findings. Salatnaya et al. (2020) observed that *T. laeviceps* activities would start when the humidity reached 70-88% and the peak activity of the bees occurred at humidity ranges of 55-71%.

## CONCLUSION

Merbabu Mountain with its surrounding areas has suitable habitats for supporting *T. laeviceps*. According to the environmental predictors, *T. laeviceps* occurrence points, and model, most of the areas of Merbabu were considered very suitable for *T. laeviceps*. While the western sides of Merbabu dominated by flat terrain were considered not suitable. The vertical distributions of *T. laeviceps* at Merbabu Mountain were limited at elevation of 1000 m. This study indicated that the areas of Merbabu Mountain were considered very suitable at the elevation of 1000 m. While, in recent times, there has been development and anthropogenic activity along these areas. These activities are then strongly recommended to be controlled since they may threaten *T. laeviceps* suitable habitats.

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## AUTHOR CONTRIBUTIONS

CDA: field data collection, research implementer, S: supervision; HP: supervision; A: data analysis, map making; HAP: field data collection, specimen identification

## CONFLICTS OF INTEREST

The authors declare there is no conflict of interest related to financial funding and authorship order for this article.

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