

Research Article



## Exploration of the Natural Habitat of *Apis dorsata* Forest Bees in the Samota Biosphere Reserve, Sumbawa: An Ecological Study and Vegetation Diversity

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### ABSTRACT

The Samota Biosphere Reserve, located on Moyo Island in Sumbawa, Indonesia, is a key ecological area, especially for the forest honey bee, *Apis dorsata*. This study investigated the natural habitat of *A. dorsata* and the factors influencing its nesting preferences within this reserve. A multidisciplinary approach, integrating field surveys, laboratory analysis, and geospatial technology, including Geographic Information System (GIS) tools, was used to identify the optimal nesting sites for *A. dorsata*. The study found that *A. dorsata* favors tall trees ( $\geq 15$  meters) with open branches (inclination of  $5^{\circ}$ - $25^{\circ}$ ), particularly species such as Ceylon Oak, Kapong, and Milkwood. These trees, characterized by a trunk diameter  $\geq 30$  cm, provided the most suitable nesting sites. Additionally, the elevation range of 50-300 meters above sea level was found to be critical for nest location. Forests with minimal human disturbance (such as roads or agricultural expansion) were prioritized. A GIS-based spatial analysis identified a total core habitat area of 2,993.03 hectares (29.93 km<sup>2</sup>), which currently meets the ecological requirements of the bee. These findings are essential for establishing conservation strategies for *A. dorsata*. The research highlights the importance of protecting forested areas, particularly those with the preferred tree species and suitable elevation ranges, to support bee populations. By preserving the integrity of the core habitat zones and minimizing human disturbances, this study provides actionable insights to ensure the long-term sustainability of *A. dorsata* populations within the Samota Biosphere Reserve, Sumbawa.



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## 1. Introduction

The Samota Biosphere Reserve, which includes Saleh Bay, Moyo Island, and Mount Tambora, is known for its exceptional biodiversity and has been designated as a UNESCO World Biosphere Reserve (UNESCO 2019; Febriansyah *et al.* 2023). This region serves as a

crucial habitat for the forest bee *A. dorsata*, a large honey bee that plays a vital role in the ecosystem through its pollination activities (Yang *et al.* 2018; Sihag 2025). In addition, *A. dorsata* holds a significant economic importance due to the high demand for its honey in both local and international markets (Matias *et al.* 2018; Mahani *et al.* 2025). However, human activities, such as land clearing, poaching, and habitat degradation, pose significant threats to the survival of this species (Rehel *et al.* 2024). The lack of scientific data on vegetation

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types, habitat structure, and the biodiversity supporting *A. dorsata* complicates effective habitat management for sustainability (Matias *et al.* 2018). Therefore, research focused on identifying the habitat of this honey bee is crucial to provide a scientific foundation for integrated conservation and management strategies (Warrit *et al.* 2023).

The forest bee *A. dorsata* in the Samota Biosphere Reserve faces numerous challenges, including environmental degradation and a lack of scientific data about its natural habitat (Rehel *et al.* 2024; Khan *et al.* 2025). This study addresses key issues, including identifying the types of vegetation that sustain *A. dorsata*, determining the ideal habitat structure for its survival, and examining how biodiversity in Samota affects the survival of this honeybee population (Basrowi *et al.* 2022; Bramasta *et al.* 2023; Pattikawa *et al.* 2023; Raffiudin *et al.* 2024). Additionally, the research investigates factors affecting nest-site preferences, providing science-based insights for conservation planning (Pratiwi *et al.* 2022; Nuraeni *et al.* 2023).

Previous studies on honeybee populations in Samota have not comprehensively identified the specific vegetation types and habitat structures that directly contribute to the well-being and survival of *A. dorsata* in this region. This research addresses that gap by applying geospatial and ecological methods to pinpoint these factors, providing novel insights into previously overlooked habitat preferences. The novelty of this study lies in its integrated use of GIS tools, field surveys, and ecological data to create a habitat model that could aid in strategic conservation planning. This model not only addresses habitat needs but also contributes to the broader field of bee conservation, complementing studies on local honeybees, such as *A. cerana*, whose productivity has been enhanced through feeding with coconut sap and sugar palm (Erwan and Agussalim 2022; Erwan *et al.* 2022). Furthermore, the quality and potency of honey produced by *A. cerana* fed with coconut and sugar palm saps (Erwan *et al.* 2021) also shed light on the role of vegetation in honeybee health, providing indirect insights into the factors influencing *A. dorsata* habitats. The research aims to establish a detailed, science-based framework for habitat management to ensure the sustainability of *A. dorsata* populations within the Samota Biosphere Reserve, Sumbawa. Ultimately, this study seeks to offer practical recommendations for habitat restoration and management in response to ongoing environmental changes.

## 2.2. Materials and Methods

### 2.1. Location and Study Design

The study was conducted across a designated 100-hectare area within Moyo Island, Sumbawa Regency (8.2203°S, 117.5731°E), chosen for its diverse vegetation and forest structure. Areas were selected based on the presence of suitable tree species for *A. dorsata* nesting and the absence of major human disturbances, such as agricultural activities or roads. A multidisciplinary approach was employed, involving field surveys, laboratory analyses, and geospatial technology, to identify the habitat of *A. dorsata* in the Samota Biosphere Reserve. Geospatial technology plays a pivotal role in this study, enabling the identification of *A. dorsata* habitats within the Samota Biosphere Reserve. This technology facilitates the collection, analysis, and visualization of spatial data pertinent to the distribution of bee habitats and their supporting ecosystem elements.

### 2.2. Field Data Collection

This stage involved conducting field surveys to determine the habitat of *A. dorsata*. A variety of plot sampling methods were employed to record vegetation types, tree heights, trunk diameters, branch slopes, and bee nest locations. Tree height was measured using a clinometer. For each selected tree, the observer recorded the angle of elevation from a fixed point at the base of the tree to its top, and height was calculated using trigonometric formulas (Burkhardt *et al.* 2018). Multiple measurements were taken to reduce error, and 50 trees across various species were selected based on their height ( $\geq 15$  meters) and suitable branching structure. To ensure data accuracy, the results were compared with measurements obtained using a laser rangefinder, which provides faster readings through laser reflection (Larjavaara and Muller-Landau 2013). For relatively small trees, direct measurements were taken with a measuring pole or a vertical tape.

Trunk diameter was measured at 1.3 meters above the ground, following the international standard known as diameter at breast height (DBH 1.3). The main instrument used was a diameter tape (D-Tape), which automatically converts trunk circumference into diameter. When a D-Tape was unavailable, circumference was measured with a flexible tape, and the diameter was calculated using the formula  $D = C/\pi$ , where  $C$  represents the trunk circumference (Zhu *et al.* 2020). Special considerations were applied in particular conditions, such as for trees

with buttresses or those growing on sloping terrain, in which the measurement point was adjusted above the irregular portion of the trunk (Kershaw *et al.* 2016). Branch inclination was measured to determine the angle formed between the main trunk and the branch. A clinometer and a goniometer were used to obtain direct angle readings of the branch relative to the vertical trunk (Pretzsch 2008).

GPS devices (Garmin GPSMAP 64) with  $\pm 3$ -meter accuracy were used to record the exact coordinates of bee nests. These coordinates were later imported into ArcGIS software for further spatial analysis and habitat mapping. Briefly, the methods applied include:

Plot sampling to characterize vegetation structure and composition.

Measurement of tree parameters such as height, diameter at breast height (DBH), and branch slope

Nest mapping to determine the distribution of *A. dorsata* colonies.

GPS-based georeferencing for accurate spatial data recording and vegetation area delineation.

### 2.3. Geospatial and Field Data Analysis

The field data were processed using ArcGIS 10.8 to generate a habitat map. Spatial analysis techniques, including buffer zones and land use classification, were applied to identify potential habitats. Additional satellite imagery and drone data were integrated to refine the habitat model. Field data analysis was conducted to understand bees' habitat preferences based on parameters collected, including vegetation types and habitat structure. To ensure the accuracy of the findings, data from drones and satellite imagery were integrated. The analysis results were then employed to develop a data-driven habitat conservation model for *A. dorsata*. This model included recommendations for the restoration and management of priority areas to support the sustainability of bee populations (Khater *et al.* 2022).

### 2.4. Creation of A Core Zone Map for the Forest Bee *A. dorsata*

The field data were processed using Geographic Information System (GIS) tools to produce a distribution map of potential habitats for *A. dorsata*. Field data analysis was conducted to determine the habitat preferences of bees based on collected parameters, including vegetation type and habitat structure. To ensure the accuracy of the findings, data from drones and satellite imagery were integrated. The final habitat conservation model was

constructed by overlaying buffer zone layers (2 km radius around nest points), elevation data (50-300 meters), and land use classifications. The resulting habitat areas were analyzed for suitability using a weighted overlay method in ArcGIS. The model incorporates recommendations for implementing measures to restore bee habitats and for prioritizing the management of areas deemed high-priority for bee conservation. The detailed flow for making the *A. dorsata* Forest Bee Core Zone Map was presented in Table 1.

## 3. Results

### 3.1. *A. dorsata* Habitat

On Moyo Island in Sumbawa, forest honey bees (*A. dorsata*) have been observed constructing nests in tall trees with open, moderately spaced branches. The local community refers to these trees as "boan." Table 2 presents the types of trees commonly used by *A. dorsata* for nesting on Moyo Island.

The results of the study indicate that *A. dorsata* exhibits specific preferences regarding the characteristics of trees used as nesting sites. Based on the data in Table 2, the giant honey bee tends to select trees with a height of 20-30 meters. This height is considered ideal because it provides protection from predators, minimizes human disturbance, and offers a broad canopy that supports the construction of large nests.

In addition to height, trunk diameter is also an important factor. Trees with relatively large trunks, typically 50-70 cm in diameter, are preferred because they provide structural stability to support the heavy weight of the nest and maintain its long-term security. Branch inclination also influences nest site selection. *A. dorsata* generally chooses branches with a slope of 10°-20°, which is considered optimal for nest attachment. Such branches are neither too flat, which can prevent water accumulation during rainfall, nor too steep, which can compromise nest stability and ease of access for the colony.

Based on the combination of these three parameters, it can be concluded that the most ideal conditions for *A. dorsata* nesting are tall trees with large trunk diameters and moderately sloping branches. Tree species that fulfill these criteria include Kapong (*Tetrameles nudiflora*), Litsea (*Litsea accedentoides*), Duabanga (*Duabanga molucana*), and Cannonball Mangrove (*Xylocarpus granatum*), which are more frequently used as nesting sites by giant honey bee colonies on Moyo Island.

Table 1. The detailed flow for making the *A. dorsata* Forest Bee Core Zone Map

Stages	Description	Input	Output
Objective setting	Focus on core habitat zones based on buffers, elevations, and suitable LULC (Land use/Land cover), especially Forest Land	—	Objectives and mapping criteria
Nest point	Nest coordinate point or active colony location	.shp, .csv	Colony coordinate point
Buffer 2 km	Create a buffer from each point as the core zone coverage limit	Nest point	Layer buffer 2 km
Elevation 50-300 m	Masking the DEM raster to only the ideal elevation for nesting	DEM raster	Elevation raster/ polygon according to
LULC classification	<ul style="list-style-type: none"> <li>• Forest Land → <input checked="" type="checkbox"/> appropriate</li> <li>• Agroforestry / Grassland → <input type="checkbox"/> not used</li> <li>• Built-up → <input checked="" type="checkbox"/> issued</li> </ul>	LULC Layer	Polygon only Forest Land
Intersect 3 layer	Merger <ul style="list-style-type: none"> <li>• Buffer 2 km</li> <li>• Elevation 50–300 m</li> <li>• Forest Land</li> </ul>	3 Layer input	Core zone initial polygon
Disturbance zone	Negative buffer 500 m from the road	Roads, settlements	Exclusion buffer
Masking disturbances	Remove parts of the core zone that overlap with human disturbance	Intersect result – buffer 500 m	Clean zone end polygon
Save as core zone	Save as Core Habitat Zone (ZC)	Final polygon	Core zone final layer
Calculate area	Calculate the total area (ha/km <sup>2</sup> ) of the ZC zone	Final layer	Core habitat area statistics
Map layout	Final map: <ul style="list-style-type: none"> <li>• Dark green = Core zone</li> <li>• Nest points</li> <li>• Scale, legend, north direction</li> </ul>	All final layers	Core habitat map layout
Narrative documentation	Technical method, narrative, and map description	All results	Methods document and results narrative

Table 2. The types of trees commonly used by *A. dorsata* bees for nesting on Moyo Island

Tree species	Tree height (m)	Trunk diameter (cm)	Branch inclination (°)
Ceylon Oak ( <i>Schleichera oleosa</i> )	15-25	30-50	10-20
Kapong ( <i>Tetrameles nudiflora</i> )	20-30	50-70	15-25
Milkwood ( <i>Alstonia</i> spp.)	20-30	40-60	10-15
Tamarind ( <i>Tamarindus</i> spp.)	10-20	30-50	5-15
Freshwater Mangrove ( <i>Barringtonia acutangula</i> )	15-25	40-60	10-20
Candlenut ( <i>Aleurites molucana</i> )	15-25	30-50	5-15
Litsea ( <i>Litsea accedentoides</i> )	20-30	50-70	15-20
Trenggulam ( <i>Protium javanicum</i> )	15-25	30-50	10-20
Duabanga ( <i>Duabanga molucana</i> )	20-30	50-70	15-25
Cashew ( <i>Anacardium occidentale</i> )	10-15	30-40	5-15
Gum ( <i>Eucalyptus</i> )	15-20	40-60	10-20
Cannonball Mangrove ( <i>Xylocarpus granatum</i> )	20-30	50-70	15-25
Fig ( <i>Ficus</i> spp.)	15-20	40-60	10-20

### 3.2. Map of Distribution of Potential Habitat of *A. dorsata*

The study yielded nine thematic maps, meticulously arranged to delineate and represent the core habitat zone of *A. dorsata* on Moyo Island. The initial map configuration entailed the Moyo Island Map (Figure 1), which served as a foundational map delineating geographical locations

and administrative boundaries for all subsequent spatial analyses. This map serves as the preliminary reference for visualizing the study area and the distribution of salient features within it. The next step involved compiling a map delineating the distribution of nesting trees or active colony locations (Figure 2). This map was constructed using coordinate data derived from field observations.

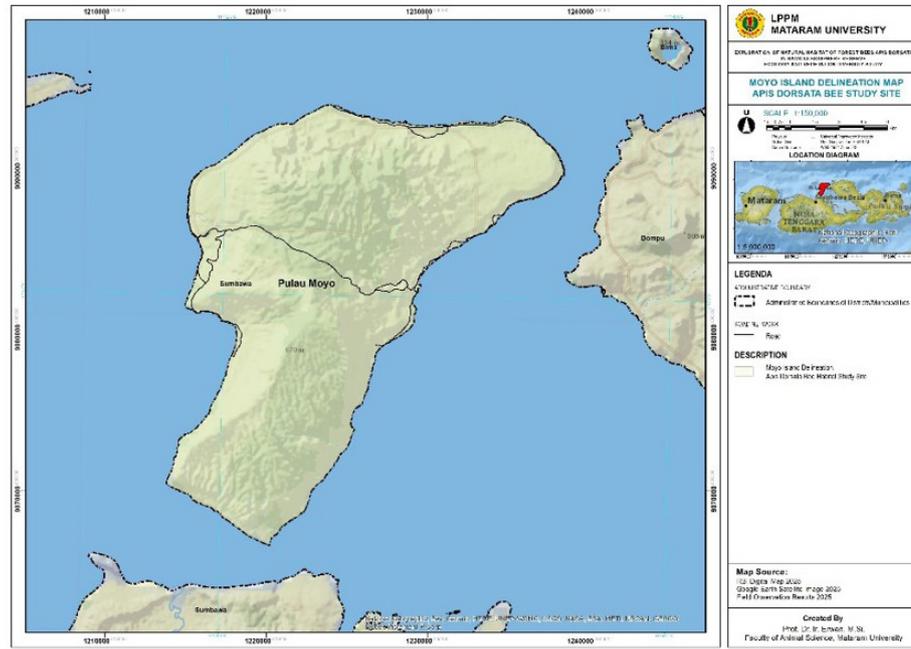


Figure 1. Delineation map of Moyo Island - *A. dorsata* bee habitat study location

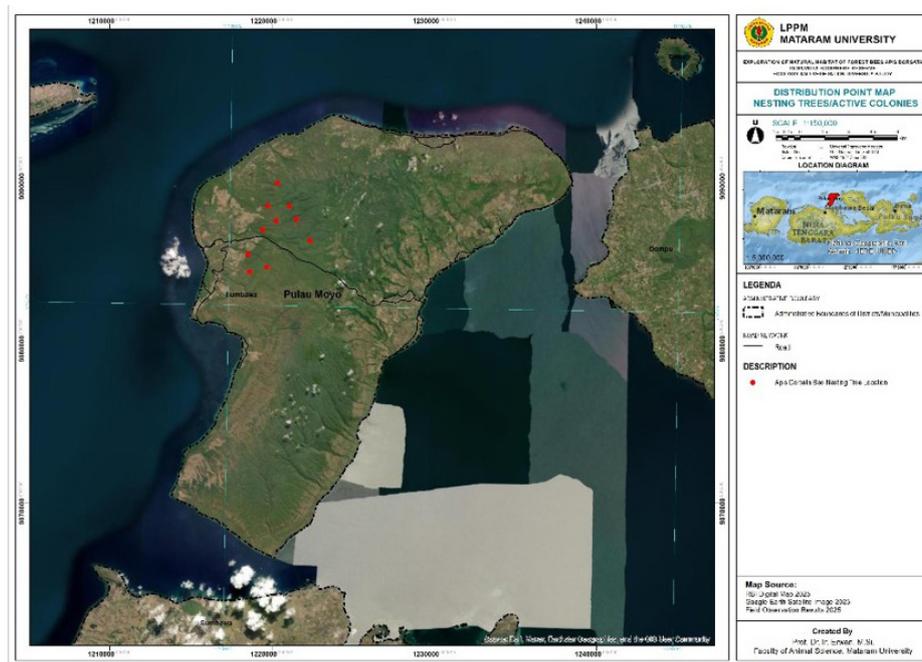


Figure 2. The distribution points of nesting trees or active colony locations

These points of interest corresponded to areas of notable tree cover, identified as potential nesting sites for *A. dorsata* colonies. These sites then served as the basis for creating buffer areas intended to establish foraging zones.

From these points, a 2-kilometer Core Zone Buffer Area Map was developed (Figure 3), illustrating the optimal foraging range limit based on existing literature. This

buffer serves as an initial representation of the potential habitat zone. The subsequent step in the analysis involved compiling an Optimal Height Elevation Map ranging from 50 to 300 meters above sea level (Figure 4) using reclassified Digital Elevation Model (DEM) data.

Subsequently, a Forest Land Cover Classification Map (Figure 5) was formulated based on the LULC

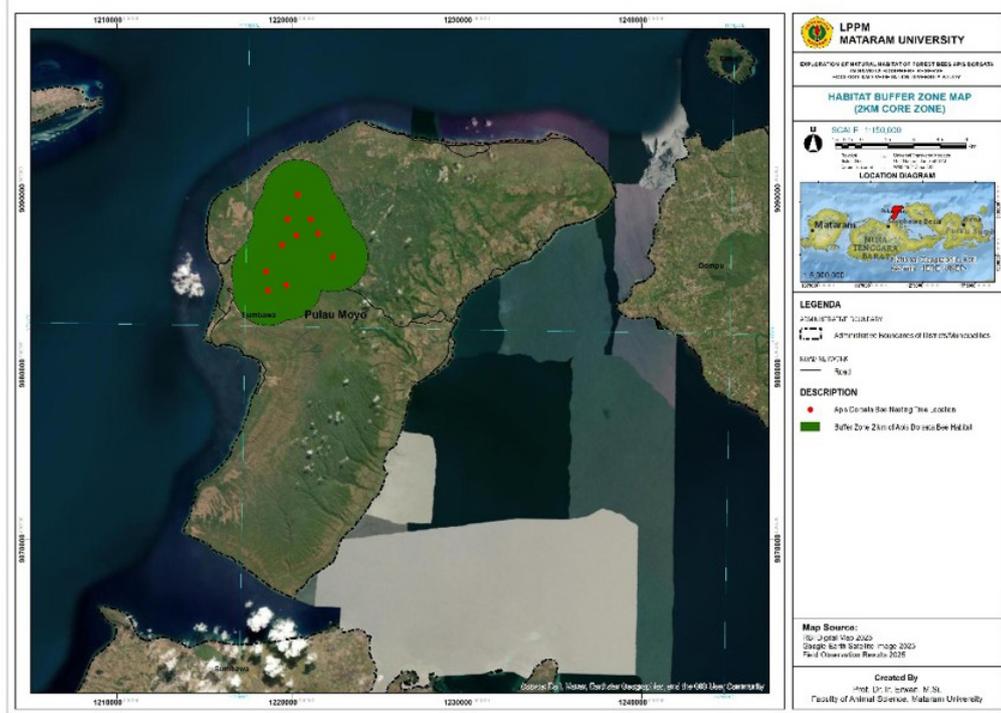


Figure 3. The 2-kilometer core zone buffer area *A. dorsata* bee habitat

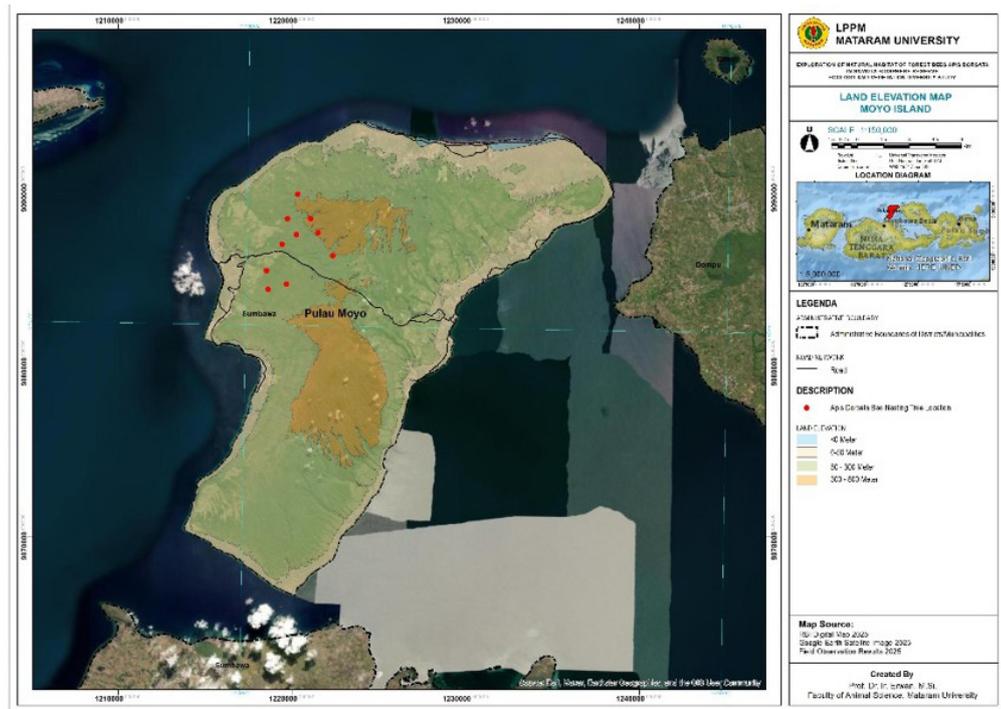


Figure 4. Land elevation map of Moyo Island



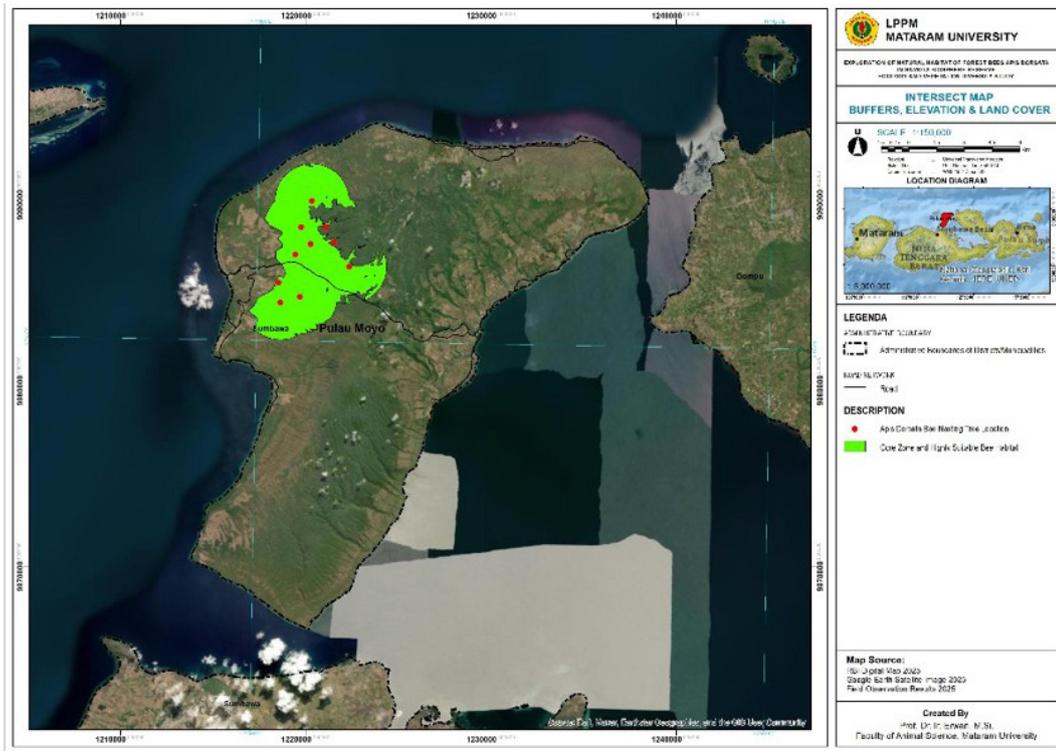


Figure 6. Intersection map of buffers, elevation, and land cover on Moyo Island

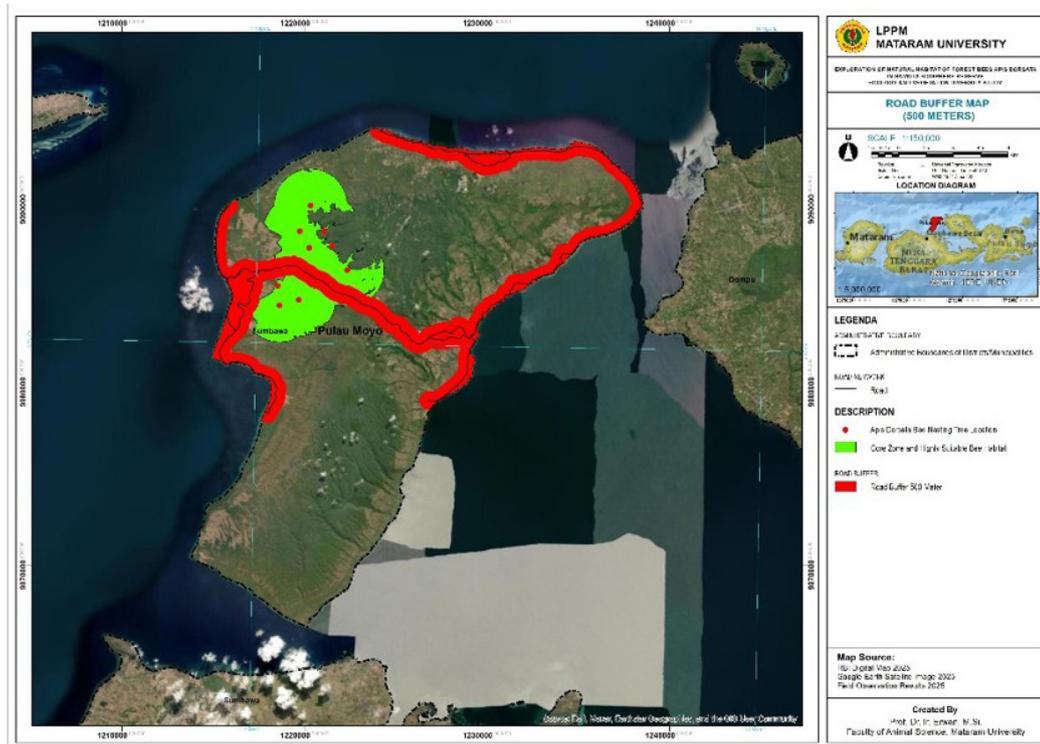


Figure 7. The road buffer zone on Moyo Island uses a 500-meter radius to delineate areas surrounding the roads

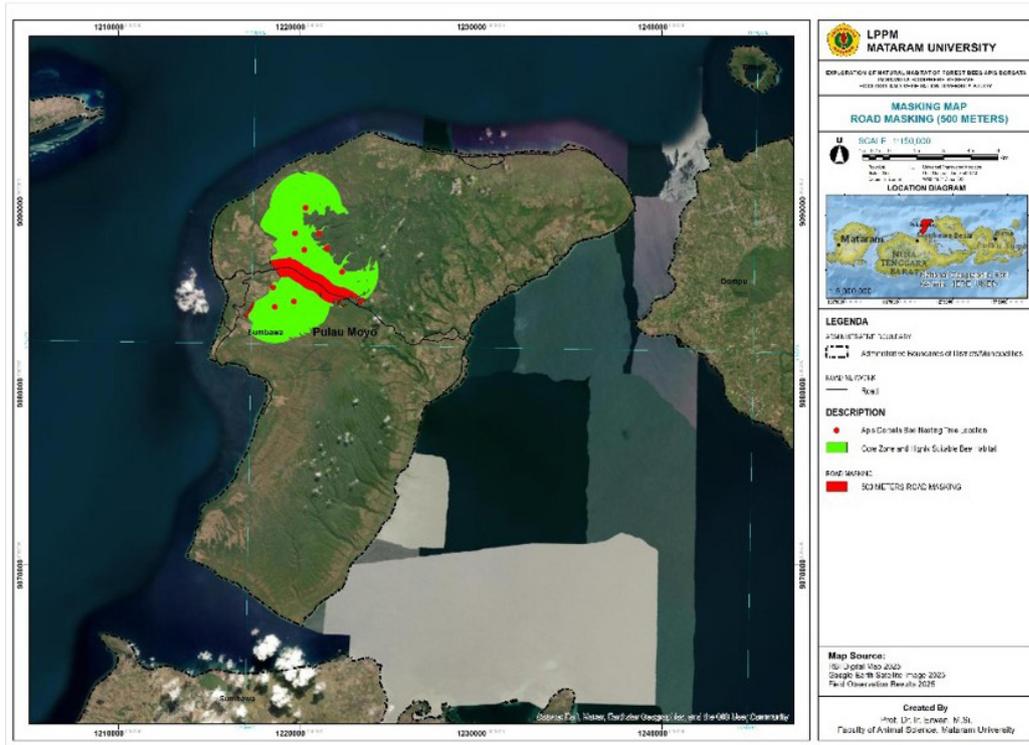


Figure 8. Masking layer over the road buffer zone within a 500-meter radius on Moyo Island

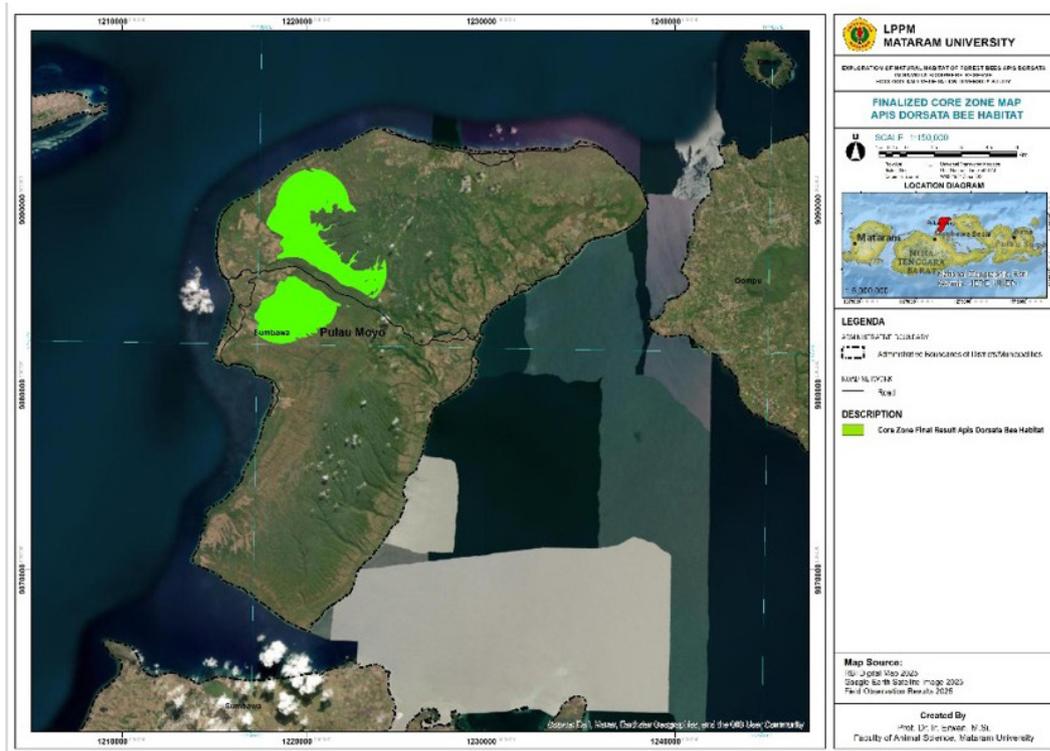


Figure 9. Finalized core zone map of *A. dorsata* bee habitat on Moyo Island

Oak (*Schleichera oleosa*) and Kapong (*Tetrameles nudiflora*), both large tree species, are frequently chosen for nesting due to their considerable height and open canopies. Research by Wijayanti *et al.* (2022) supports this observation, indicating that bees prefer tall trees because this height provides a safer environment for their nests, shielding them from predators. Additionally, a substantial trunk diameter, typically ranging from 30 cm to 70 cm, is another characteristic that *A. dorsata* bees prefer. Larger trunks provide stability and a solid base for nest construction. Trees such as Kapong (*Tetrameles nudiflora*) and Milkwood (*Alstonia* spp.) are particularly favored for their robust trunks, which provide the support and security nests need. Handoko and Hidayatullah (2019) found that trees with thicker trunks offer a more resilient environment for the bees' nesting activities.

Regarding branch inclination, *A. dorsata* bees prefer trees with moderately inclined branches, typically 10°-25°. Trees like Freshwater Mangrove (*Barringtonia acutangula*) and Litsea (*Litsea accedentoides*) offer the ideal branch structure, providing bees with a stable and secure foundation for their nests. Wijayanti *et al.* (2022) suggested that a larger branch slope facilitated nest construction in a more stable, protected environment, making these trees optimal. In addition to providing suitable nesting sites, the trees used by *A. dorsata* bees also serve as crucial nectar and pollen sources. Some favored nesting species are also valuable foraging trees. Ceylon Oak, for example, not only provides an ideal nesting site but also serves as a nectar source for bees. The flowers of the Ceylon Oak attract bees, making it a dual-purpose tree for both nesting and foraging. Similarly, Kapong and Milkwood are rich in nectar, supporting the bees' foraging needs, as confirmed by Handoko and Hidayatullah (2019) and Ahsani *et al.* (2023). Moreover, Tamarind (*Tamarindus* spp.), although smaller than typical nesting trees, provides nectar-rich flowers crucial for local bee populations (Wijayanti *et al.* 2022).

Freshwater Mangrove (*Barringtonia acutangula*), another large tree, also serves as an essential nectar source, particularly during its flowering seasons. Even smaller trees like Cashew (*Anacardium occidentale*), though less preferred for nesting, provide valuable nectar and pollen seasonally. This study reveals that the trees of Moyo Island provide not only the ideal physical characteristics for nesting but also the necessary foraging resources. These trees, such as Ceylon Oak, Kapong, Milkwood, Tamarind, Freshwater Mangrove, and others, provide a critical, multifaceted habitat for *A. dorsata*

bees, consistent with observations in other Indonesian regions (Sumatra, Kalimantan, Sulawesi, and East Nusa Tenggara). Overall, the trees of Moyo Island are essential for sustaining local bee populations, thereby supporting the ecological balance and the honey production industry. Incorporating local communities in the management and restoration of *A. dorsata* habitats is critical for the long-term success of conservation efforts. While this study highlights the ecological importance of preserving the core habitat zones, conservation policies must also address the socio-economic needs of local people. Effective habitat management strategies should include promoting sustainable land-use practices, managing buffer zones, and creating economic opportunities for local populations that reduce pressure on natural resources.

The initial map (Figure 1) delineates Moyo Island, showing administrative boundaries and the designated *A. dorsata* bee habitat study area. Moyo Island is characterized by a high diversity of flora, which makes it an ideal habitat for forest honey bees. The surrounding Samota Biosphere Reserve plays a pivotal role in conserving flora and fauna, including bees. This map provides an initial overview of areas requiring conservation and highlights that Moyo Island's ecosystem requires sustainable management (Ferreira *et al.* 2022).

The second map (Figure 2) illustrates the distribution of trees utilized by bees for nesting, with red dots indicating the locations of *A. dorsata* bee colonies. The significance of these trees for the survival of bees is indisputable, as they serve as a crucial habitat for the construction of nests. Within the Samota Biosphere Reserve, these dots denote locations that need protection from human disturbance. The preservation of these nesting trees is crucial to the conservation model of the Samota Biosphere Reserve, as they must be meticulously managed and protected from habitat destruction, such as logging or land conversion, to ensure the survival of bees (Payne *et al.* 2024).

The third map (Figure 3) delineates the core zone of *A. dorsata* bee habitat, characterized by environmental conditions highly conducive to the proliferation of *A. dorsata* bee colonies. The green-delineated area encompasses regions that serve as the primary habitats for bees and should be accorded a high priority in any conservation policy. The core zone of the Samota Biosphere Reserve is crucial for bee habitat conservation, requiring strict management to protect large nesting trees and minimize human disturbance to ensure the survival of *A. dorsata* colonies (Wijayanti *et al.* 2022).

Figure 4 presents a map of Moyo Island, illustrating the distribution of areas based on sea level and the corresponding variations in land elevation. *A. dorsata* bees have been observed to utilize a variety of tree species for nesting, with certain elevations exhibiting a higher prevalence of nesting sites. This map shows areas with higher elevations, which have been shown to offer bees a more protected habitat and less human disturbance. This map is instrumental in delineating higher and protected areas, which can be designated as priority conservation areas within the Samota Biosphere Reserve. The preservation of these higher-elevation areas is imperative to safeguard the integrity of bee habitats and ensure their continued stability and undisturbed condition from anthropogenic activities (Nicholls and Altieri 2012).

Figure 5 shows various land cover types, including agricultural land, forests, and grasslands. The forest on Moyo Island constitutes the primary habitat of *A. dorsata* bees. This map provides a synoptic view of changes in land cover and the potential ramifications for bee habitat. In the context of the conservation model implemented within the Samota Biosphere Reserve, the preservation of the forest area on Moyo Island is of paramount importance, as its conversion into agricultural or residential zones must be prevented. The preservation of primary and secondary forests on Moyo Island should be accorded a high priority, as these forest ecosystems play a vital role in supporting bee habitats, which, in turn, are essential components of the local ecosystem (Markum *et al.* 2022). The map delineates the road disturbance zone (Figures 7 and 8), located 500 meters from the main road. Disturbance from road construction can fragment bee habitats and increase pollution levels, both of which can have a deleterious effect on bee health. The map delineates regions susceptible to disruption from road infrastructure. A primary objective of the Samota Biosphere Reserve conservation model is to mitigate the impact of development on bee habitat. This map guides the identification of areas that should be protected from road and other infrastructure disturbance, and helps plan more environmentally friendly development around the bee habitat.

The map illustrates the habitat boundaries, delineated by a 2-kilometer radius from the nesting tree. This area is to be safeguarded to ensure the well-being of the bees (Figure 9). The buffer zone is intended to prevent external disturbances, such as infrastructure development or agricultural activities, that could damage the bees' habitat. In the context of the conservation model

implemented within the Samota Biosphere Reserve, the designated buffer zone must be meticulously managed and continuously monitored to mitigate potential threats to the integrity of the habitat effectively. This buffer zone is a critical component in preserving bees' habitat within the Samota Biosphere Reserve. The preservation of the buffer zone is imperative for ensuring the bees have sufficient space to breed and forage undisturbed by human activities in their vicinity. The management policy for this buffer zone must involve active participation from the community and other relevant parties.

The maps presented offer a foundation for the conservation model for the *A. dorsata* bee habitat in the Samota Biosphere Reserve. This model should use an ecosystem-based approach that accounts for land cover, elevation, and protection zones, including buffer zones. The following elements are incorporated into the model: The effective management of buffer zones is imperative to prevent disturbance from human activities; The protection of core habitat zones that are most suitable for bee habitat is crucial; Sustainable land use policies, with a focus on forest conservation and limiting land conversion to agricultural areas, are essential; The participation of local communities in conservation management, especially in maintaining trees used as nesting sites by bees, is vital. Establishing a 2-kilometer buffer zone around nesting sites, while essential for protecting bee habitat, may lead to conflicts with local communities. These areas could overlap with land traditionally used for agriculture or settlement, posing challenges for communities that depend on these lands for their livelihood. There is a potential for resistance if the buffer zone is perceived as restricting access to essential resources. To mitigate these conflicts, it is crucial to adopt a participatory approach to conservation that involves local communities in decision-making. Alternative livelihood programs and awareness campaigns can help align conservation goals with communities' economic needs.

The Samota Biosphere Reserve exemplifies this approach, demonstrating effective strategies for conserving bee habitat and promoting biodiversity in the region. This study concludes that Moyo Island, within the Samota Biosphere Reserve, provides an optimal environment for *A. dorsata* bees. This species requires large trees with open branches for sustenance and shelter. The core and buffer habitat zones must be safeguarded to ensure the viability of this species. It is imperative to meticulously manage human activities in the vicinity of bee habitats, such as imposing limitations on road construction and land conversion, to avert

habitat degradation. The survival of *A. dorsata* bees on Moyo Island depends on the involvement of local communities and the implementation of an ecosystem-based conservation model. This model must encompass spatial management and the restoration of degraded habitats.

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