

Habitat suitability of Javan langur (*Trachypithecus auratus*) in Gunung Babakan, West Java, Indonesia

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Abstract. Fauzi A, Suwandhi I, Suhaya Y. 2025. Habitat suitability of Javan langur (*Trachypithecus auratus*) in Gunung Babakan, West Java, Indonesia. *Biodiversitas* 26: 3815-3826. The Forest Management Unit (FMU) Ciamis is one of the forest management areas owned by Perum Perhutani, which has the predicate of High Conservation Value Forest (HCVF). One of the categories of HCVF was HCV 3, which encompassed areas with rare or endangered ecosystems. The endangered animal species found in the Gunung Babakan of FMU Ciamis is the Javan langur (*Trachypithecus auratus*). This study aimed to analyze the suitability of Gunung Babakan as a habitat for the Javan langur, assessing the feasibility of secondary forest conditions as an area of high conservation value, using a deductive research approach. The methods used were vegetation analysis with purposive sampling, Canopy Height Model (CHM), and Habitat Suitability Index (HSI) model based on research conducted by Maulahila et al. (2023) with several adjustments. In addition, the validation was conducted on the HSI model, using a Receiver Operating Characteristic (ROC) curve. The study results showed there were 66 plant species, 33 were feeding trees for Javan langurs, and 13 of them were the main food source. Moreover, the canopy conditions in the Gunung Babakan secondary forest were dominated by stratum C (4-20 m; 84% of the area), followed by stratum B (20-30 m; 14% of the area). Based on the results of the habitat suitability index scoring, Gunung Babakan Secondary Forest had a score ranging from 0.55 to 0.85, which was categorized as 'high' (0.55-0.75; 59% of the area) and 'excellent' (0.76-0.85; 41% of the area). Furthermore, the results showed the HSI of the Javan langur had a moderate model accuracy level with an AUC value of 0.742. Overall, based on feeding vegetation, canopy height, and the HSI model, the area was suitable as a habitat for Javan langurs with several conservation measures.

Keywords: Canopy, feeding tree, habitat modeling, HSI, Javan langur

Abbreviations: CHM: Canopy Height Model, FMU: Forest Management Unit, HCVF: High Conservation Value Forest, HSI: Habitat Suitability Index

INTRODUCTION

Perum Perhutani is a state-owned company that manages several forest areas on Java Island, Indonesia. Ciamis Forest Management Unit (FMU) is one of Perhutani's production forest units that contains a High Conservation Value Forest (HCVF). HCVF is an area that supports and maintains the sustainability of biological, social and ecological functions and benefits. Ciamis FMU encompasses 7,597.72 hectares HCVF area which is classified into 6 types of High Conservation Values: HCV1, HCV2, HCV3, HCV4, HCV5, and HCV6. One of these types, HCV3 includes areas containing rare, threatened, or endangered ecosystems. An endangered animal species found in Ciamis FMU is the Javan langur (*Trachypithecus auratus* (É. Geoffroy Saint-Hilaire, 1812)) (KPH Ciamis 2022), which inhabits Gunung Babakan Secondary Forest in Cisaga Sub-district, Ciamis District, West Java, Indonesia.

Javan langurs are arboreal animals, almost all of their activities are spent in trees, from looking for food to sleeping. During their activities, Javan langurs move from tree to tree to find the top of their food source with certain paths (Santono et al. 2016). Javan langurs are active in four strata of habitat space, namely the canopy top, the middle of the tree, the lower tree, and the forest floor. Meanwhile,

for sleeping places, Javan langurs occupy three strata, namely the canopy top, the middle of the tree, and the lower tree (Santono et al. 2016). The dominant activities of Javan langurs vary according to the habitat they occupy. According to Fitriyani and Purba (2023), Javan langurs in the wild have a dominant activity of moving around, while Javan langurs in captivity have a dominant activity of resting (Sulistiyadi et al. 2013). However, another observation conducted by Sulistiyadi et al. (2013) at the Gunung Pancar Nature Tourism Park, West Java, revealed that the most frequent activity carried out by Javan langurs is resting.

Recently, Javan langurs are rare animals protected under the Regulation of the Minister of Environment and Forestry Number P106/MenLHK/Setjen/Kum.1/12/2018. In addition, it is listed in Convention on International Trade in Endangered Species (CITES) Appendix II, and the IUCN Red List categorizes the species as Vulnerable (VU). Currently, the existence of Javan langurs are increasingly threatened by various factors such as habitat loss, fragmentation, and human disturbance (Subarkah et al. 2011).

As a HCVF area, it is essential to ensure the habitat suitability of endangered species, including Javan langurs, in Gunung Babakan Secondary Forest. Therefore, further analysis is required to assess the habitat suitability of Javan langurs to support their long-term conservation. The habitat

suitability of Javan langurs can be evaluated through aspects such as vegetation, canopy cover, and other parameters, which are measured using the HSI. By understanding the habitat suitability of Javan langurs in Gunung Babakan Secondary Forest, Ciamis FMU can develop strategic measures to protect and manage this critical habitat in alignment with HCV principles.

Despite the ecological and conservation significance of the Javan langur and the protected status of its habitat within the HCVF area, there is currently a lack of baseline data on key ecological parameters, particularly vegetation composition and canopy cover, which are essential for assessing habitat suitability. Additionally, no prior assessments or scoring using relevant ecological variables within and around the study area have been conducted. Although the Habitat Suitability Index (HSI) model is known for its simplicity and effectiveness, it has rarely been applied for Javan langur conservation planning. The recent research about the HSI modeling was conducted by Maulahila et al. (2023) in Alas Purwo National Park, Indonesia, which was the benchmark of this research. However, using the HSI for habitat assessment of Javan langurs is still insufficient due to the lack of supporting aspects that can't be included directly as HSI variables, such as food source availability and canopy cover condition. Therefore, this research not only utilized the HSI model, but also analyzed other supporting aspects including feeding tree vegetation and canopy height, to enhance the comprehensiveness of the results.

This research aimed to assess suitability of Javan langur habitat in Gunung Babakan Secondary Forest. Three main aspects are analyzed in this research, including feeding tree vegetation, canopy, and Habitat Suitability Index (HSI)

scoring. Therefore, this research could be a reference for Perhutani Ciamis FMU in the context of planning and taking further strategic steps in order to improve and preserve the habitat of the Javan langur in HCVF area.

MATERIALS AND METHODS

Study area

This research was conducted in Gunung Babakan Secondary Forest, which was managed by Gadung Forest Management Resort, under North Banjar Forest Management Unit Section, Perhutani Ciamis FMU. Administratively, this secondary forest was located in Bangunharja Village, Cisaga Sub-district, Ciamis District, West Java, Indonesia. The secondary forest was located at an elevation of 20 m to 239 m above sea level, with air temperatures between 26.6°C and 31.6°C, air humidity ranging from 63.5% to 89.7%, pH between 5.8 to 6.8, soil moisture ranging from 10% to 75%, and light intensity between 280 and 6,870 Lux.

Data collection

This research was conducted from June to December 2024, with the primary data collection period taking place in September 2024 in the field. Primary data were collected using the purposive sampling method, which was a sampling technique based on specific considerations such as sample criteria and data characteristics (Sugiyono 2016). Purposive sampling was employed based on the assumption of previous survey points where sightings of the langur were suspected.

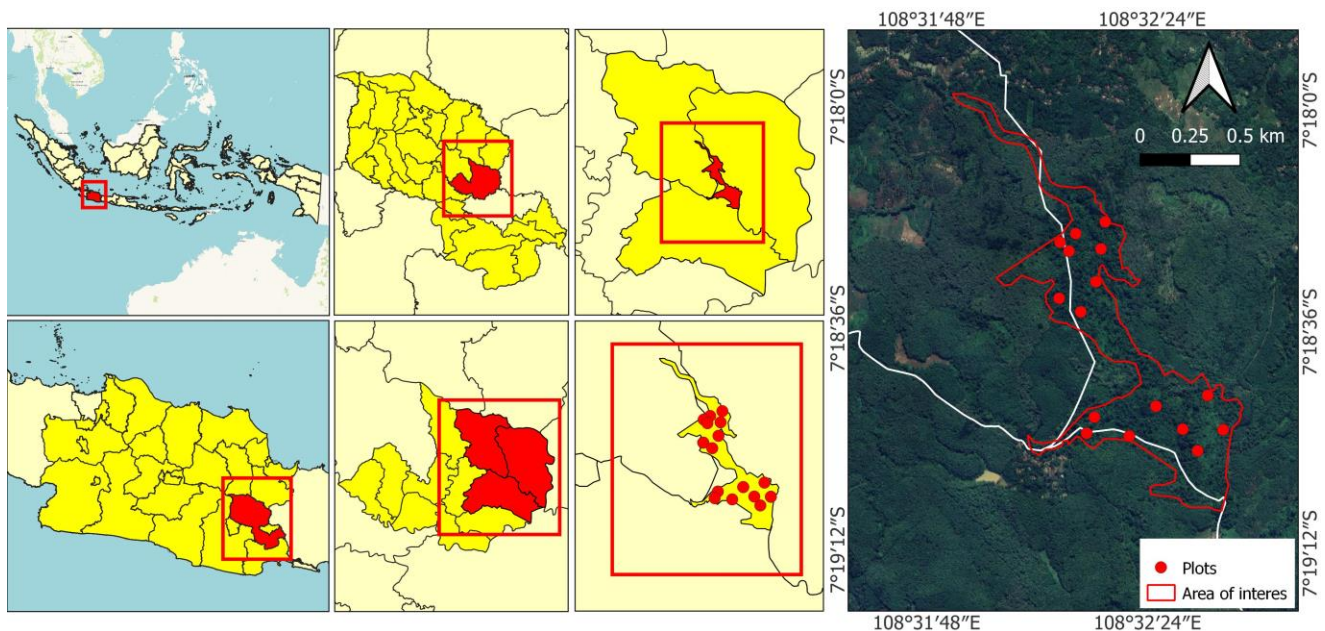


Figure 1. Map of study area and location of vegetation analysis plots in Gunung Babakan Secondary Forest, Ciamis, West Java, Indonesia

The number of plots was determined using the species-area curve method. When the addition of more plots no longer results in an increase in the cumulative number of species, the number and area of the plots are considered representative of the study area (Al-Huda et al. 2024).

The plots were established using the quadrat method of 20 m × 20 m, with subdivisions of 2 m × 2 m for seedling data collection, 5 m × 5 m for saplings, 10 m × 10 m for poles, and 20 m × 20 m for trees. Seedlings are plants with a height of less than 1.5 m. Saplings are plants with a height of more than 1.5 m and a Diameter at Breast Height (DBH) of less than 10 cm. Poles are plants with a DBH of 10 cm or more but less than 20 cm. Trees are plants with a DBH of 20 cm or more.

The plant species were identified by a local guide using their local names and verified by a curator for their scientific names. The accepted scientific names were further confirmed through the Plants of the World Online (POWO) database.

Spatial data in the form of the Canopy Height Model (CHM) was obtained from the research of Tolan et al. (2023) regarding global canopy height modeling. The map could be accessed via Google Earth Engine (GEE). Additionally, for HSI model scoring, several data were obtained, such as NDVI, DEMNAS, roads data, rivers data, and settlements data. NDVI data were obtained from Landsat 8 imagery; DEMNAS data, roads data, and settlements data were from the Geospatial Information Agency (BIG); and river data and maps of the study area and its surroundings were from Perum Perhutani, West Java and Banten Regional Division. Both canopy and HSI model data were processed using ArcMap 10.4.1.

For the evaluation of the HSI model, Rstudio 2022.07.2 was used to analyze multicollinearity of each data set and generate Receiver Operating Characteristic (ROC) curves. The presence points of Javan langur were obtained from research conducted by Athifah (2024). The method used was direct observation with binoculars by visiting each designated point where the locals had allegedly encountered the langurs within the previous two days to two weeks. Additional potential points, identified based on suitable habitat characteristics, were also visited. Meanwhile, pseudo-absence points were generated randomly across the study area using ArcMap 10.4.1, ensuring that these points were located outside the known presence locations of the Javan langur. Also, 50-meters buffer was applied around each confirmed presence point to minimize potential overlap, thereby reducing the risk of misclassifying true presence locations as absences.

Data analysis

This study adopted a deductive approach, as it relied on established ecological theories and species-specific knowledge to assess habitat suitability. Rather than generating new concepts from observation, the research applied pre-defined variables such as feeding tree composition, canopy height, and spatial modeling through the HSI framework to evaluate the habitat suitability of Javan langurs. The deductive approach was chosen to assess pre-condition of Gunung Babakan itself without considering the presence of

Javan langurs due to the lack of encounter points in the research conducted by Athifah (2024) at the same location. However, the HSI model was also evaluated using the encounter points to ensure the accuracy of the results.

Tree species composition and dominance

Vegetation analysis used the quadrat method to determine the Importance Value Index (IVI). IVI illustrates the importance of a species in the ecosystem. IVI values were an accumulation of density, dominance, and frequency of each species as shown in the following equations. If a species has high IVI value, then the species influences stability of the ecosystem. (Wardhana et al. 2022). In addition, Shannon-Wiener Diversity Index depicts how diverse the ecosystem. The older or more stable the condition of a community, the higher the species diversity (Wardhana et al. 2022).

Density

$$\text{Density} = \frac{\text{Number of individuals of each species}}{\text{Total plot area}}$$

$$\text{Relative Density} = \frac{\text{Density of each species}}{\text{Total density of all species}} \times 100\%$$

Dominance

$$\text{Tree basal area (LAB)} = \frac{1}{4} \times \pi \times \text{DBH}^2$$

$$\text{Dominance} = \frac{\text{LAB of each species}}{\text{Total plot area}}$$

$$\text{Relative Dominance} = \frac{\text{Dominance of each species}}{\text{Total dominance of all species}} \times 100\%$$

Frequency

$$\text{Frequency} = \frac{\text{Number of species encounter plots}}{\text{Total plots}}$$

$$\text{Relative Frequency} = \frac{\text{Frequency of each species}}{\text{Total frequency of all species}} \times 100\%$$

Importance Value Index (IVI)

$$\text{IVI (\%)} = \text{Relative Density} + \text{Relative Frequency} + \text{Relative Dominance}$$

Shannon-Wiener Diversity Index (H')

$$H' = -\sum pi \times \ln pi$$

Where pi is the ratio between the number of individuals of a species and the total number of individuals.

Security status of availability of feeding tree species for Javan langurs

The status of the availability of Javan langur feed was needed to determine the potential for Javan langur feed in the long term. The feeding trees were identified by both literature about Javan langurs feeding species and local guide explanation. The status of the availability of Javan langur feed was determined based on the IVI of Javan langur feed vegetation across various life stages (seedlings, saplings, poles, and trees), which were then grouped into four levels: very secure, secure, insecure, or very insecure (Ramdhani 2021), as shown in Table 1.

Canopy Height Model (CHM)

Canopy Height Model is a high-resolution raster layer modeling that measures the height of objects above the ground, such as tree canopies. CHM can support biodiversity modeling (Lang et al. 2023) and habitat suitability particularly for arboreal animals. This CHM modeling used data in the form of sub-meter resolution canopy height maps with self-supervised learning and vision transformer trained transformers on Aerial and GEDI Lidar (Tolan et al. 2023). These maps were generated by extracting features from self-supervised models trained on Maxar imagery, and training a dense prediction decoder on aerial LIDAR maps. These maps were open-access through GEE. Forest vegetation stratifications were classified into five strata based on tree height, namely strata A, B, C, D and E, with the following details in Table 2.

Habitat Suitability Index (HSI)

In the context of Javan langurs, the habitat suitability index is used to assess the suitability and feasibility of an area as a habitat for Javan langurs. In a study conducted by Maulahila et al. (2023) in Alas Purwo National Park, the suitability of the Javan langur habitat was measured from several variables, including NDVI, elevation, distance from rivers, distance from settlements, and distance from tourist areas. Meanwhile, in this study, the variables used to measure HSI were NDVI, elevation, distance from rivers, distance from settlements, and distance from roads. The variable "distance from the tourist area" was replaced with "distance from roads as human activities" considering that the location was closer to settlements and roads rather than tourist areas. These variables were used considering their ecological relevance to Javan langurs, such as food and water source availability and human disturbance. The analysis used equal weighting for all variables in the HSI calculation, assuming their same contribution to assess the habitat suitability (Maulahila et al. 2023). The variables measured have the following scores in Table 3. In addition, all scores were summed and divided by the number of variables used, and then the scores were categorized as shown in Table 4.

Furthermore, to ensure the independence of each data set, the multicollinearity analysis was conducted. Data with a VIF value under 10 was considered to have no multicollinearity, and values above 10 were considered to indicate high multicollinearity (Ningtyas et al. 2024).

Moreover, the validation for HSI modeling was conducted using a Receiver Operating Characteristic (ROC) curve based on the logistic regression between Javan langur encounter points, pseudo-absence points, and HSI itself. The evaluation was illustrated as an AUC value, which was categorized as shown in Table 5. This validation used a threshold of 0.5 to distinguish between suitable and unsuitable habitats, following a standard threshold widely used in binary classification models (Fernández and Morales 2019).

Table 1. Categorization of security status of the availability of feeding tree species for Javan langurs

Category	Explanation
Very secure	Vegetation was found at all life stages with IVI values in the upper quartile
Secure	Vegetation was found at all life stages with IVI values outside the upper quartile
Insecure	Vegetation was not found at one of life stages
Very insecure	Vegetation was found at only one life stages

Table 2. Stratification of canopy height

Crown strata	Height
A	>30 m
B	20-30 m
C	4-20 m
D	1-4 m
E	0-1 m

Table 3. Javan langur habitat variable score

Habitat variables	Classification	Score
NDVI	<-0.5	1
	-0.5-0	2
	0-0,5	3
	>0.5	4
Elevation (masl)	0-100	4
	100-200	3
	200-300	2
Distance from rivers (m)	>300	1
	0-100	4
	100-200	3
	200-300	2
Distance from settlements (m)	>300	1
	0-250	1
	250-500	2
	500-750	3
Distance from roads (m)	>750	4
	0-250	1
	250-500	2
	500-750	3
	>750	4

Table 4. Habitat suitability classification (Maulahila et al. 2023)

Habitat suitability level	Habitat Suitability Index (HSI)
Excellent	0.76-1.0
High	0.51-0.75
Average	0.26-0.50
Below average	0.0-0.25

Table 5. Model performance accuracy based on AUC (Area Under ROC Curve)

AUC value	Model performance
0.6-0.7	Not good
>0.7 - ≤0.8	Good
> 0.8	Very good

RESULTS AND DISCUSSION

Vegetation composition

Based on the research results, 17 plots were obtained using the purposive sampling method and the number was determined based on the species-area curve as shown in Figure 2. In the 15th to 17th plots, there was no increase in the number of species accumulation. When the addition of more plots no longer results in a significant increase in cumulative species, the number and area of the plots were considered representative of the study area, ensuring adequate sampling for biodiversity assessment (Al-Huda et al. 2024). Therefore, it could be concluded that the 17 vegetation analysis plots were quite representative of the species diversity in Gunung Babakan Secondary Forest area.

Dominance of species

Based on vegetation analysis in 17 plots, there were 66 species from 33 families. This importance value index was used to determine the dominant vegetation composition in the Javan langur habitat. The dominant species in each life stage are listed in Table 6.

Feeding tree species for Javan langurs

Based on vegetation analysis, there were 34 feeding tree species of Javan langurs, as shown in Table 7. Among these 34 species, 13 species were the main food sources for Javan langurs.

Tree species diversity

The Shannon-Wiener Diversity Index (H') for the Gunung Babakan Secondary Forest was 3.61, with H' values of 3.34 for seedlings, 3.03 for saplings, 2.63 for poles, and 2.8 for trees. The diversity index was closely related to species richness within an ecosystem, so a high diversity index indicates high biodiversity, productivity, and pressure on the ecosystem, as well as greater ecosystem stability (Ismaini et al. 2015). As a comparison, in areas with similar ecosystems, the Pananjung Pangandaran Nature Reserve had a diversity index of 3.55 (Salwanafi et al. 2023), while the Dungus Iwul Nature Reserve had a diversity index of 2.76 (Polosakan and Alhamd 2017). Based on these comparisons, the Gunung Babakan Secondary Forest demonstrated high biodiversity, particularly in the seedling and sapling layers, and moderate biodiversity in the pole and tree layers. Therefore, the Gunung Babakan ecosystem tended to be stable with high biodiversity. This high biodiversity and ecosystem stability were attributed to the long-standing conservation of the area, which had been preserved and considered sacred by the local community, resulting in minimal disturbance or damage.

Security status of feeding trees for Javan langurs

The security status of feeding trees for Javan langurs was assessed based on IVI values and the presence of individuals at each life stage of the 13 main feeding tree species. The main feeding tree species was determined based on their importance as a food source for Javan langurs

(Solihat and Bintarawati 2018; Ramdhani 2021) and their IVI to the ecosystem. These species were categorized as very secure, secure, insecure, or very insecure, as shown in Table 8.

Of the 13 main feeding tree species, 4 were categorized as very secure, 1 as secure, 5 as insecure, and 3 as very insecure. Some species classified as insecure or very insecure lacked individuals in one or more life stages. Suppose the missing stage is the pole or tree stage. In that case, it suggests the vegetation is in an early phase of regeneration, a condition commonly found in secondary forests that have experienced disturbances. Forest regeneration is typically influenced by disturbances such as canopy gaps (Yan et al. 2012). Conversely, if the missing stage is the seedling or sapling, it indicates low regeneration potential. This low potential may result from several factors, including slow regeneration rates, unpredictable rainy and dry seasons affecting the flowering and fruiting cycles of certain species, and unsuitable site conditions that hinder growth (Ramdhani 2021).

Canopy stratification

Javan langurs are arboreal animals that spend most of their life on trees. Thus, tree canopy connectivity is vital for them. In Figure 3.A, stratum B, with a height of 20-30 m, tended to be separated from one another, except in the central part of the Gunung Babakan Secondary Forest. This indicated that the connectivity of the upper canopy was relatively low, making it difficult for Javan langurs to move and travel through the upper canopy (Siddiq et al. 2024). In addition, in Figure 3.B, the highest percentage of canopy strata in Gunung Babakan was dominated by stratum C (4-20 m), accounting for 84%. Several studies have shown that Javan langurs prefer to carry out their activities in stratum C, followed by stratum B (Sulistiyadi et al. 2013; Siddiq et al. 2024). This indicated that the dominant canopy stratum in the area aligned well with the ecological activity preferences of the Javan langur, suggesting suitable habitat conditions.

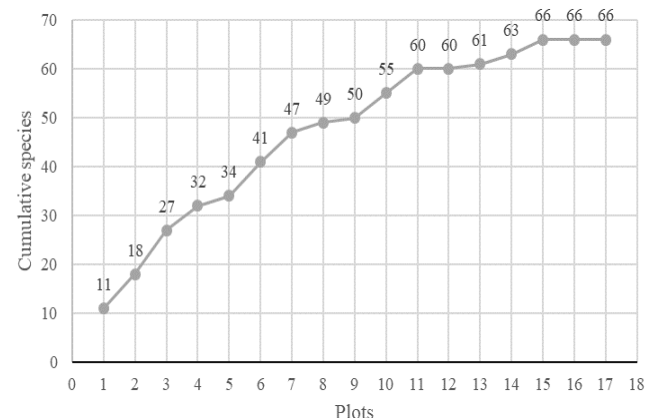


Figure 2. Plant species-area curve of the study area

Habitat suitability

In Figure 4.A, vegetation with an NDVI of less than 0.5 tended to be in the edge areas, while vegetation with an NDVI of greater than or equal to 0.5 tended to be in the core areas. This is because the edge areas were adjacent to teak forests, community plantations, and roads, resulting in more open vegetation cover. However, the area with an NDVI of 0.5 or greater is larger than the area with an NDVI of less than 0.5. This indicated that vegetation in the HAS Gunung Babakan area was still predominantly dense. According to Maulahila et al. (2023), Javan langurs tended to prefer dense vegetation ($NDVI \geq 0.5$) because it offers advantages such as shelter, activity space, and more abundant food sources.

Gunung Babakan Secondary Forest is situated in a lowland area with elevations ranging from 40 to 239 m above sea level, as illustrated in Figure 4.B Javan langurs can be found at elevations of up to 1,600 m above sea level (Al-Huda et al. 2024). However, lowland areas are preferred by Javan langurs due to more diverse vegetation structure. The variety in vegetation structure leads to a greater range of food plant options. Additionally, lowland areas generally have warmer temperatures and suitable humidity levels, making them more preferable for Javan langur activities (Maulahila et al. 2023). Therefore, the central and southern areas were more suitable as a habitat for Javan langurs.

In the area around Gunung Babakan Secondary Forest, there were several human settlements located at varying distance, ranging from less than 250 m to more than 750 m, as shown in Figure 4.C The areas closest to the settlements were mostly protruding areas, which are also surrounded by plantations and teak forests. The nearest settlement to Gunung Babakan Secondary Forest was located only 50 m away. The close proximity of the Javan langurs' habitat to human settlement is not ideal, as Javan langurs tend to avoid encounters with humans (Maulahila et al. 2023). The farther the area is from human settlements, the more preferable it is for the langurs. In Figure 4.C, the area farthest from the settlements was located in the core area, indicating that the core area was more suitable as a habitat for Javan langur.

The roads within and around Gunung Babakan Secondary Forest consist of two types: village roads and footpaths. Village roads serve as the main access for local residents to carry out their daily activities. These roads were generally paved and located near the edges of the secondary forest. Meanwhile, footpaths were used by Perhutani for harvesting teak forest products. These paths were still unpaved. In addition, there were footpaths used by local residents to access water sources. As shown in Figure 4.D, the areas farthest from roads are located in the central part, while areas closer to the main roads are found in the northern, western, and eastern part of the secondary forest. Human presence, especially along roads, can indirectly cause stress to primates (Maulahila et al. 2023). Therefore, the central area is more suitable as a habitat for the Javan langur.

There were several small streams within Gunung Babakan Secondary Forest, with distances ranging from 0 to more than 200 m, as shown in Figure 4.E. The

availability of water sources is essential for Javan langurs to meet their hydration needs (Subarkah et al. 2011). Nevertheless, in emergencies or during periods of water scarcity, Javan langurs can fulfill their water requirements solely through the consumption of young leaves (Maulahila et al. 2023).

Based on the scoring results of five variables-NDVI, elevation, distance from roads, distance from settlements, and distance from rivers-a habitat suitability map for the Javan langur was generated, as shown in Figure 5. The map indicates that areas with very high suitability indices tend to be located in the central and eastern parts of Gunung Babakan Secondary Forest, while areas with high suitability indices are generally found in the western and northern parts. This pattern is primarily due to the elongated shape of the landscape in the western and northern sections, which leads to increased edge effects (Santana et al. 2021). In addition, the presence of human settlements and roads near the western part of the area contributes to lower HSIs compared to the eastern region.

The Habitat Suitability Index (HSI) map categorizes the area into two suitability classes: high (scores ranging from above 0.5 to 0.75) and excellent (scores ranging from 0.76 to 1). Within the area, HSI range from 0.55 to 0.85, as shown in Figure 6.

These results indicate that the overall habitat suitability for Javan langurs in Gunung Babakan Secondary Forest is relatively high. However, it is not sufficient to be classified as highly suitable, as only 41% of the area falls into the 'excellent' category, while the remaining 59% is categorized as 'high.'

In addition, a multicollinearity analysis was conducted to ensure that each variable in the HSI model is independent of the others. The multicollinearity analysis was shown as Variance Inflation Factor (VIF) value in Table 9. All variables had VIF values below 10, indicating no multicollinearity among the variables (Ningtyas et al. 2024).

Table 6. Dominant species in each life stage

Life stage	Species	IVI
Seedlings	<i>Antidesma tetrandrums</i> Blume	16.21
	<i>Donax canniformis</i> (G.Forst.) K.Schum.	16.21
	<i>Dysoxylum densiflorum</i> (Blume) Miq.	12.22
Saplings	<i>Dysoxylum densiflorum</i> (Blume) Miq.	42.69
	<i>Antidesma tetrandrums</i> Blume	27.25
	<i>Tectona grandis</i> L.f.	17.87
Poles	<i>Archidendron pauciflorum</i> (Benth.) I.C.Nielsen	40.82
	<i>Artocarpus elasticus</i> Reinw. ex Blume	31.34
	<i>Macaranga tanarius</i> (L.) Müll.Arg.	29.74
	<i>Dysoxylum densiflorum</i> (Blume) Miq.	24.66
	<i>Mimusops elengi</i> L.	23.07
Trees	<i>Antidesma tetrandrums</i> Blume	22.64
	<i>Tectona grandis</i> L.f.	41.59
	<i>Antidesma tetrandrums</i> Blume	29.04
	<i>Artocarpus elasticus</i> Reinw. ex Blume	24.38
	<i>Dillenia indica</i> L.	23.74
	<i>Dysoxylum densiflorum</i> (Blume) Miq.	23.11
	<i>Vitex pubescens</i> B.Heyne ex Wall., 1829	19.24

Table 7. List of feeding tree species for Javan langurs

Species name	Family	Local name	Main feeding tree	Edible part	Notes
<i>Alstonia scholaris</i> (L.) R.Br.	Apocynaceae	<i>Lame</i>		Leaves	Wardhana et al. (2022)
<i>Antidesma bunius</i> (L.) Spreng.	Phyllanthaceae	<i>Huni</i>	v	Leaves, fruit	Ramdhani (2021)
<i>Archidendron pauciflorum</i> (Benth.) I.C.Nielsen	Fabaceae	<i>Jengkol</i>	v	Leaves, fruit	Perhutani
<i>Artocarpus elasticus</i> Reinw. ex Blume	Moraceae	<i>Benda</i>	v	Fruit	Mustari and Pasaribu (2019)
<i>Artocarpus heterophyllus</i> Lam.	Moraceae	<i>Nangka</i>		Leaves, fruit	Permana and Santoso (2021)
<i>Barringtonia acutangula</i> (L.) Gaertn.	Lecythidaceae	<i>Putat</i>		Leaves	Mustari and Pasaribu (2019)
<i>Bischofia javanica</i> Blume	Phyllanthaceae	<i>Gadog</i>	v	Leaves, fruit	Solihat and Bintarawati (2018)
<i>Cinnamomum iners</i> (Reinw. ex Nees & T.Nees) Blume	Lauraceae	<i>Ki teja</i>		Leaves	Putra et al. (2024)
<i>Dendrocnide sinuata</i> (Blume) Chew	Urticaceae	<i>Pulus</i>		Leaves	Pramudita (2024)
<i>Dracontomelon dao</i> (Blanco) Merr. & Rolfe	Anacardiaceae	<i>Dahu</i>		Leaves, fruit	Kurniawan et al. (2019)
<i>Dysoxylum densiflorum</i> (Blume) Miq.	Meliaceae	<i>Kedoya</i>	v	Leaves	Ihsanu et al. (2013)
<i>Elaeocarpus sphaericus</i> (Gaertn.) Ettingsh.	Elaeocarpaceae	<i>Ganitri</i>		Leaves	Qomariah (2015)
<i>Eugenia uniflora</i> L.	Myrtaceae	<i>Ki tambaga</i>		Leaves, fruit	Solihat and Bintarawati (2018)
<i>Ficus benjamina</i> L.	Moraceae	<i>Caringin</i>		Leaves, fruit	Aryanti and Azizah (2019)
<i>Ficus callosa</i> Willd.	Moraceae	<i>Pangsor</i>		Leaves, fruit	Kurniawan et al. (2019)
<i>Ficus hispida</i> L.fil.	Moraceae	<i>Bisoro</i>	v	Leaves, fruit	Aryanti and Azizah (2019)
<i>Ficus montana</i> Burm.fil.	Moraceae	<i>Amis mata</i>		Leaves, fruit	Qomariah (2015)
<i>Ficus septica</i> Burm.fil.	Moraceae	<i>Ciciap</i>		Leaves, fruit	Ramdhani (2021)
<i>Ficus variegata</i> Blume	Moraceae	<i>Kiara</i>	v	Leaves, fruit, flowers	Ramdhani (2021)
<i>Grewia paniculata</i> Roxb. ex DC.	Malvaceae	<i>Ki darewak</i>		Leaves	Ramdhani (2021)
<i>Leea</i> sp.	Vitaceae	<i>Ki buaya</i>		Leaves	Ramdhani (2021)
<i>Litsea</i> sp.	Lauraceae	<i>Huru</i>		Leaves	Ihsanu et al. (2013)
<i>Macaranga tanarius</i> (L.) Müll.Arg.	Euphorbiaceae	<i>Mara</i>	v	Leaves, fruit	Kurniawan et al. (2019)
<i>Mallotus philippensis</i> (Lam.) Müll.Arg.	Euphorbiaceae	<i>Ki meong</i>		Leaves	Aryanti and Azizah (2019)
<i>Melicope latifolia</i> (DC.) T.G.Hartley	Rutaceae	<i>Ki sampang</i>		Leaves	Solihat and Bintarawati (2018)
<i>Nephelium lappaceum</i> L.	Sapindaceae	<i>Rambutan</i>		Leaves	Faizi and Srimulyaningsih (2023)
<i>Parkia timoriana</i> (DC.) Merr.	Fabaceae	<i>Peundeuy</i>		Leaves, fruit, flowers	Kurniawan et al. (2019)
<i>Sterculia oblongata</i> R.Br.	Sterculiaceae	<i>Hantap</i>	v	Leaves, fruit	Ihsanu et al. (2013)
<i>Swietenia macrophylla</i> G.King	Meliaceae	<i>Mahoni</i>	v	Leaves	Ihsanu et al. (2013)
<i>Syzygium jambos</i> (L.) Alston	Myrtaceae	<i>Jambu bol</i>		Leaves, fruit	Qomariah (2015)
<i>Syzygium polyanthum</i> (Wight) Walp.	Myrtaceae	<i>Salam</i>		Leaves, fruit	Qomariah (2015)
<i>Tabernaemontana sphaerocarpa</i> Blume	Apocynaceae	<i>Hamperu badak</i>	v	Leaves, fruit	Aryanti and Azizah (2019)
<i>Tectona grandis</i> L.f.	Lamiaceae	<i>Jati</i>	v	Leaves	Faizi and Srimulyaningsih (2023)
<i>Vitex pubescens</i> B.Heyne ex Wall., 1829	Lamiaceae	<i>Heras</i>	v	Leaves, fruit	Ramdhani (2021)

The HSI model was also evaluated by 8 presence points (Athifah 2024) and 8 pseudo-absence points with AUC. Eventually, the AUC score was obtained to determine how effective performance of the model. The results of the AUC test evaluated the model's ability to estimate the suitability of Javan langur habitats. The result of this test showed an AUC value of 0.742, with sensitivity and specificity were respectively 0.875 and 0.625. This AUC value is categorized as a good level of model accuracy, as shown in Figure 7. This result depicted the model's ability to distinguish between suitable and unsuitable habitats for the Javan langur with relatively high accuracy. AUC values between

0.7 and 0.8 generally indicate acceptable to good model performance, suggesting that the combination of the variables of HSI provided a reliable prediction of habitat suitability (Ningtyas et al. 2024). While the HSI model for Javan Langurs in Gunung Babakan Secondary Forest yielded a good accuracy level, it is crucial to acknowledge the limitations stemming from the sample size used for its validation. The evaluation of this model was based on a relatively small datasets. However, given that this research employed a deductive approach, the validity of the model could be strengthened, provided that the data sources were reliable (Field 2018).

Table 8. Security status of the main food source for Javan langurs in Gunung Babakan Secondary Forest

Species	Local name	Quartile				Status
		Seedling	Sapling	Pole	Tree	
<i>Antidesma bunius</i> (L.) Spreng.	Huni	-	4	-	-	D
<i>Archidendron pauciflorum</i> (Benth.) I.C.Nielsen	Jengkol	-	3	1	-	C
<i>Artocarpus elasticus</i> Reinw. ex Blume	Benda	2	2	1	1	A
<i>Bischofia javanica</i> Blume	Gadog	3	2	-	3	C
<i>Dysoxylum densiflorum</i> (Blume) Miq.	Kedoya	1	1	2	1	A
<i>Ficus hispida</i> L.fil.	Bisoro	1	1	4	-	B
<i>Ficus variegata</i> Blume	Kiara	-	-	3	-	D
<i>Macaranga tanarius</i> (L.) Müll.Arg.	Mara	2	-	1	3	C
<i>Sterculia oblongata</i> R.Br.	Hantap	3	-	-	-	D
<i>Swietenia macrophylla</i> G.King	Mahoni	1	2	3	2	A
<i>Tabernaemontana sphaerocarpa</i> Blume	Hamperu badak	-	-	4	2	C
<i>Tectona grandis</i> L.f.	Jati	-	-	4	1	C
<i>Vitex pubescens</i> B.Heyne ex Wall., 1829	Heras	3	2	3	1	A

Note: A: Very secure, B: Secure, C: Insecure, D: Very insecure

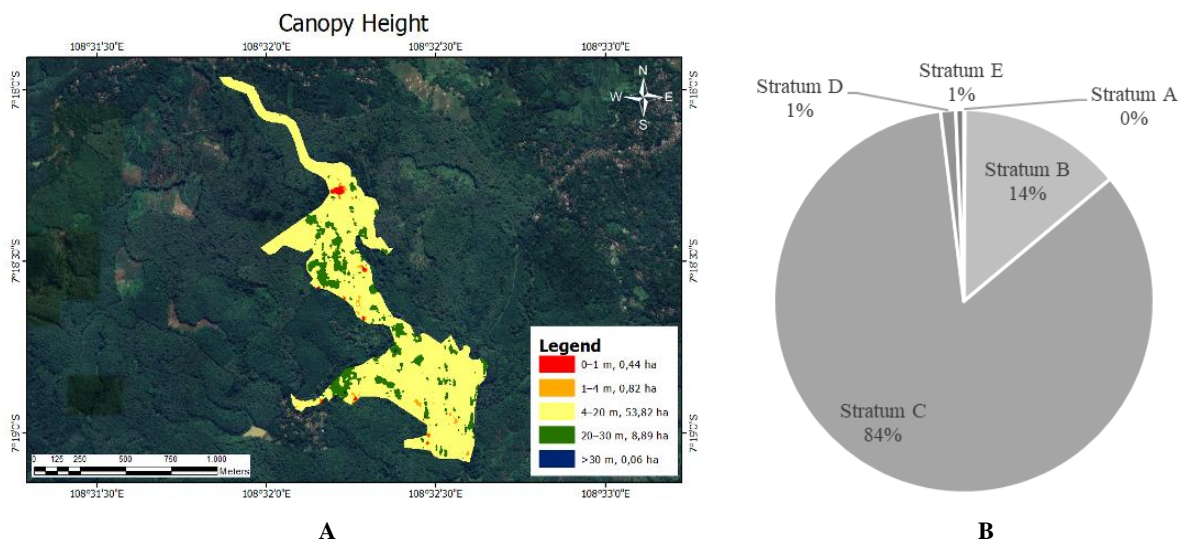


Figure 3. A. Canopy Height Model (CHM) map, B. Percentage of each stratum

Discussion

According to each life stage, there were 1-3 species that served as food sources for the Javan langur. In the seedling layer, there was *kedoya* (*Dysoxylum densiflorum*); in the sapling layer, there are *kedoya* and teak or *jati* (*Tectona grandis*); in the pole layer, there are *jengkol* (*Archidendron pauciflorum*), *benda* (*Artocarpus elasticus*), and *mara* (*Macaranga tanarius*); while in the tree layer, there are *jati* (*Tectona grandis*) and *benda* (*Artocarpus elasticus*). This indicates a high abundance of Javan langur food species in the study area. Moreover, a high IVI suggests that these species are able to make optimal use of the available resources in the environment. Additionally, relatively even IVI values among many species indicate higher biodiversity in the ecosystem (Ismaini et al. 2015). The results indicated a diverse and abundance of food source for Javan langurs. Although several main food sources were still categorized

as insecure and very insecure due to a lack of seedlings, it can be maintained by management strategies such as planting seedlings of Javan langurs' feeding trees to enhance availability. Based on diversity and abundance of feeding trees, Gunung Babakan still provided a sufficient food source to support the livelihood of Javan langurs.

In Gunung Babakan Secondary Forest, many teak individuals were found, especially in the edge area bordering the teak forest area. There are two possible explanations for this. The first possibility is that teak seeds from the adjacent teak forest were dispersed into the secondary forest, allowing them to grow alongside native forest species. The second possibility is that the edge area was previously part of a teak forest area before the designation and re-delineation of the secondary forest, which would explain the presence of teak planting in that area.

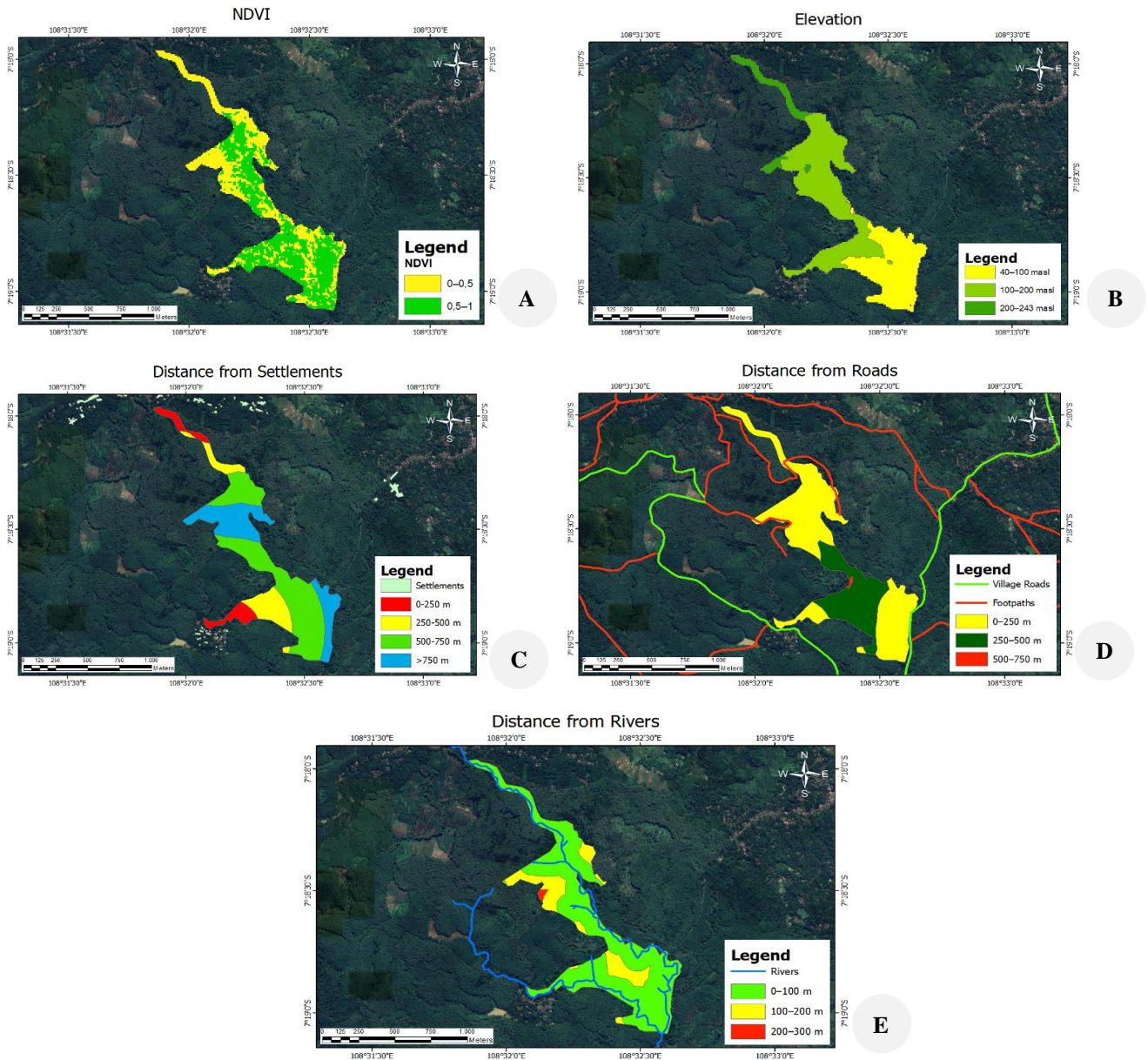


Figure 4. Map of each variable of the habitat suitability index for Javan langur: A. NDVI, B. Elevation, C. Distance from settlements, D. Distance from roads, E. Distance from rivers

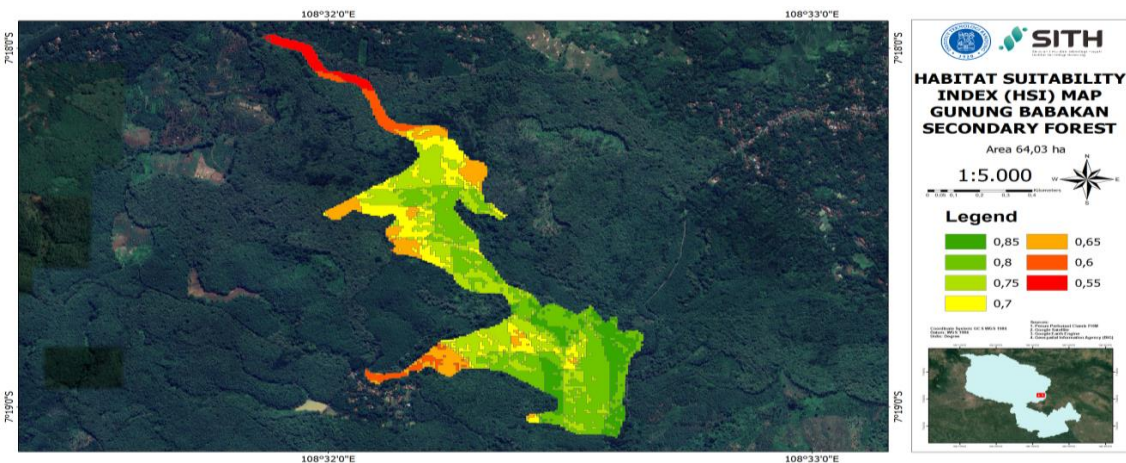


Figure 5. Habitat Suitability Index (HSI) map for Javan langurs in Gunung Babakan Secondary Forest, Ciamis, West Java, Indonesia

Table 9. Multicollinearity analysis of HSI variables

Variable	VIF
NDVI	1.524
Elevation	2.136
Distance from roads	1.835
Distance from rivers	1.660
Distance from settlements	1.941

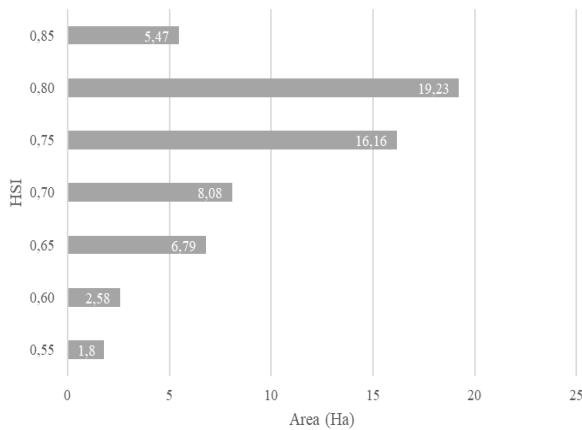


Figure 6. Area bar chart in each HIS

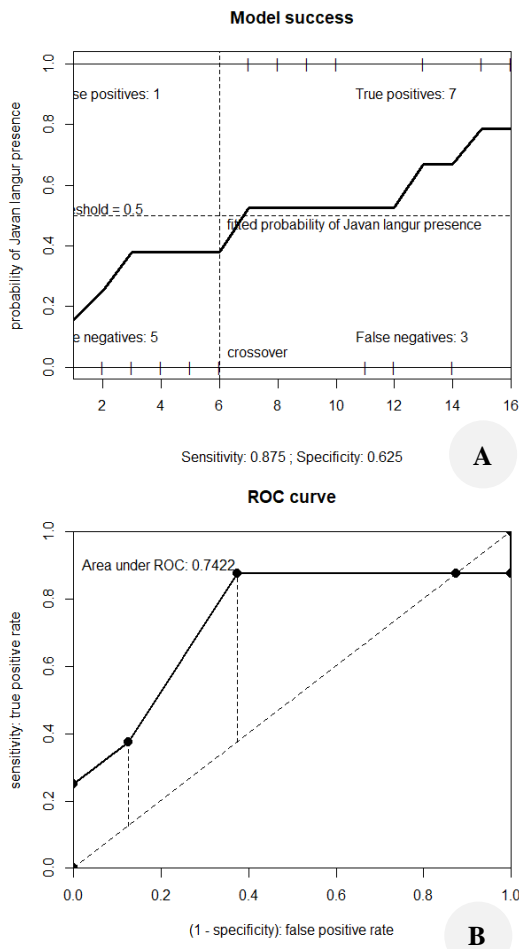


Figure 7. A. Model success of HSI based on actual presence/pseudo-absence point, B. ROC curve

The average tree height in an area influences the Javan langurs' preference for a particular canopy stratum. This is also supported by local residents, who stated that langurs are often found in areas with mid and lower canopy cover, both in the forest interior and at the edges (Siddiq et al. 2024). Therefore, the condition of Gunung Babakan Secondary Forest, which is dominated by stratum C, indicates that it remains a relatively suitable habitat for the Javan langur. In a study conducted by Sulistyadi et al. (2013) on langur habitat in the Gunung Pancar Nature Park, Bogor, it was found that Javan langur activity was predominantly in stratum C (4-20 m) with a percentage of 80-85%, followed by stratum B (20-30 m) with a percentage of 13-17%. In addition, Siddiq et al. (2024), in their study at Meru Betiri National Park, found that langur activity was mostly observed in stratum C (82.40%), followed by stratum B (16.31%). However, different results were reported by Zainal (2008), who stated that Javan langurs used the upper stratum the most (43.11%) in natural habitats and the middle stratum (49.22%) in captivity. Meanwhile, research by Subarkah et al. (2011) showed that 50.53% of Javan langur activity occurred in the upper canopy, 41.99% in the middle canopy, and only 2.49% in the lower canopy. These differing findings are likely due to variations in research site conditions, particularly the average tree height in each area. Gunung Pancar, for example, is a natural forest surrounded by plantations and residential areas, similar to the condition of Gunung Babakan Secondary Forest, which is bordered by teak monoculture forests, plantations, rice fields, and is located near human settlements. However, the canopy height in Gunung Babakan was still suitable for Javan langurs' activities. According to Athifah (2024), Javan langurs are encountered in the canopy at a height of 10-20 m.

The HSI model indicated that Gunung Babakan Secondary Forest is suitable as a habitat for Javan langurs, particularly in the core area. The relatively high scores can be attributed to several favorable factors, such as proximity to water sources and dense vegetation cover. These high scores were further supported by two ecological factors analyzed in this study: food source availability and canopy height. Nonetheless, several limiting factors prevent the area from being classified entirely as 'excellent' suitability. These include proximity to human settlements and roads. Gunung Babakan Secondary Forest is characterized by a nearly fragmented landscape, surrounded by plantation forests and village roads, which serve as areas of human activity that may disturb primate behavior, particularly that of the Javan langur. According to Maulahila et al. (2023), high levels of human activity can disrupt Javan langurs and influence their spatial distribution. Moreover, the presence of humans may induce stress in primates. Based on the HSI model, 41% of total areas categorized as 'excellent' (0.76-0.85), indicate these areas are very safe as Javan langurs habitat. On the other hand, 59% of the total areas categorized as 'high' (0.55-0.75) indicate that the areas are safe, but several actions should be implemented by Perhutani, such as expanding habitat areas beyond teak-dominated forests adjacent to conservation zones, and restricting unauthorized access by local villagers.

Additionally, regarding the use of pseudo-absence points generated by ArcMap, they may influence ecological modeling since these points do not accurately represent the absence of Javan langurs. However, based on the evenness of Javan langurs' encounter points, the pseudo-absence points could still be used to validate this HSI model (Descombes et al. 2022). Moreover, although the CHM model used in this research was validated by Tolan et al. (2023) and had high resolutions, further direct canopy height measures could be conducted to improve the accuracy of the CHM.

Gunung Babakan Secondary Forest presents a complex ecological landscape for Javan langurs, characterized by high biodiversity, abundant food sources, and a dominant canopy structure (Stratum C) that supports their arboreal lifestyle. These conditions are further enhanced by favorable lowland topography and water availability. Therefore, since only eight encounter points were recorded and the existing population consists of just 5-8 individuals (Athifah 2024), reintroduction programs could be considered given the current habitat suitability. However, this vital habitat faces significant ecological challenges, including regeneration vulnerabilities of certain key feeding tree species and limited upper canopy connectivity. Perum Perhutani should implement several management strategies to improve habitat suitability, such as replanting potential feeding tree species, expanding habitat areas beyond teak-dominated forests adjacent to conservation zones, and restricting unauthorized access by local villagers. Social measures are also necessary, including community education and awareness campaigns to highlight the importance of conserving Javan langurs.

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