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The Analysis of Habitat Suitability for Macaca Tonkeana in the Pangi Binangga Natural Reserve of West Toboli Village Using SIG and PCA Approach

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Abstract. The boti monkey, also known by its scientific name Macaca tonkeana, is a type of endemic primate found on Sulawesi Island. This study aims to determine the suitability of Macaca tonkeana habitat by using spatial analysis methods to determine the most suitable areas for survival. The study used a sample of locations conducted by observation method. The data collected was then spatially analysed by overlaying, classing, weighting, and scoring. PCA analysis was used to classify variables and assign weights to each parameter. Based on the habitat suitability model developed, the study sites were classified into three suitability levels: low, medium and high. Low suitability with an area of 9.475621 ha (0.374%). Medium suitability with an area of 461.777729 ha (18.184 %). High suitability with an area of 2065.896076 ha (81.442%). The model validation showed that most of the validation points were located within the high suitability class, with 92.59% of the total validation points. This indicates that the study site is likely to be a highly suitable habitat for Boti Monkeys.

Keywords: Habitat Suitability, Macaca Tonkeana, SIG, Spatial Analysis

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1. Introduction

Central Sulawesi is among the provinces in Indonesia in the center of Wallacea, a region with a unique wealth of biological natural resources, which includes abundant endemic flora and fauna [1]. Flora consists of all types of plants that can be found in Central Sulawesi Province, while fauna refers to the various types of animals that exist in the region [2].

Central Sulawesi, precisely in Parigi Moutong Regency, has a nature reserve, namely the Pangi Binangga Nature Reserve, where there is flora and fauna [3]. According to Law Number 5 of 1990 concerning the Conservation of Biological Natural Resources and Ecosystems, Nature Reserves (CA) are protected natural areas because they have unique plants, animals, and ecosystems or specific ecosystems that require natural protection. The determination of CA Pangi Binangga is based on the Decree of the Minister of Forestry and Plantation Number 399/Kpts-2/1998 with an area of more than 6,000 hectares, administratively located in Parigi Moutong district, Central Sulawesi Province.

Macaca tonkeana is one of seven endemic monkey species that can be found in the central region of Sulawesi [4]. One of them is along the Trans Palu-Parigi road, which is located in the Pangi Binangga Protected Forest and Nature Reserve. This area is the natural habitat (home range) of Macaca tonkeana.

The boti monkey, also known by its scientific name Macaca tonkeana, is a type of endemic primate found on Sulawesi Island [5]. The Boti Monkey (Macaca Tonkeana) in West Toboli Village is a protected animal, but currently, its existence is threatened, so there is a need for data regarding the suitability of the black monkey's (Macaca Tonkeana) habitat. One of the main reasons why the existence of the boy monkey (Macaca tonkeana) is threatened is the destruction of its habitat due to human activities in forest exploitation, natural disasters, and lack of food availability [6].

Spatial research combines GIS, satellite imagery, and aerial photos to evaluate habitat factors for Macaca tonkeana conservation, aiming to understand parameter impacts and develop a habitat suitability model for West Toboli Village's Pangi Binangga Nature Reserve. [7]. This research aims to identify optimal areas for the black monkey's survival, recognizing the significance of distribution data and spatial analyses for conservation efforts.[6].

2. Methods

2.1 Research Location and Time

This research was carried out in the Pangi Binangga Nature Reserve area, West Toboli Village, Parigi Moutong Regency, Central Sulawesi. This research was carried out from September to November 2023.

2.2. Data Collection and Analyses

The research was conducted by observing and sampling locations, collecting precise coordinates of monkey nests using GPS. The collected data was then analysed using spatial analysis techniques such as overlay, class division, weighting, and scoring, which are essential for identifying spatial models and relationships between variables [8]. Data were collected using a purposive method, by searching for nests and signs of boti monkeys, selected based on information from local communities and conservation officers. Nest sites were selected by considering the nightly nesting habits of boti monkeys. Sites were also selected with respect to distance from roads. Boti monkey nests and tracks were identified and their coordinates recorded using GPS.

The stages for spatial analysis of habitat suitability are as follows:

1. Collect data based on each function to create a distribution map of boti monkeys. The types of data required include coordinate points (GPS points) and Landsat 8 images.
2. Spatial Distribution Mapping. Analysis of the spatial distribution of boti monkeys was carried out by utilizing all coordinate points obtained based on their location [9]
3. Habitat suitability parameters include distance from settlements, roads, rivers, slope, height, and NDVI for land cover.[10]
4. Distance Maps are created based on predetermined variables, then buffering the parameters used via ArcGIS 10.8 [11].
5. Making vegetation density maps. Normalized Difference Vegetation Index (NDVI) is used to determine vegetation density[12].
6. The use of PCA analysis aims to identify the factors that have the most significant impact [13]. The PCA analysis was carried out using XLSTAT software. The PCA results are used to determine the weight of each habitat factor and for spatial analysis to produce the following equation ;

$$Y = aFK1 + bFk2 + cFk3 + dFk4 + eFk5 + fFk6 + gFk7 \quad (1)$$

Information:

Y : Total Habitat Suitability Value a-f: Weight Value of Each Variable
Fk1: Distance Factor From River Fk2: Distance Factor From Road
Fk3: Distance Factor from Settlements Fk4: NDVI Factor
Fk5 : Slope Factor Fk6: location Height Factor

7. In spatial analysis, important factors include the location of macaca tonkeana distribution points, which are considered in terms of distance from rivers, road networks, and settlements, as well as NDVI values [14].

The Mathematical Model used is:

- The interval value of the habitat suitability classification score is determined based on the distribution of pixel values:

$$Interval = \frac{Smax - Smin}{K} \quad (2)$$

Information:

Smax : Highest Pixel Value Smin : Lowest Pixel Value

K : There are many classifications of habitat suitability

- Validation value of habitat suitability classification:

$$Validation = (n - N)\ 100\ \% \quad (3)$$

3. Results and Discussion

Spatial habitat suitability modeling is essential in understanding and protecting sustainability. In creating a spatial model of forest suitability, several data are needed, including habitat suitability parameters, PCA data analysis, and spatial data analysis.

3.1. Habitat Suitability Parameters

Six parameters - settlement, roads, rivers, elevation, slope, and NDVI - are analyzed to form a habitat suitability model for boti monkeys..

3.1.1 Distribution of Nests Based on Distance from the River

The results of the nest distribution buffer parameters (n) and area size based on distance from the river are presented in Table 1.

Table 1. Nest distribution (n) and area area based on distance class from the river

Class	N	Nest (%)	Area (ha)	Area Percentage (%)	Nest Density/ha
0 - 2000	54	100%	2527,673402	100%	699,63
Total	54	100%	2527,673402	100%	

Table 1 displays nest distribution and area relative to river distance. Within 0-2000 meters, 54 nests cover 2527.673402 hectares, with a nest density of 699.63 per hectare.

3.1.2 Distribution of Nests Based on Distance from Settlements

Settlement is a factor that influences the habitat of boti monkeys. The results of the nest distribution buffer parameters (n) and area size based on distance from the river are presented in Table 2.

Table 2. Nest distribution (n) and area based on distance class from settlement

Class	N	Nest (%)	Area (ha)	Area Percentage (%)	Nest Density/ha
0 – 1000	0	0%	331,347126	13%	0
1000 – 3000	14	26%	700,669164	28%	1998,31
3000 – 5000	40	74%	815,129139	32%	4906,75
5000 – 7000	0	0%	671,091259	27%	0
> 8000	0	0%	9,436714	0%	0
Total	54	100%	2527,673402	100%	

Table 2 presents nest distribution and area by distance from the reference point to the settlement. Majority of nests were within 1000-5000 meters, with densest concentration (4906.75/ha) at 3000-5000 meters, suggesting optimal habitat for boti monkeys.

3.1.3 Nest distribution based on distance from the road

The results of the nest distribution buffer parameters (n) and area size based on distance from the road are presented in Table 3.

Table 3. Nest distribution (n) and area based on distance class from road

Class	N	Nest (%)	Area (ha)	Area Percentage (%)	Nest Density/ha
0 – 1000	54	100%	1703,72846	67%	2297,05

1000 – 3000	0	0%	815,535556	32%	0
3000 – 5000	0	0%	8,409386	0%	0
Total	54	100%	2527,673402	100%	

Table 3 shows nest distribution and area by road distance. In the 0-1000 meter class, 54 nests cover 1703.72846 hectares with a nest density of 2297.05 nests/ha. Subsequent classes have zero nests.

3.1.4 Distribution of Boti Monkey Nests Based on NDVI

Vegetation density is a factor that influences the habitat of boti monkeys. The results of nest distribution (n) and area size based on NDVI are presented in Table 4.

Table 4. Nest distribution (n) and area based on NDVI

Class	N	Nest (%)	Area (ha)	Area Percentage (%)	Nest Density/ha
0-0,3	3	6%	348,693824	14%	0,86
0,3-0,4	10	19%	884,071802	35%	1,13
0,4-0,5	37	69%	1098,10306	43%	3,37
>0,5	4	7%	196,804716	8%	2,03
Total	54	100%	2527,673402	100%	

Table 4 illustrates nest distribution by NDVI, reflecting boti monkey habitat. Classes range from 0 to >0.5, correlating with vegetation. Class 0.4-0.5 harbored most nests (69%), covering 43% of the area. Higher NDVI classes, though fewer nests, maintained high nest density, emphasizing NDVI's significance in nest distribution.

3.1.5 Nest Distribution Based on Height

Height is a factor that influences the habitat of boti monkeys. The results of nest distribution (n) and area size based on height are presented in Table 5.

Table 5. Nest distribution (n) and area based on height

Class	N	Nest (%)	Area (ha)	Area Percentage (%)	Nest Density/ha
0-300	4	7%	792,811956	31%	5,05
300-400	1	2%	282,42392	11%	3,54
400-500	5	9%	308,288903	12%	16,16
500-750	42	78%	692,47269	27%	60,65
>750	2	4%	451,675933	18%	4,43
Total	54	100%	2527,673402	100%	

Table 5 displays nest distribution across five altitude classes, from 0-300 meters to over 750 meters. Most nests (78%) were found at 500-750 meters, suggesting altitude's importance in boti monkey nest distribution.

3.1.6 Nest Distribution Based on Slope

The slope is a factor that influences the habitat of boti monkeys. The results of nest distribution (n) and area size based on slope are presented in Table 6.

Table 6. Nest distribution (n) and area area based on slope

Class	n	Nest (%)	Area (ha)	Area Percentage (%)	Nest Density/ha
0-8	23	43	0,004756	0	4831679,01
8-15	13	24	799,075532	32	1625,78
15-25	16	30	806,72522	32	1984,59

25-40	0	0	738,191813	29	0
>40	2	4	161,047063	6	1242,33
Jumlah	54	100	2505,044384	100	

Table 6 depicts orangutan nest density by slope class. The 0-8 degree class exhibits the highest density (23 nests, 43%) in a small area (0.004756 ha). Slopes of 0-25 degrees contain most nests, emphasizing slope's role in nest distribution.

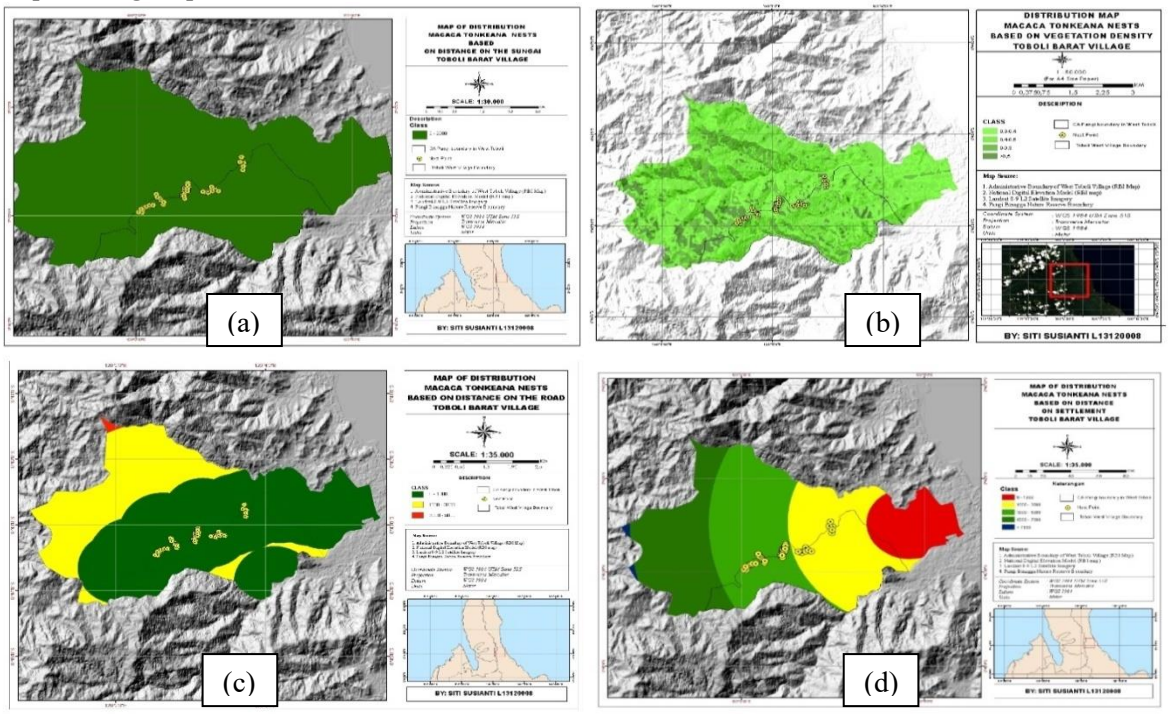

Figure 1. (a). map of macaca tonkeana nest distribution distance from rivers (b). map of macaca tonkeana nest distribution NDVI (c). map of macaca tonkeana nest distribution distance from roads (d). map of macaca tonkeana nest distribution distance from settlements.

3.2 Habitat Suitability Model Data Analysis Using PCA

PCA identifies relationships between variables to create new independent variables. Previous studies [15] have indicated that PCA can be used to assign scores or weights to variables in predicting the habitat of a species. Therefore, in this study, PCA was utilized to classify variables and determine scores or weights for each group of variables or factors (PC) generated. Meanwhile, to ascertain the weights of each tested variable, regression analysis was conducted using the factor scores of each PC against all variables that formed it. PCA analysis and regression analysis were performed using the XLSTAT software.

From the results of the PCA analysis involving 6 principal components, 3 principal components were found to be significant in the total variation, which are described in Table 7. The usable and representative principal component is the third principal component with a cumulative diversity value of 76.1%. The cumulative diversity value is considered to represent the total diversity of the data, because the cumulative diversity lies between 70%-80%.

Table 7. Total Diversity of Principal Components

Main component	**Characteristic Roots**		
	Total	**Diversity (%)**	**Cumulative diversity (%)**
River	3,908	78,158	78,158

Settlement	4,415	88,309	88,309
Road	4,415	88,309	88,309
NDVI	4,419	88,376	88,376
Height	3,696	73,92	73,92
Slope	3,328	66,567	66,567

Data from Table 8 analysis is utilized to establish weights for each parameter, showcasing the relationship between the six influencing parameters for boti monkey habitat suitability.

Table 8. PCA Habitat Characteristic Vector

Parameter	Main component		
	1	**2**	**3**
River	5,752	5,752	5,756
Settlement	6,499	6,499	6,504
Road	6,499	6,499	6,504
NDVI	6,504	6,504	6,509
Height	5,440	5,440	5,444
Slope	4,899	4,899	4,902

The weights of each variable to obtain the habitat suitability model for orangutans are obtained from the PCA feature vector values of each variable with the highest positive values towards the principal component produced. The results above indicate that variables such as river, road, settlement, NDVI, elevation, and slope have a high positive relationship with the third principal component. Thus, the magnitude of the weights of each variable is presented in the table below.

Hasil dari Tabel 8 menunjukkan bahwa setiap variabel dikategorikan dalam komponen utama. Sehingga Keenam parameter tersebut termasuk ke dalam kelompok komponen tiga, sehingga pembobotannya disesuaikan. Nilai koefisien untuk sungai, pemukiman, jalan, NDVI, ketinggian, dan kemiringan lereng masing-masing adalah 5,756, 6,504, 6,504, 6,509, 5,444, dan 4,902.

Information regarding the scores used in the habitat suitability analysis, where each parameter is given a score ranging from 1 to 5 to determine habitat suitability, has a different range of scores. Where Score 1 represents the worst condition for Macaca tonkeana, Score 2 represents poor condition, Score 3 represents fair condition, Score 4 represents good condition, and Score 5 represents the best condition for Macaca tonkeana. Settlement parameters have scores that vary from 1 to 5, with higher scores indicating better habitat conditions. In contrast, scores for parameters such as roads, rivers, slopes, elevation and NDVI also range from 1 to 5, but the variability depends on the specific category or range of values. Determining these values is critical to understanding the level of habitat suitability and provides the basis for appropriate conservation measures.

From the calculations carried out using XLSTAT for each variable, an equation can be formulated for the boti monkey habitat suitability model as follows:

Y = 6,504jln + 6,504pkm + 5,756sng + 6,509ndvi + 5,444elev + 4,902slope

This equation highlights that vegetation cover (NDVI), roads (jln), and settlements (pkm) have the highest coefficients (weights) compared to other variables. The variables river (sng) and height (elev) are next in order, followed by the slope (slope), which has the most negligible weight. Thus, the weight results of each parameter are used to determine the habitat suitability value from the overlay process.

3.3 Habitat Suitability for Boti Monkeys

The constructed fit equation yields maximum and minimum values, ranging from 57.18 to 160.66. These values are divided into three classes based on their differences: the smallest range indicates low suitability, the middle range indicates medium suitability, and the largest range indicates high suitability.

$$Interval = \frac{160.66 - 57.18}{3} = 14.16$$

The suitability of boti monkey habitat in the study site is classified into three levels, namely low, medium, and high suitability, which are described in Table 10. In addition, a map of boti monkey habitat suitability is also presented in Figure 2. The high suitability level reached 81.72%. Locations with high suitability are mostly in the Pangi Binangga nature reserve area, while locations with low suitability tend to be in settlements. The area of West Toboli Village, which is mostly highland and hilly, is mostly inhabited by people who work as farmers. Areas with high suitability generally have good land cover and there are many fruit trees that are a source of food for boti monkeys.

According to [16], monkeys in Sulawesi tend to choose large trees with many branches, allowing all members to rest. They also prefer the edges of tree canopies because there are usually parts of the plants they consume, such as fruit, flowers, and young leaf shoots. The characteristics of trees used as resting places by monkeys are large trees with many branches and dense leaves.

Table 9. Habitat Suitability Index Value Habitat Area for Boti Monkeys

Interval	Area (ha)	Percentage	Conformity Classification
5,444 - 57,18267	9,475621	0,374	Low
57,18267 - 108,9213	461,777729	18,184	Medium
108,9213 - 160,66	2065,896076	81,442	High
Total	2537,149426	100	

The medium suitability level, covering 18.184% (461.777729 ha) in light green on Figure 2, lies predominantly amidst settlements and agricultural plots. The region's contoured topography, with hills, valleys, and diverse elevations, contributes to its medium suitability status. Low suitability, comprising 0.374% (9.475621 ha), marked in red on Figure 10, is situated within residential zones and areas approximately 300 meters above sea level.

The existence of conservation areas must be maintained due to their strategic role as life support systems, biodiversity protection, and sustainable utilization of natural resources. In maintaining the existence of potential conservation areas, one of the applied management concepts is to exclude all community activities from the conservation areas [16]. From the habitat suitability data, it can be used to conserve the Macaca Tonkeana species to enhance their existence and protection. Several factors influencing habitat suitability include roads, rivers, settlements, NDVI, elevation, and slope.

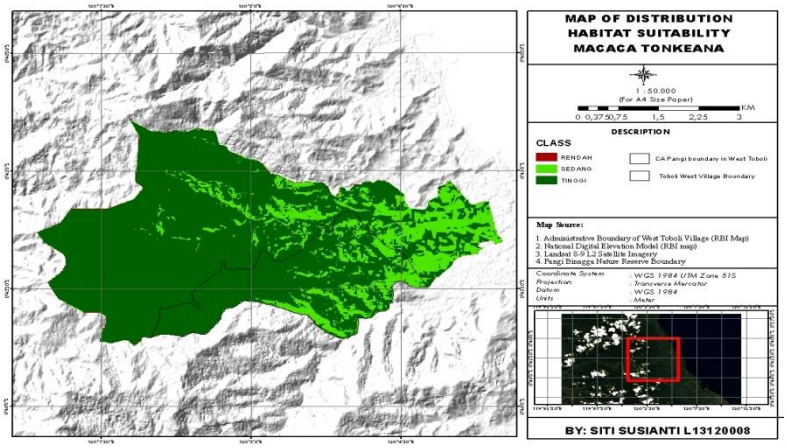

Figure 2. Boti Monkey Habitat Suitability Map

3.4 Validasi

Validation is conducted to test the accuracy of the prepared model using specially prepared validation data [14]. At this stage, fifty-four observation points (30% of the total observation data) were used. From the results of this combination, the following data is obtained in Table 10:

Table 10. Habitat suitability model validation results

Conformity Class	Number of Points	Percentage
Low	0	0
Medium	4	7,41
High	50	92.59
Total	54	100

Table 10 displays validation outcomes of the boti monkey habitat model, categorized into low, medium, and high suitability. None fell in the low class, while 4 (4%) were medium, and 50 (92.59%) were high. This suggests the research area is highly suitable for boti monkeys, affirming the model's accuracy.

4. Conclusion

The study concluded that various factors such as distance from rivers, settlements, roads, NDVI (Normalised Difference Vegetation Index), altitude, and slope affect the habitat suitability of Boti Monkeys. PCA analysis assigned weights to each parameter. The study sites were classified into low, medium, and high suitability levels, with low suitability mainly in residential areas, covering 9.475621 ha. Medium suitability was generally found among settlements, covering 461.777729 ha, while high suitability was dominated by the Pangi Binangga nature reserve, covering 2065.896076 ha. Model validation showed that the study site is a suitable habitat for Macaca tonkeana.

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