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SPATIAL MODELING OF BLACK CRESTED MACAQUE (*Macaca nigra* Desmarest, 1822) HABITAT SUITABILITY

(*Model Spasial Kesesuaian Habitat dari Macaca Nigra*)

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ABSTRACT

The remaining habitat of Black Crested Macaques in Sulawesi is limited only in conservation areas, and therefore it is an urgent need to map its habitat suitability model. This work can be achieved by application of Geographic Information System (GIS). Data observation was conducted in Tangkoko Nature Reserve and Batuputih Nature Recreation Park from July to September 2009. The model was then extrapolated to Tangkoko Nature Reserve, Duasudara Nature Reserve, Batuputih Natural Recreation Park, and Batu Angus Nature Recreation Park. Modelling of Black Crested Macaque's habitat was conducted by spatial identification of their encounter points toward habitat and disturbance factors. Habitat suitability model of Black Crested Macaque was $Y = (2.399 \times FC_{road}) + (2.399 \times FC_{river}) + (2.399 \times FC_{NDVI}) + (2.399 \times FC_{elevation}) + (1.142 \times FC_{building}) + (0.957 \times FC_{slope})$. Cumulative score was divided into three classes namely high suitability habitat, medium suitability habitat, and low suitability habitat. Tangkoko Nature Reserve has highest rate of high suitability habitat whereas Duasudara Nature Reserve has lowest rate of high suitability habitat. Tangkoko Nature Reserve forms the best suitable habitat for Black Crested Macaque whereas both Duasudara Nature Reserve and Batu Angus Nature Recreation Park are the least suitable habitat for species.

Keywords: model, habitat, Black Crested Macaque.

ABSTRAK

INTRODUCTION

Black Crested Macaque (*Macaca nigra* Desmarest, 1822) is one of eight endemic Celebes macaques with a small geographic distribution (Nowak 1999). Black Crested Macaque is listed in the IUCN 2008 Red List as Critically Endangered (Supriatna and Andayani 2008). This status was given because of their decreasing population due to large-scale forest degradation for agriculture and settlement (Supriatna and Andayani 2008). They can be found naturally only in the northern peninsula of Sulawesi and introduced in Bacan Island, Moluccas as an introduced species (Rosenbaum *et al.* 1998). Their remaining habitats are limited to conservation areas such as Tangkoko Nature Reserve, Duasudara Nature Reserve, Batuputih Nature Recreation Park, and Batu Angus Nature Recreation Park in Bitung District, North Sulawesi.

Research on Black Crested Macaques in these conservation areas have been conducted intensively since 1980. Both local and foreign researchers are interested in Black Crested Macaques' ecology and behavior research such as behavior, diet and movements of the Sulawesi Crested Black Macaque (Kinnaird and O'Brien 1997); population densities of Sulawesi Crested Black Macaques (*Macaca nigra*) on Bacan Island and Sulawesi, Indonesia: Effect of habitat disturbance and hunting (Rosenbaum *et al.* 1998); and domination characteristic of Black Crested Macaque (Saroyo 2005). Beside ecology and behavior research, Black Crested Macaque habitat research using geographic information system (GIS) and remote sensing (RS) need to be developed to manage its habitat conditions in these areas.

The questions that would to answer in this research were how far GIS could help us to build habitat model of

black crested macaques and the importance of that model for habitat management. This spatial model would be transformed into a suitability habitat map to provide information on the highest suitability habitat for Black Crested Macaque. In this study, habitat spatial modeling of Black Crested Macaque was built based on life requirements and disturbance factors in the four conservation areas.

MATERIAL AND METHOD

1. Data Collection

Data preparation was conducted by collecting Landsat satellite image, vector data, and Black Crested Macaque ecology information. Data observation to build model was conducted in Tangkoko Nature Reserve and Batuputih Nature Recreation Park from July to September 2009. That area is located geographically on the northern part of Celebes peninsula at 125°3' - 125°15'E and 1°30' - 1°34'N (Fig 1). Habitat spatial model requires points of Black Crested Macaques encounters recorded using global positioning system (GPS).

Direct encounter following transect was the method employed to determine macaque encounter points. Daily range observation of four identified groups was done to collect sleeping tree point, feeding tree point, and their habits in each habitat type.

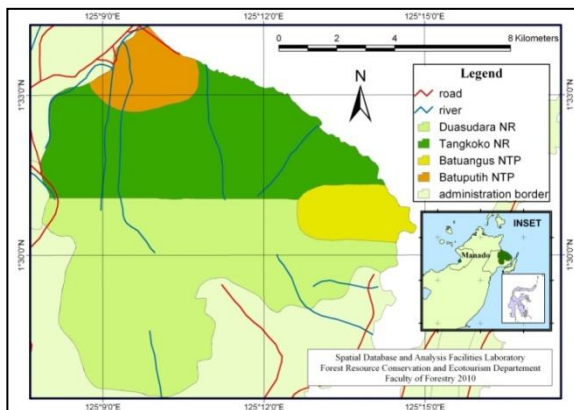


Figure 1. Study area: Tangkoko NR, Duasudara NR, Batuangus NTP and Batuputih NTP, North Sulawesi

2. Data Processing

a. Creating Thematic Layer

Habitat suitability model of Black Crested Macaques was extrapolated to Tangkoko Nature Reserve, DuaSaudara Nature Reserve, BatuPutih Nature Recreation Park, and Batu Angus Nature Recreation Park. Black Crested Macaque habitat modeling was conducted through spatial identification of Black Crested Macaque encounter points for living requirements and

disturbance factors. Living requirements of Black Crested Macaques for this model were cover, water, and accessibility. Cover was represented by NDVI (Normalization Difference Vegetation Index), water was represented by distance from river, and accessibility was represented by elevation and slope. Distance from road, and distance from building represent disturbance factors.

NDVI was used to measure quantity of vegetation important for Black Crested Macaque diet which consists of 66% fruits of all feeding bouts and consumes more than 145 species (Kinnaird and O'Brien 1997). NDVI was obtained based on the ratio of near infra red wave and red wave reflection from electromagnetic spectrum. Both spectrums have better ability to absorb chlorophyll and vegetation density. In Landsat image, near infra red and red wave were found in band 4 and band 3. Higher NDVI values represent higher photosynthesis activities and higher vegetation density (Lillesand and Kiefer 1979). Elevation and slope maps were made using TIN (Triangulated Irregular Network). Distance from river and distance from road maps were made using Indonesian base map.

b. Weighting Using PCA

Habitat suitability model formula was determined through variable values using PCA (Principal Component Analysis). Weight factor explain proportion of each variable used to build the habitat model. The purpose of PCA is to simplify observed variables using dimension reduction method. This method removes correlations between variables and then transforms them into new uncorrelated variables called principal component. The numbers of principal components that can be used are sufficient if total variance explained ranges from 70% to 80%.

The formula used to build the model in spatial analysis is the following:

$$Y = aF_1 + bF_2 + cF_3 + dF_4 + eF_5 + fF_6$$

Y = Black Crested Macaque habitat model; a-e = variable weight value; F₁ = Elevation factor; F₂ = Slope factor; F₃ = NDVI factor; F₄ = River distance factor; F₅ = Road distance factor; F₆ = Building distance factor.

c. Spatial Analysis

Spatial analysis was conducted by classification, scoring, and overlaying all layers. Distance layers (river, road and building) were classified based on average radius of Black Crested Macaque's home range that was considered circles. Black Crested Macaque home range according to Rowe (1996) covers 114-320 hectares and according to O'Brien and Kinnaird's research in Tangkoko Nature Reserve of three groups are 218 hectares for Malonda group, 406 hectares for Rambo group, and 156 hectares for Dua group (O'Brien and Kinnaird 1997). Each suitable class for distance layers was 850 meters.

Classification of slope layer was given based on government regulations, including Decision Letter of Minister of Agriculture No. 837/Kpts/II/1980 concerning Criteria and Procedure of Establishment of Protected Forest and Decision Letter of Minister of Agriculture No. 683/Kpts/Um/II/1981 concerning Production Forest Determination Procedure (Dewi 2005).

Suitability class is divided to three categories: 1 (low); 2 (medium); and 3 (high). Interval for each class was given based on pixel value (Table 1). The scheme of this research is presented in the flow chart (Fig 2).

Table 1. Suitability Class Intervals

No.	Suitability Class	Interval
1	1	Minimum pixel – (mean - standard deviation)
2	2	(mean - standard deviation) – (mean + (standard deviation / 2))
3	3	(mean + (standard deviation / 2)) – Maximum pixel

RESULTS

1. Black Crested Macaque Habitat Model

Habitat model of Black Crested Macaque was created using 50 Black Crested Macaques encounter points. The encounter points were analyzed against six variables representing life requirements and disturbance

factors using ArcGIS software, and statistically analyzed using PCA.

Three principal components were used to build the model with cumulative total variance explained was 74.97%. Weighting for habitat model used total eigen values of three principal components (Table 2).

In the PCA component matrix, there are four variables with positive correlation and higher value in first component, which are road distance, river distance, elevation, and NDVI (Table 3). Building distance has positive correlation and higher value in second component whereas slope has positive and higher correlation with third component. Habitat model of Black Crested Macaques is

$$Y = (2.399 \times Fc_{road}) + (2.399 \times Fc_{river}) + (2.399 \times Fc_{NDVI}) + (2.399 \times Fc_{elevation}) + (1.142 \times Fc_{building}) + (0.957 \times Fc_{slope}).$$

2. Suitability Habitat Map

The formula of habitat model was used in the overlay of six thematic maps/layers using ArcGIS software. Prior, each thematic layer was classified into several classes based on ecological study.

Scoring was given to all classes in every layer based on importance level toward life requirements of Black Crested Macaque. Higher score was given for classes that were considered more suitable for Black Crested Macaque (Table 4). The result of overlay process is suitability habitat of Black Crested Macaque map (Fig 3 and Fig 4).

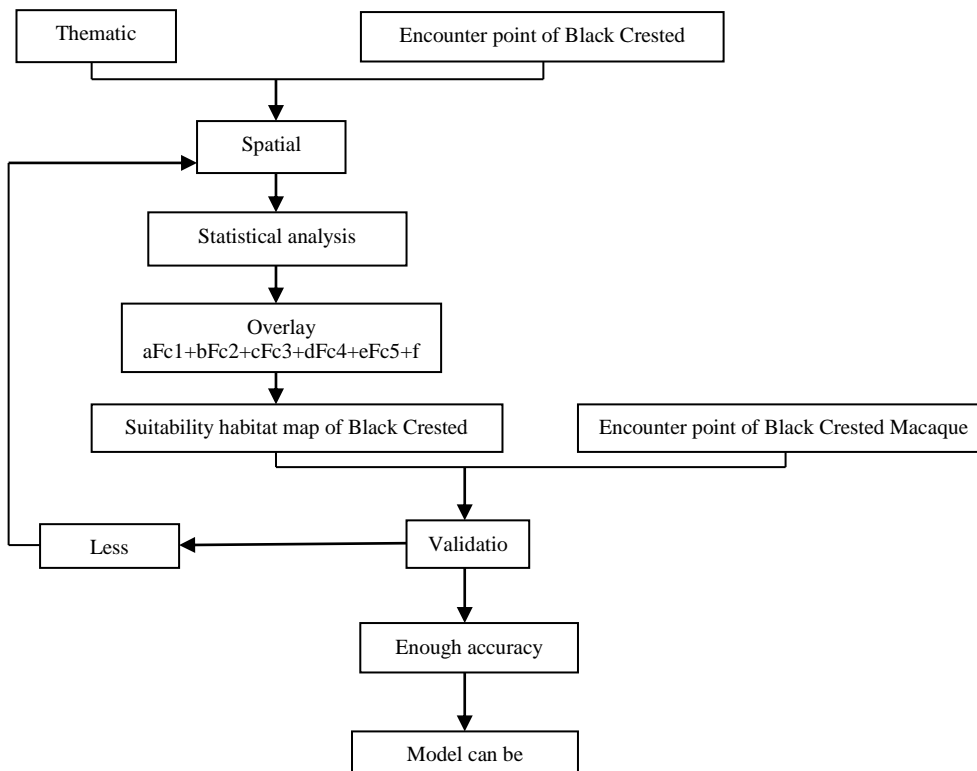


Figure 2. Flow diagram of the research

Table 2. Initial Eigenvalues of Six Principal Components

Principal component	Initial Eigenvalues		
	Total	% of Variance	Cumulative (%)
1	2.399	39.982	39.982
2	1.142	19.032	59.014
3	0.957	15.957	74.970
4	0.824	13.728	88.698
5	0.427	7.109	95.808
6	0.252	4.192	100.000

Table 3. Component Matrix

No.	Variable	Component		
		1	2	3
1	Road distance	0.897	0.112	-0.076
2	River distance	0.476	-0.638	0.349
3	Elevation	0.772	-0.353	0.094
4	Slope	0.375	0.450	0.651
5	NDVI	0.600	-0.031	-0.626
6	Building distance	0.520	0.627	-0.076

Table 4. Classes of Variables Scores

Elevation		Slope		NDVI		River distance		Road distance		Building distance	
Class	Score	Class	Score	Class	Score	Class	Score	Class	Score	Class	score
0-400	3	0-8	5	0-0.1	1	0-850	5	0-850	1	0-850	1
400-800	2	8-15	4	0.1-0.2	2	850-1700	4	850-1700	2	850-1700	2
>800	1	15-25	3	0.2-0.3	3	1700-2550	3	>1700	3	>1700	3
		25-40	2	0.3-0.4	4	2550-3400	2				
		>40	1	>0.4	5	>3400	1				

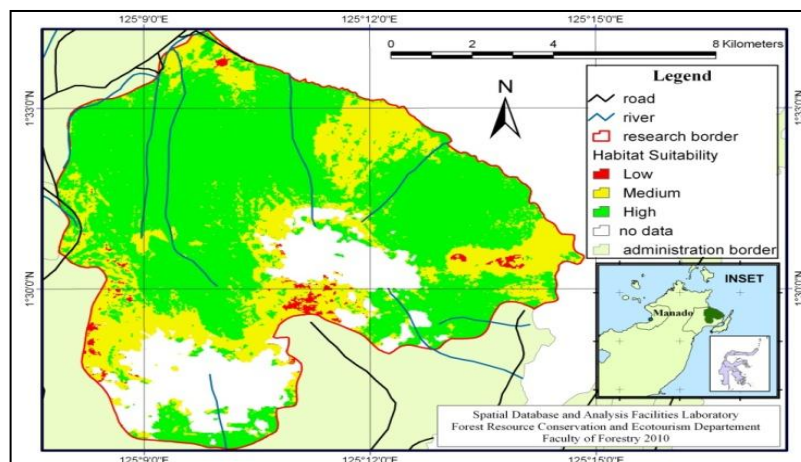


Figure 3. Suitability Habitat of Black Crested Macaque Map

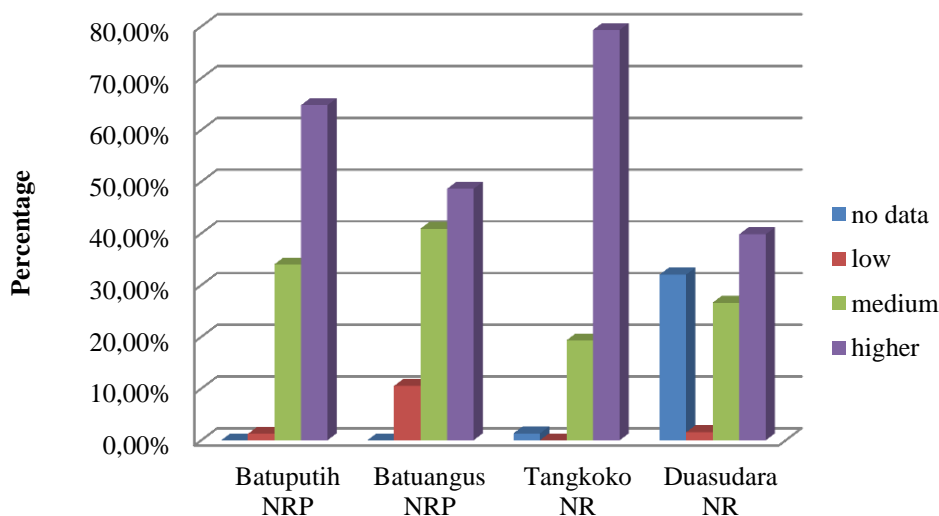


Figure 4. Suitability Habitat Percentage on Each Conservation Area

Black Crested Macaque habitat in the study site is dominated by highly suitable habitat covering 5,160.96 hectares or 52.64% from the total area that are fragmented with medium suitability class and low suitable habitat (Table 5). A total of 1595.43 hectares of the study area which could not be included to any suitability class due to lack of data to built model in these areas.

Validation was used to clarify the confidence levels of the model. Total amount of encounter points used for validation were 30 encounter points of Black Crested Macaques. The model can be accepted because of its accuracy in predicting highly suitable habitat for Black Crested Macaque by as much as 76.67% (Table 6).

Table 5. Areas of Habitat Suitability Class

Suitability class	Range	Area (hectares)	Percentage (%)
Low	18.78 – 28.17	204.39	2.08
Medium	28.17 – 36.29	2,843.10	29.00
High	36.29 – 46.60	5,160.96	52.64
No data	-	1,595.43	16.27

Table 6. Validation of Habitat Suitability Class

Suitability Class	Encounter Points	Percentage (%)
Low	0	0.00
Medium	6	20.00
High	23	76.67
No data	1	3.33
Total	30	100.00

DISCUSSION

From the suitability habitat map can be seen that Tangkoko Nature Reserve has highest rate of high suitability habitat (79.34%) whereas Duasudara Nature Reserve has lowest rate of high suitability habitat (39.83%). Batu Angus Nature Recreation Park has highest rate of medium and low suitability habitat with 40.91% and 10.48% (Fig. 4). Based on the above suitability habitat classes, it can be concluded that Tangkoko Nature Reserve forms the best suitable habitat for Black Crested Macaque whereas both Duasudara Nature Reserve and Batu Angus Nature Recreation Park are the least suitable habitats for Black Crested Macaque.

Tangkoko Nature Reserve contains a larger area of high suitability class for Black Crested Macaque but also receives high pressures from human activity. Tangkoko Nature Reserve and Batuputih Nature Recreation Park is the home range of two groups of Black Crested Macaques with large populations. According to Saroyo (2005) each group (Rambo 1 and Rambo 2) comprise 51 individuals and Newman *et al.* (2010) stated that Rambo 1 population was 75 individuals and Rambo 2 consists of 65 individuals. Population data collected during this particular research determine that the population of Rambo 1 was 72 individuals and Rambo 2 was 64 individuals. The problem are that area has medium suitability habitat that located at the border with settlement and farmland and tourism activity has cause the macaque already habituate with human. Both situations cause a problem between villagers and Black Crested Macaques. Based on suitability habitat map, area manager, in this case are BKSDA North Sulawesi, can increase protection in all high suitable habitat and at the border Batu Putih Nature Recreation Park to mitigate Black Crested Macaque and human conflicts.

Model of Black Crested Macaques habitat, $Y = (2.399 \times F_{\text{road}}) + (2.399 \times F_{\text{river}}) + (2.399 \times F_{\text{NDVI}}) + (2.399 \times F_{\text{elevation}}) + (1.142 \times F_{\text{building}}) + (0.957 \times F_{\text{slope}})$, that was produced in this research already has good validation so that the model can be applied in other area. Modification in applying this model can be done on classification and scoring process based on habitat characteristic in that area. To improve validation of the model and map, further observation of Black Crested Macaque in Duasudara and Batu Angus is required. Follow-up study is necessary to create a model which includes LAI (Leaf Area Index) to comprehend vegetation cover effect toward Black Crested Macaque's habitat.

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