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HABITAT DISTRIBUTION MODELS OF FLORES HAWK-EAGLE (Nisaetus floris) IN EAST NUSA TENGGARA

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ABSTRACT

Flores hawk-eagle (Nisaetus floris) was a Critically Endangered endemic raptor species in Lesser Sunda Region, especially in East Nusa Tenggara. The lack of information and difficulties in reaching the Flores hawk-eagle's distribution area have caused difficulties in conservation efforts for this species. One of the efforts that could be made was by spatial modeling distribution of Flores hawk-eagle habitat in East Nusa Tenggara based on GIS. Using habitat distribution spatial modeling could predict the potential place where a species can live. Logistic regression was one of the methods applied in animal distribution spatial modeling, where this method was considered to have better accuracy. Through the analysis, it was found that the potential habitat for Flores hawk-eagle was 6390.48 km^2 (22%), and the non-potential habitat was 22,459.59 km ^{2} (78%). The habitat factors that determine the distribution of the Flores hawk-eagle include slope, altitude, rice fields, plantation, forests, and shrubs. The availability of nesting trees and food for Flores Hawk-eagles may influence the distribution of existing habitats. The results of the distribution mapping of the Flores Hawk-eagle can be used as a reference in efforts to manage the habitat of the Flores hawk-eagle in East Nusa Tenggara.

Key words: *Endemic Raptor, Habitat Modelling, Logistic Regression, Nisaetus floris, Species Priority*

INTRODUCTION

Flores Hawk-eagle *(Nisaetus floris)* was a raptor species endemic to the Lesser Sunda Islands. Initially, this species was one of the subspecies of the Changeable Hawk-eagle *(Spizaetus cirrhatus),* which was then separated into its own based on morphological differences from existing specimens (Gjershaugh et al. 2004). This species was commonly found on large islands such as Flores, Sumbawa, and Lombok, as well as some small surrounding islands. Recent records state that there was an encounter with this species on Alor Island which could be one of the considerations of this species of conservation strategy (Collaerts et al. 2013). Flores Hawk-eagles can be found in lowland forests up to 1600 m (Birdlife International 2020). The existence of this species plays an important role as one of the apex predators, especially in the Lesser Sunda Islands.

The separation of this species from the Changeable Hawk-eagle puts its conservation status to Critically Endangered, with an estimated population of approximately 100-200 individuals in the wild (IUCN Redlist 2018). However, the number of viable populations in the wild has yet to be ascertained. It tends to decrease due to the many threats to the sustainability of Flores Hawk-eagles, including reduced habitat due to human activities in hunting. The continuing threat prompted the government, especially the Indonesian Ministry of Environment and Forestry, to draw up the conservation strategy and action plan for Flores Hawk-eagle 2019-2029 (KLHK 2019). One of the visions and goals of this document was to improve the research and monitoring of the Flores Hawk-eagle, where this activity still needed to be carried out more. Information relating to the population and distribution of Flores Hawk-eagles would be an important basis for this species' preservation and conservation activities.

Lesser Sunda Island, or Nusa Tenggara Islands, was one of the ecoregions with unique characteristics because it had a combination of characteristics between the Asiatic and Australian regions. The characteristics of habitats dominated by deciduous forests and savanna created various species of endemic wildlife and plants that cannot be found elsewhere (WWF 2020). Flores Hawk-eagle was one of the endemic species that adapted in this region, but their distribution information had yet to be fully mapped properly.

Efforts to estimate the distribution and population of this species have been conducted, one of them related to distribution mapping efforts in East Nusa Tenggara. Syartinilia and Setiawan (2021) studied the distribution of Flores Hawk-eagles and found that potential habitats were in forests and savannas with slope contours as nesting sites and open land as their hunting area, and one of its actual habitats was Kelimutu National Park. In the Lesser Sunda Islands area, difficulties reaching the Flores Hawk- eagle distribution area became one of the obstacles in preparing the Flores Hawk-eagle habitat management model. Species distribution modeling could be applied as one of the approaches that could be done to suspect potential habitats for the existence of Flores Hawk-eagles.

Modeling the distribution of wildlife species was one of the techniques that could be done to determine the suitability of the habitat of a species so that it could estimate the potential area where the animal was distributed. Among others, several methods could be applied by using Maxent and Logistic Regression. The Maxent method uses *presence* data from the findings of a species which was then used to predict the distribution of a particular species (Phillips et al. 2006; Merow et al. 2013). In contrast to Maxent, the logistic regression model was once applied to estimate the distribution of Javan Hawk-eagles using presence and absence data from existing nest findings. The application of the logistic regression model was thought to have better accuracy for estimating the distribution of animals (Syartinilia and Tsuyuki 2008). This research purposed to create a habitat distribution model of Flores Hawk-Eagle in East Nusa Tenggara Islands. The designed model could be used to predict the distribution and restoration of the population for the Flores Hawk-eagle in East Nusa Tenggara Islands.

RESEARCH METHOD

The study was conducted in March-April 2021. The research site was located in East Nusa Tenggara, covering an area of 37,848.43 km^2. Research model areas included Flores, Alor, Lembata, and small islands in the region (Figure 1).

Flores Hawk-eagle points were collected from research data that had been done from Raptor Indonesia (RAIN) and Raptor Conservation Society (RCS). A ground truth check was conducted to confirm the availability of nests and individuals in the Ende Regency. Tools needed to conduct the survey were GPS, camera, binocular, and smartphone. Officers from Kelimutu National Park, members of the Jatabara Flores Hawk-eagle community, and people from Wolojita and Ndito Villages were involved in helping the Flores Hawk-eagle nest and vegetation surveys.

Flores Hawk-eagle distribution data were analyzed using logistic regression (Syartinilia and Tsuyuki 2008). Distribution data in modeling uses 184 presence and pseudo-absence points from the Flores Hawk-eagle nest findings. Presence data uses the meeting point of the Flores Hawk-eagle nest via direct findings through surveys and nest encounter points obtained by the Kelimutu National Park and other institutions. Pseudo-absence data was obtained randomly by sampling on a grid spread across the East Nusa Tenggara area (Flores, Alor, and surrounding small islands) using the Hawth Tools *plug-in* on *ArcGIS* software. 70% of points (124 points) were used to build the model, while the rest (60 points) were used for model validation.

Several parameters could be used as variables in preparing habitat suitability models. These parameters include height, slope, and land cover. These parameters were used as appropriate environmental variables to see suitable habitats for Flores Hawk- eagles, assuming this species has the same habitat selection tendency as the Javan Hawk-eagle (Syartinilia and Tsuyuki 2008).

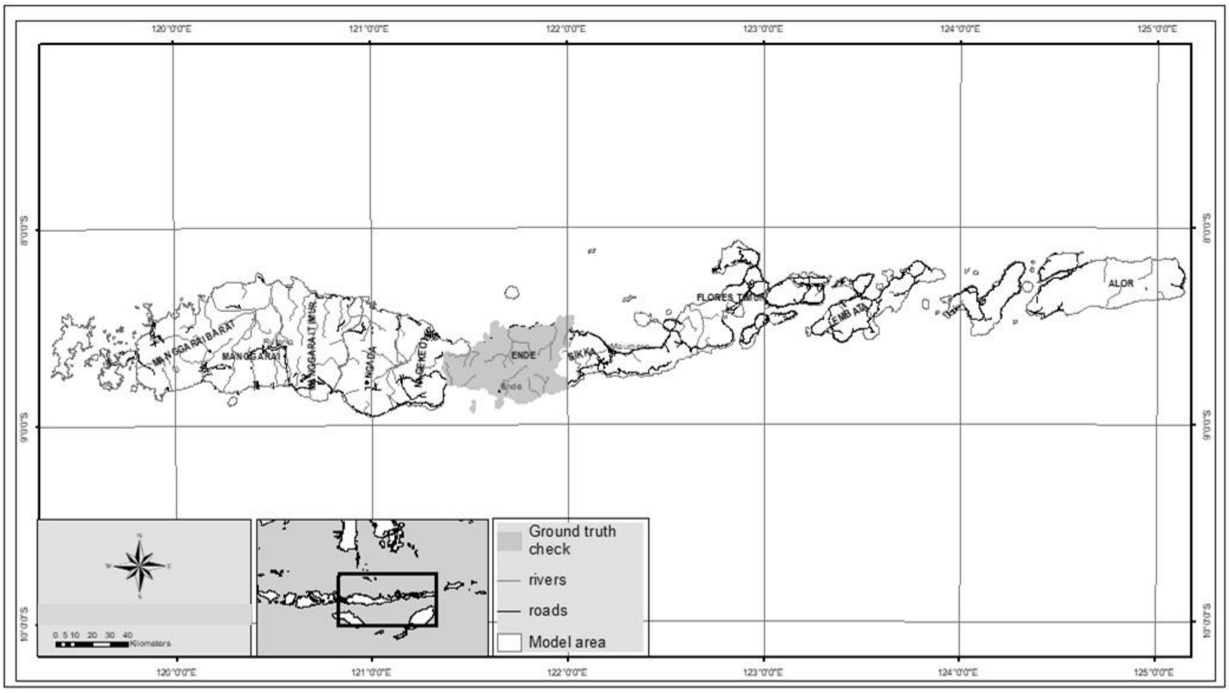

Figure 1 Research area of Flores Hawk-eagle distribution mapping at Nusa Tenggara Timur

Environmental variables were created using *euclidean distance,* intended to provide information about each cell in the raster to the nearest distance to specific variables. The environmental parameters used were then classified into several maps of the nearest distance. Elevation maps were classified into seven variables. Slope maps were classified into six variables, and land cover maps were classified into nine (Table 1). The environmental variable map was then converted into a binary map with *reclassify* and *recode* processes. The raster-shaped binary map obtained was then converted into a vector form.

Environment variables firstly will be tested to see if there're any multicollinearities between variables using SPSS 25. Multicollinearity would be detected if it had VIF Value > 10, and those variables should be eliminated. The selected variables would be used to build a habitat distribution model using raster calculator in ArcGIS 9. The logistic regression equation was used as follows:

$$Pi = \frac{1}{1+\exp[-(1{,}399|TE7 + 12{,}675|TE6 - 1{,}399|TE7 - 43{,}425|TK4 - 269{,}359|TK1 - 349{,}504|TK2 - 22{,}330\ |TPt - 35{,}492|TSM - 12{,}221|TSw - 937{,}005|TH + 10{,}093)]}$$

Where *Pi* = probability of Flores Hawk-eagle's encounter; *xji* = variables (covariate); β0 was constant and βj was coefficient of variables; and k was numbers of the covariate.

The value of potential habitat for Flores Hawk-eagle was categorized into two categories. The potential habitat was categorized if it has a probability value of 0,5<*Pi*<1, while the value of 0<*Pi*<0,5 was categorized as non-potential habitat.

The model was then evaluated using *goodness-of-fit* to look at the model's similarity to factual conditions. The test used was Hosmer-Lemeshow (H-L) with a significance level of > 0.05 (Peng et al. 2002). Nagelkerke R2 then determined the coefficient of determination to show the precision of the models to predicted the actual condition.

The model would be validated with 30% of points (60 points). Validation of models would be needed to find 2 (two) errors in the model. First, omission error when a model error in predicting the location of Flores Hawk-eagle's presence. In contrast, commission error was a model error in predicting the presence of Flores Hawk-eagles in inappropriate areas. Finally, Kappa Accuracy was needed to confirm the accuracy of the model of the Flores Hawk-eagle distribution map.

Table 1 Environment variables of Flores Hawk Eagle distribution mapping.

No.	**Environment Variables**	**Abbreviation**	**Source**
1	Elevation 0-300 m	ELV1	Extraction from ASTER DEM made into *Euclidean Distance* map
2	Elevation 300-500 m	ELV2	
3	Elevation 500-700 m	ELV3	
4	Elevation 700-1000 m	ELV4	
5	Elevation 1000-1500 m	ELV5	
6	Elevation 1500-2000 m	ELV6	
7	Elevation >2000 m	ELV7	
8	Slope 0-3%	SLP1	Extraction from ASTER DEM made into *Euclidean Distance* map
9	Slope 3-8%	SLP2	
10	Slope 8-15%	SLP3	
11	Slope 15-25%	SLP4	
12	Slope 25-45%	SLP5	
13	Slope >45%	SLP6	
14	Waterbody	WTR	Extraction from land cover map made into *Euclidean distance*map
15	Forest	FRT	
16	Plantation	PLT	
17	Paddy Fields	PDF	
18	Open Land	OPL	
19	Built-up Area	BLA	
20	Shrub	SHB	
21	Savanna	SVN	
22	Road	ROD	

RESULT AND DISCUSSION

The suitable habitat for the distribution of Flores Hawk-eagle of 6,390.48 km^2 (22%), which includes West Manggarai, Manggarai, East Manggarai, Ngada, Nagakeo, Sikka, Ende, East Flores, and Alor (Figure 2). Based on calculations, the omission error value of 0.2262 (22.62%) and the commission error of 0.2307 (23.07%) were obtained. Overall model accuracy was rated through Kappa Accuracy of 0.877 (87.7%). Nagelkerke R^2 value of 0.804 indicates that the model variable can explain 80.4% of the overall actual variable condition of Flores Hawk-eagle habitat. Hosmer and Lemeshow's test scores of 0.197 (>0.05) indicate that the model was usable. The variables used to build the model can be shown in Table 2.

The Regression Logistics Equation used in the model was as follows:

$Pi = 1 + \exp\ [-(1{,}399ELV7 + 12{,}675ELV6 - 1{,}399ELV7 - 43{,}425SLP4 - 269{,}359SLP1 - 349{,}504SLP2 - 22{,}330\ PLT - 35{,}492SHB - 12{,}221PDF - 937{,}005FRT + 10{,}093)]$

Through logistic regression tests, of the 33 parameters used, there were 11 significant parameters to be used in habitat distribution models. Based on the model showed that the altitude (ELV5, ELV6, ELV7), slope (SLP1, SLP2, SLP4), paddy fields (PDF), shrubs (SHB), plantation (PLT), roads (ROD) and forests (FRT) affect the distribution of Flores Hawk-eagles in East Nusa Tenggara. The selected parameters were altitude 1000-1500 m (ELV5), 1500-2000 m (ELV 6), >2000 m (ELV7), slope 0- 3^0 (SLP1), 3-8^0 (SLP2), and slope 25-45^0 (SLP5), forest (FRT), shrub (SHB), road (ROD), paddy fields (PDF), and plantation (PLT).

Table 2. Logistic regression test results variable.

Variables in the Equation			
		B	Sig.
Step 9[a]	ELV5	-43.425	.051
	ELV7	1.399	.098
	ELV6	12.675	.136
	SLP5	-35.883	.068
	SLP2	-349.504	.079
	SLP1	-269.359	.033
	PLT	-22.330	.101
	PDF	-12.221	.014
	ROD	-27.860	.015
	SHB	-35.492	.011
	FRT	-937.005	.053
	Constant	10.093	.001

a. Variable(s) entered on step 1: ELV5,ELV7, ELV6, ELV4, SLP6, SLP5, SLP4, SLP3, SLP2, SLP1, BLA, JTPb, WTR, PDF, ROD, OPL, JTS, SHB, JTH.

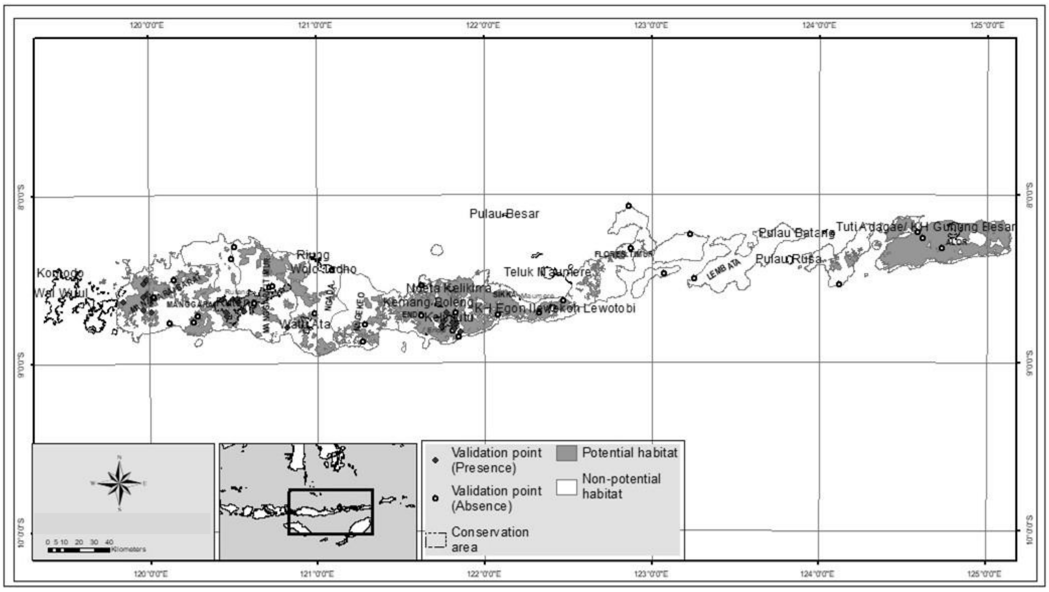

Figure 2. Flores Hawk-eagle Habitat Distribution Model at Nusa Tenggara Timur.

The largest potential habitat includes Ende, Sikka, and Ngada Districts, with most of the area being in Ende Regency. That makes it possible to confirm the existence of Kelimutu National Park as one of the actual habitats of the Flores Hawk-eagle. Another potential habitat found in Alor Island that allows this region was probably still potentially a habitat of Flores Hawk-eagle. In accordance with Collaerts et al. (2013), where the Alor region found several individual eagles with an estimated 20-30 pairs of individuals on this island.

Based on the model, the potential habitat for Flores Hawk-eagles was at an altitude of 1000-2000 m above sea level. Referring to the findings of Raharjaningtrah and Rahman (2004), Flores Hawk-eagles could occupy high altitudes, especially in the Ruteng and Kelimutu regions. Competition with two other lowland eagles, the Rufous- bellied and Bonelli’s Eagle, allowed this species to occupy the plateau as its nesting habitat. Other findings indicated Flores Hawk-eagles were more common in sub-montana forest areas (>900 mapl) than lowland forests. At some points of observation, it could still be found as this species flies over residential areas or lowland forests, but the relationship between encounters with altitude was insignificant (Suparman 2012). The availability of large trees at high altitudes also allowed this species to be more commonly found in the region. The selection of an appropriate habitat by birds was based on the suitability of the needs of the bird species (Widiana et al. 2017).

In addition to altitude, slope affected the nesting habitat preferences of Flores Hawk-eagles (Syartinilia and Tsuyuki 2008). The slope factor was related to the safety and accessibility of Flores Hawk-eagles in finding food. Flores Hawk-eagles can be found in areas with slopes of 0-8% and 25-45%. This model updated findings in previous studies in which Flores Hawk-eagles prefer slope character by 45% (Syartinilia and Setiawan 2021). Based on the modeling of the distribution of Flores Hawk-eagles that had been done, the slope of 25-45% was likely to be used as a nesting habitat for Flores Hawk-eagles, while Flores Hawk-eagles utilized areas with a slope of 0-8% as hunting areas. Both differences in preferences were influenced by the condition of the vegetation that inhabits the area. The selection of a region based on vegetation was very important for eagles because the character of vegetation will determine the availability of nesting trees and the availability of food for eagles and their fledglings (Gunawan et al. 2017). The selection of slope preferences on Flores Hawk-eagles could be expected not much different from the Changeable Hawk-eagle, where the selection of nesting sites was based on the ease for Flores Hawk-eagles to monitor prey and access in and out of the nest they built (Withaningsih et al. 2015).

After overlaying the land cover of East Nusa Tenggara with the Flores Hawk- eagle habitat distribution model, it was found that secondary forests dominate the Flores Hawk-eagle habitat patch (70%) followed by primary forest (10%) and shrubs (8%). The existence of secondary forests was important for the survival of Flores Hawk-eagles (Rohman et al. 2019). This statement was in accordance with previous research, where Flores Hawk-eagles rely heavily on forest areas as their habitat (Gjershaugh et al. 2004; Raharjaningtrah and Rahman 2004; Collaerts et al. 2013). Based on the selected habitat variables, Flores Hawk-eagles tend to stay away from places with low vegetation and high levels of human activities. High levels of human activity, such as mining or settlements, could potentially disrupt the activity of Flores Hawk-eagles (Arroyo et al. 2004; Xu et al. 2018). The existence of plantations, paddy fields, and roads may not interfere much with the activity of Flores Hawk-eagles. Some species of reptiles could still use vegetation in agricultural areas or paddy fields as one the prey for this species of eagle. The abundance of reptile populations depends on the region's vegetation cover density (Mizsei et al. 2020).

Modeling the spatial distribution of the existing Flores Hawk-eagle habitat could be utilized as one of the aspects that need to be considered in protecting and managing the habitat of Flores Hawk-eagles (KLHK 2019; Mengist et al. 2021). The existence of several patches covering more than one district required cooperation from various *stakeholders* involved in the region. The role between institutions in synergy had an important meaning in the successful management that would be carried out. Potential habitat distribution with a small area and spread out showed the fragmentation of the habitat of Flores Hawk-eagle in East Nusa Tenggara that required further monitoring of the suitability of the habitat for Flores Hawk-eagle (Cuervo and Møller 2019). Fragmentation of habitat would affect the availability of prey and nesting habitat for Flores Hawk-eagle (Matos et al. 2018; Halstead et al. 2019).

This study will be implied for updating the locations of Flores Hawk-eagle's findings, especially in the Lembata region and other islands. Modeling existing spatial distribution could be a reference for Flores Hawk-eagle monitoring locations for national parks and the Regional Office of Nature Conservation Area, Ministry of Environmental and Forestry; Indonesia and Research And Development Center East Nusa Tenggara Region. Research on the condition of nesting vegetation and its location could provide better ecological information of Flores Hawk-eagles.

CONCLUSION

Based on the model, the habitat distribution of Flores Hawk-eagle covering an area of 6,390.48 km2 (22%) of the research area, including West Manggarai, Manggarai, East Manggarai, Ngada, Nagakeo, Sikka, Ende, East Flores, and Alor. The preferable habitat characteristics that affect the distribution of Flores

Hawk-eagles were forests, shrubs, roads, paddy fields, plantations, slopes of 0-8º and 25-45º, as well as altitudes of 1000-2000 m above sea level.

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