BIODIVERSITAS
Volume 21, Number 5, May 2020
Pages: 1890-1900

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d210515

Better providers of habitat for Javan slow loris (*Nycticebus javanicus* E. Geoffroy 1812): A species distribution modeling approach in Central Java, Indonesia

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Manuscript received: 6 February 2020. Revision accepted: 9 April 2020.

Abstract. *Sodik M, Pudyatmoko S, Yuwono PSH, Tafrichan M, Imron MA. 2020. Better providers of habitat for Javan slow loris (*Nycticebus javanicus *E. Geoffroy 1812): A species distribution modeling approach in Central Java, Indonesia. Biodiversitas 21: 1890-1900.* The Javan slow loris is an arboreal and nocturnal primate endemic to Java, which is known to inhabit primary and secondary forest habitats, such as swamps, plantations, and bamboo forest. The population of the Javan slow loris continues to decline significantly due to forest degradation, habitat loss/fragmentation, and illegal trade. Conservation of this small primate in Java has been hampered by a paucity of local data on how conservation areas support this species. This study aims to build a spatial distribution model of the Javan slow loris and analyzing the role of each stakeholder plays on land use type to support the conservation of *N. javanicus*. By utilizing Species Distribution Modeling (SDM) with Maximum Entropy species distribution modeling approach, the researchers were able to highlight the importance of which conservation areas in Central Java that play crucial role to conserve the *N. javanicus* population. Data on the presence of the Javan slow loris was obtained from the result of a survey undertaken in 2017 and communication with researchers. Elevation, slope, landcover, rainfall, distance to road, distance to settlement, distance to river (water source), and NDVI were used as environmental variables. Results showed that 0.76% (25,715.4 ha) of the total area of the Central Java Province is suitable for their habitat. In addition, results revealed that 2.2% of suitable habitat is present within conservation areas, 4.6% in protected forest areas, and 93.2% outside of protected areas. The Javan slow loris is predicted to be mostly scattered in the northern part of Central Java Province. The Javan slow loris is widely distributed in plantations, their most dominant habitat. The findings of this study show that the small percentage of suitable habitat presents within protected forest and conservation areas cannot sustainably maintain the extant Javan slow loris population. Thus, it is important for the Indonesian government and other key related stakeholders to work together in combination with educating local communities to preserve the habitat and population of *N. javanicus.*

Keywords: Central Java Province, habitat suitability, Javan slow loris, maxent, protected area

INTRODUCTION

Indonesia exhibits rich biodiversity, especially primates. Mittermeier et al. (2013) reported that 5 of the 11 known primate families inhabit Indonesian islands, with 38 species being endemic. However, despite this, Indonesia's terrestrial habitats also support a substantial number of endangered species. According to IUCN Red List (2013), Indonesia supports 539 vulnerable species, 197 endangered species, and 69 critically endangered species. The Javan slow loris (*Nycticebus javanicus*) is no exception, having been listed as critically endangered since 2008 (Voskamp et al. 2014). *N. javanicus* is an arboreal nocturnal primate of the Lorisidae family, endemic to the island of Java. (Nekaris and Bearder 2007). *N. javanicus* are known to inhabit primary and secondary forest habitats, such as swamps, plantations, and bamboo forest (Nekaris et al. 2008; Thorn et al. 2009), including human-dominated landscapes (Voskamp et al. 2014).

Habitat loss and fragmentation are the main threats faced by Indonesian primates (Estrada et al. 2018) such as the Javan slow loris. Similiar research reported that primates in particular are affected by habitat fragmentation (Arroyo-Rodríguez et al. 2013; Benchimol and Peres 2014). Research confirmed that behavior and densities of primates has changed due to alterations in forest structure (Marshall et al. 2009). Marsh and Chapman (2013) stated that forest has been changed into small and isolated fragments to create farmlands and extract wood, minerals, and oil from the land. Nearly over the past 50 years, humans have changed forest ecosystems more quickly, and more extensively than at any other time (Millennium Ecosystem Assessment 2005). For tropical countries, such as Indonesia, and especially on the island of Java, habitat loss, habitat fragmentation, forest degradation, and poaching/wildlife trade are the most serious and dominant threats of biodiversity. The continuous decrease of natural resources in Java generates habitat fragmentation

(Higginbottom et al. 2019), which causes a reduction in the home range of the animals, and the emergence of small, isolated patches of habitat. These conditions threaten the Javan slow loris with extinction.

Java is the most populated island in Indonesia with 1,071 inhabitants per square kilometer (Rode-Margono et al. 2014). Rapid population increase is one of the main factors that has lead Java to experience high rates of deforestation, habitat loss, and habitat fragmentation because of a requirement for more infrastructure such as roads, urban areas, and other industrial activities (Whitten et al. 1999). In the early 1990s, less than 9% of forest area remains in Java Island (Balen 1999) in which most are montane forests, with only a very small amount of lowland forest remaining (Reinhardt et al. 2016).

The negative impact on biodiversity has been associated with a decrease in the extent of forest cover in Java. Forest loss has also had a negative impact on the lives of various wild animals, including the Javan slow loris. This pressure is exacerbated by poaching and illegal trading of the Javan slow loris. Malone et al. (2002) stated that the slow loris is the most highly prized "pet" species in both Java and Bali. Compilation data of wildlife trade showed that at least 2,290 slow lorises were traded in the animal market during the period of 1990 - 2006 (Montes and Navaro 2008 in Winarti 2011). The high rate of hunting and trading of slow lorises affects the abundance of wild populations, contributing significantly to declining populations, threatening the species with extinction. Establishing several new conservation areas in Java has the potentials to protect *N. javanicus* from increasing habitat loss, deforestation, habitat fragmentation, and poaching. Conservation areas are believed to be the most beneficial solution for preventing biodiversity loss in Java (Higginbottom et al. 2019).

However, currently the establishment of wildlife conservation areas is considered to be insufficient (Sulistyari 2013). Its ability to sustainably support biodiversity is shrinking. Conservation areas are scattered and too small when compared to the total area of Java. Therefore, these areas cannot provide maximum support for biodiversity protection (Sulistyari 2013). On the other hand, deforestation and forest loss have been occurring in Java continuously, which threatens wildlife, especially the Javan slow loris (Higginbottom et al. 2019).

Information concerning distribution and habitat suitability for the Javan slow loris is currently very limited, both inside and outside conservation areas. The identification of potential habitat of *N. javanicus* is crucial for supporting conservation management of the small dan isolated population of *N. javanicus*. Habitat suitability modelings are nowadays commonly used for exploring the availability of potential habitat and the environmental factors determining the presence of the animals (Jerina et al. 2003; Rondinini et al. 2005). In order to provide important and accurate predictions of its spatial distribution and habitat suitability, species distribution modeling of the Javan slow loris is necessary. However, presence data is mostly more available in such tropical countries compared to the absence data since reliable absence data is frequently difficult to obtain (Phillips et al. 2006). Therefore, Habitat suitability modeling based on species presence-only occurrence data such as maximum entropy model is very valuable (Phillips et al. 2006). Wisz et al. (2008) stated that maximum entropy has proven to be a useful tool for analyzing information on the distribution of species especially for rare sample species with very low sample size.

The main question asked in this research was how big the potential habitat of *N. javanicus* could be used to facilitate the area expansion for promoting a further recovery of this animal in the future. Here, by using maximum entropy modeling, the researchers aim to identify the potential habitat of *N. javanicus* that are likely to be occupied in the future by this endangered species population. Therefore, our research question was (i) how big the potential habitat of *N. javanicus* in Central Java, (ii) Distribution of *N. javanicus* under conservation area, protected forest area, forest production area, and other land use type and analyzing the role of each stakeholder plays on land use type to support the conservation of *N. javanicus*, and (iii) what is the implications for the conservations of *N. javanicus* from the findings of this study. Similar research has been conducted by Voskamp et al. (2014) in which this study surveyed on Java island as basic data of the modeling, including some areas of Central Java Province. This study confirmed that they did not find the *N. javanicus* within Central Java Province and most researchers who worked there had never seen them. However, In 2017, a new sighting of this species was discovered by Sodik et al. (2019) in which a main major finding of this study is a confirmation of *N. javanicus's* presence within Central Java Province, which is very important. Therefore, this study proposes to improve the prediction model of the study by Voskamp et al. (2014) and verify the distribution of Javan slow loris by using presence data from Central Java Province only.

MATERIALS AND METHODS

Presence data

The researchers performed a survey within Kemuning forest and surrounding area in Temanggung Regency to detect the presence of *N. javanicus* within Cental Java Province. Kemuning forest in Temanggung Regency is one of the Central Java Regions (Krisanti et al. 2017) that still inhabited by *N. javanicus* (Sodik et al. 2019). The night surveys were carried out using occupancy techniques (MacKenzie et al. 2002) by dividing the study area into 141 grids with a dimension of 200m x 200m (4ha) each. The researchers also interviewed the locals to obtain information on the location of sightings of *N. javanicus*. Additionally, the researchers also used communication with researchers especially with Lembaga Ilmu Pengetahuan Indonesia (LIPI)/ The Indonesian Scientific Authority to find any information about the presence of *N. javanicus* in Central Java. The majority of sightings occurred in Temanggung District as result of the survey and 1 presence data in Pekalongan District, Central Java Province, based on communication with LIPI's staff, were applied in the modeling process using Maxent program. A total of 36 *N. javanicus* sightings occurred in Central Java between 2013 and 2018; this data has used in the final modeling process (Table 1). The researchers assume that during this period, each individual encountered was still present in the observed location.

Preparing environmental layer for Maxent

The Maxent program requires samples and environmental layers in its process. The researchers used eight environmental variables considered to be important to predict the presence of *N. javanicus* in our model. First, distance to river was used in our model as water sources are key factor in the survival of most wildlife. Second, *N. javanicus* is also known to be sensitive to human activities; therefore, the researchers also used the variable of distance to road, and distance to settlement as representing human disturbances. Elevation is a widely used practical proxy for ambient temperature and precipitation (Hijmans et al. 2005). Slope is considered as a proxy for accessibility by natural resource users (van Gils and Kayijamahe 2010). Slope as a part of indirect factor gradient together with elevation always be involved in distribution modeling as predictors (Franklin 2009). Rainfall as distal variable affects directly to organism and has a role as a proximal variable in the availability of water for plants (Austin 2007). Finally, Normalized Difference Vegetation Index (NDVI) is the most popular vegetation index (Xu and Guo 2014) that can be applied to determine the greenness of a patch of land and canopy biophysical properties (Jiang et al. 2006). This variable is important as *N. javanicus* needs certain canopy conditions to thrive. The NDVI can be applied to figure out the greenness on a patch of land and vegetation canopy biophysical properties (Jiang et al. 2006). Therefore, the environmental variables used in our model include distance to river, distance to road, distance to settlement, elevation, slope, landcover, rainfall, and NDVI (Table 2).

Table 1. The occurrence data used in the final maxent model

Species	Longitude	Latitude	Locality	Data Source
N. javanicus	402003	9210948	Temanggung District, Central Java Province	Survey in 2017
N. javanicus	402201	9210897		
N. javanicus	402244	9210966		
N. javanicus	402260	9211024		
N. javanicus	401905	9211196		
N. javanicus	402564	921154		
N. javanicus	402424	9211695		
N. javanicus	401936	9211349		
N. javanicus	401770	9211508		
N. javanicus	401898	9211395		
N. javanicus	402358	9211524		
N. javanicus	402426	9211691		
N. javanicus	401293	9212227		
N. javanicus	399819	9211428		
N. javanicus	402558	9211165		
N. javanicus	401275	9212239		
N. javanicus	401815	9212559		
N. javanicus	401767	9210861		
N. javanicus	401011	9210034		
N. javanicus	400825	9211642		
N. javanicus	402157	9210885		
N. javanicus	402054	9211215		
N. javanicus	401963	9211444		
N. javanicus	401937	9211317		
N. javanicus	402007	9211367		
N. javanicus	402820	9211461		
N. javanicus	401743	9212509		
N. javanicus	402287	9210958		
N. javanicus	402161	9210904		
N. javanicus	403106	9211208		
N. javanicus	402256	9210929		
N. javanicus	401798	9211481		
N. javanicus	401973	9210958		
N. javanicus	402202	921087		
N. javanicus	401122	9212252		
N. javanicus	350235	92147	Pekalongan District, Central Java Province	Communication with LIPI *

Note: *LIPI: Lembaga Ilmu Pengetahuan Indonesia (Indonesian Institute of Sciences)

Table 2. List of environmental variables used within the Maxent model

Variables	Data source	Format data	Data scale
Distance to river	RBI 25K http://tanahair.indonesia.go.id/	Shapefile	1: 25,000
Distance to road			1: 25,000
Distance to settlement			1: 25,000
Elevation	SRTM NASA https://dwtkns.com/srtm30m/	Raster hgt	Pixels 30 m x30 m
Slope			
Landcover	BPKH Jawa Tengah	Shapefile	1: 25,000
Rainfall			1: 25,000
NDVI	Citra Landsat 8 USGS https://earthexplorer.usgs.gov	Raster TIFF	Pixels 30 m x30 m
Conservation Forest map*	BAPLAN	Shapefile	1:50,000
Protected forest map*	BAPLAN	Shapefile	1:50,000
Administrative map*	RBI 25K http://tanahair.indonesia.go.id/	Shapefile	1: 25,000

Note: *maps are not included in the modeling.

Table 3. Multicollinearity test and percent contribution result

Environmental variables	VIF value	Percent contribution
Distance to river	1.179015	1.6
Distance to road	2.395125	4.8
Distance to settlement	2.459133	4.1
Elevation	1.721351	14.2
Slope	2.053221	2.1
Landcover	NA	33.7
Rainfall	NA	25.9
NDVI	1.316241	13.6

The researchers created a map of the distance from the river, road, and settlement by using the 2015 model of the Rupa Bumi Indonesia (RBI) map which uses 1:25.000 scale. By using a base map, Euclidean to distance was calculated in ArcGIS 10.2. The researchers derived the topographic layers such as elevation and slope from the *Shuttle Radar Topography Mission* (SRTM) 1 Arc-Second available from NASA (https://dwtkns.com/srtm30m/). The researchers obtained the rainfall data from the 2015 National Spatial Planning Agency (BAPLAN) of the Ministry of Forestry, Central Java Unit map with 1:25,000 scale. The researchers derived the landcover map from the 2015 National Spatial Planning Agency (BAPLAN) of Ministry of Forestry, Central Java Unit map with 1:25,000 scale. Landcover classification was based on the Ministry of Environment and Forestry of the Republic of Indonesia's landcover classification. The NDVI value as environmental layer in this study was derived from 2018 Landsat 8, which was classified based on Al-Doski (2013). It has been processed in Arc GIS 10.2 software. All these environmental variables were converted to ASCII format in the 30m resolution and WGS_1984_UTM_Zone 49s coordinate system.

Multicollinearity test

The condition in which two or more explanatory variables have linear function is described as multicollinearity (Voss 2004). This condition creates a problem in the descriptive data set: the failure in identification of relevant variables as increasing in regression variance (Dormann et al. 2013). A multicollinearity test was applied to inspect the linear function among continuous environmental variables. Thus, this test in the study was carried out prior to the modeling process as suggested by Franklin (2009). First, all environmental variables were put in multicollinearity test using R *software* 3.5.3 with 1000 random points and the sighting data of *N. javanicus* as a sample (Hijmans and Elith 2019), and excluded the variables which had a Variance Infection Factor (VIF) value of more than 10 (Hair et al. 2010) (Table 3).

Running the Maxent model

The Maxent program requires samples and environmental layers in its process (Phillips et al. 2006). Presence data of the Javan slow loris was used as input samples, and environment variable data was used as input environmental layers. Feature classes used were Linear, Quadratic and Hinge as only 36 presence points were used in this modeling which is relatively few observation data (Phillips et al. 2006; Philipps and Dudık 2008). In terms of model accuracy, the occurrence data were split into two parts as 75% and 25%, for training data and test data respectively (Phillips et al. 2006; Philipps and Dudık 2008; Wardatutthoyyibah et al. 2019). The modeling process conducted in 50 replications (Phillips and Research 2017; Redon and Luque 2010), and bootstrap was chosen as an indicator of population accuracy (Guissan and Zimmermann 2000). The assessment of habitat and non-habitat in this study uses a threshold value, in which values higher than the threshold value are categorized as suitable habitat and the other way around. The researchers used 10 percentile training presence as a threshold rule to create a map of the potential *N. javanicus's* distribution. Therefore, the probability values below the threshold rule based on modeling results indicate the unsuitable habitat area, and values above the threshold rule indicate the suitable habitat areas (Philipps and Dudık 2008).

Evaluating model and evaluating variable contribution.

Model evaluation in SDM is important in order to quantify the accuracy of predictions which describe the level of model performance or validity (Franklin 2009). To evaluate model performance, the researchers used the AUC

(Area Under a Receiver Operating Characteristic-ROC-Curve) and the Omission Rate Value (Fawcett 2006; Phillips et al. 2006), which indicates how efficiently a model differentiates between occurrence and background location. AUC values from 0.7 to 1 generally suggest that the model has adequate predictive ability (Araujo et al. 2005). Therefore, the best model was chosen based on AUC value> 0.75, and the lowest omission rate value (Elith et al. 2006; Phillips et al. 2006; Redon and Luque 2010). Meanwhile, A jackknife test was also applied to evaluate the contribution percentage of each variable to the model (Elith et al. 2011). The Jackknife test shows the gain in AUC value of each variable when used in isolation and the lack of gain when removed from the full set of variable.

Distributions of *Nictycebus javanicus* under land cover type, land use policy, and involved stakeholders

To determine the size of the overlap between *N. javanicus's* distribution, land cover type, conservation area, protected forest area, and the involved stakeholder, the researchers overlaid the *N. javanicus's* distribution map with maps of conservation area, protected forest area, and the Central Java administrative map. The researchers obtained conservation area data and protected forest area data from the 2015 National Spatial Planning Agency (BAPLAN) of the Ministry of Forestry, Central Java Unit map with 1:25,000 scale. This map covers the data of national parks, nature reserves, wildlife reserves, nature recreation parks, grand forest parks, and forest protection data. The administrative data was derived from the 2015 Rupa Bumi Indonesia (RBI) map which uses 1:25,000 scale.

RESULTS AND DISCUSSION

Performance and variable model responses

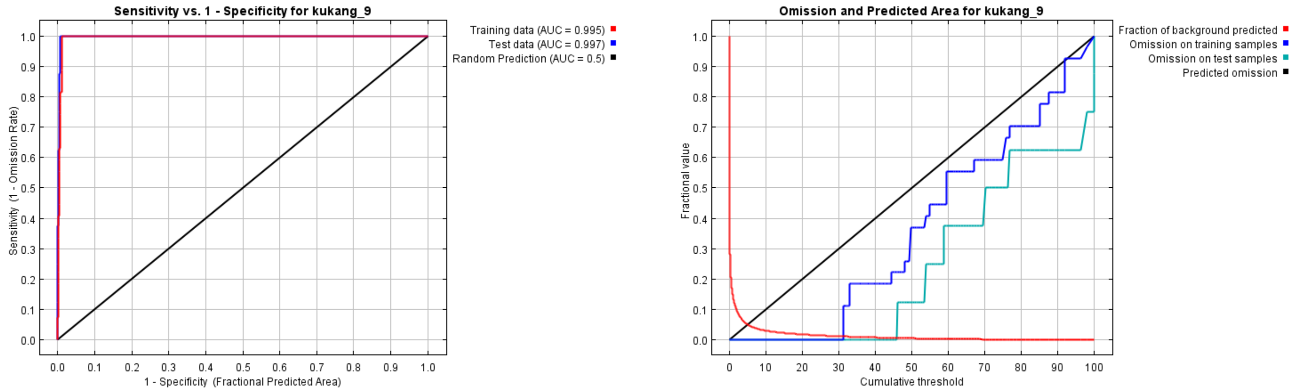
The model of *N. javanicus's* distribution (Figure 1) showed the best results of the replicated running AUC test of 0.995 with 0 omission rate value. AUC values ranged from 0.7 to 1 generally suggest that the model has adequate predictive ability in measuring the presence and absence of *N. javanicus* (Schneider and Pontius 2001; Araujo et al. 2005; Elith et al. 2006). The high value of AUC on the model can be explained by the fact that AUC value is higher for species with small range size (Phillips et al. 2006; Elith et al. 2011). Meanwhile, the most contributive variables in developing the model were landcover, rainfall, and elevation which took 33.7%, 25.9%, and 14.2% contribution respectively. The details of variable contribution are displayed in (Table 3).

The jackknife test was used to identify the important variable. The jackknife of training gain of each variable in the model can be observed in (Figure 2.A). The model produced two important variables: elevation and landcover. However, omitting rainfall as a variable in the model will most affect the training gains. Rainfall was the most influential environmental variable; if omitted it caused the biggest decrease in gains. The rainfall information does not exist in the other variables, and shows the most useful information. Meanwhile, the Jackknife test of AUC illustrates the effective single variable for predicting the *N. javanicus* distribution in Central Java (Figure 2b). The figure showed that elevation was the most effective single variable.

Nycticebus javanicus's distribution in Central Java

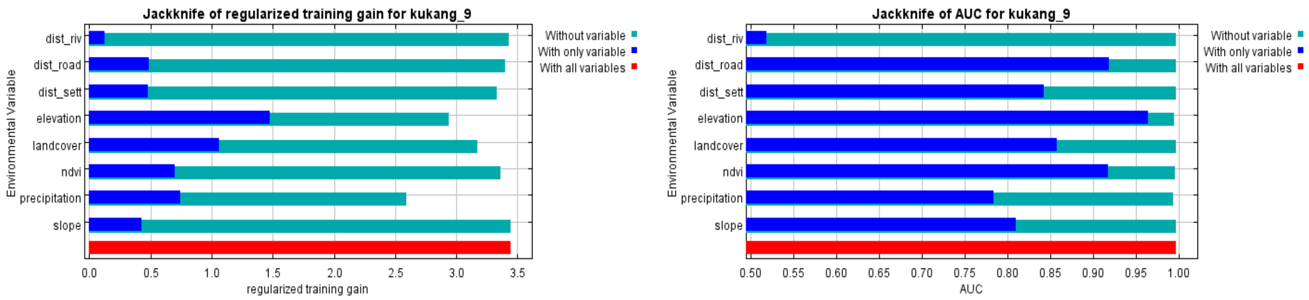
The category of Javan slow loris habitat in this study was based on a 10 percentile training presence logistic threshold. Our model showed that the threshold value generated from the model to determine the suitable - unsuitable habitat area of the Javan slow loris was 0.4205. Thus, the researchers present the latest knowledge about the distribution of *N. javanicus* in Central Java (Figure 3) since the high level of land cover changes in Java requires an update in research to be more relevant for current use. The distribution of *N. javanicus* has been reported by Voskamp et al. (2014) that they surveyed some areas of Central Java, but they did not find the Javan slow loris, and the result of predicted habitat suitability (constrained to the 24 variables used) from the Maxent model shows more suitable habitats are in the southern part of Central Java. In contrast, our model reported that the occurrence data of *N. javanicus* used was within Central Java, and the resulting predicted habitat suitability (constrained to the 8 variables used) from the Maxent model for *N. javanicus* was in the Northern part of Central Java and some areas were in the Southern part of Central Java. In addition, the result of this study provides detailed potential field survey areas along with Central Java Province which could be used as governmental guidance to conserve the *N. javanicus* populations. Efforts focused on conserving *N. javanicus* such as habitat management, habitat restoration, animal release, and land use type within Central Java can be concentrated in these potentially suitable habitat areas.

This study covers about 3,371,380.38 ha of Central Java. It is estimated 0.76% (25,715.4 ha) of the total area of Central Java Province was suitable for *N. javanicus* habitat. The Javan slow loris was predicted to be mostly scattered in the northern part of central Java Province (Figure 3). The Javan slow loris was widely distributed in plantation area (25,518.98 ha) (Table 4), which was the most dominant habitat. This study also revealed that 2.2% (563.31 ha) of the suitable habitats were in conservation areas, 4.6% (1,196.19 ha) in protected forest areas, and 93.2% (23,955.93 ha) were outside the protected area (Table 5). This result was more or less similar to the study carried out by Voskamp et al. (2014). This study reported that 86% of sightings are in forest plantations and agricultural areas located outside of protected areas, with high levels of disturbance.



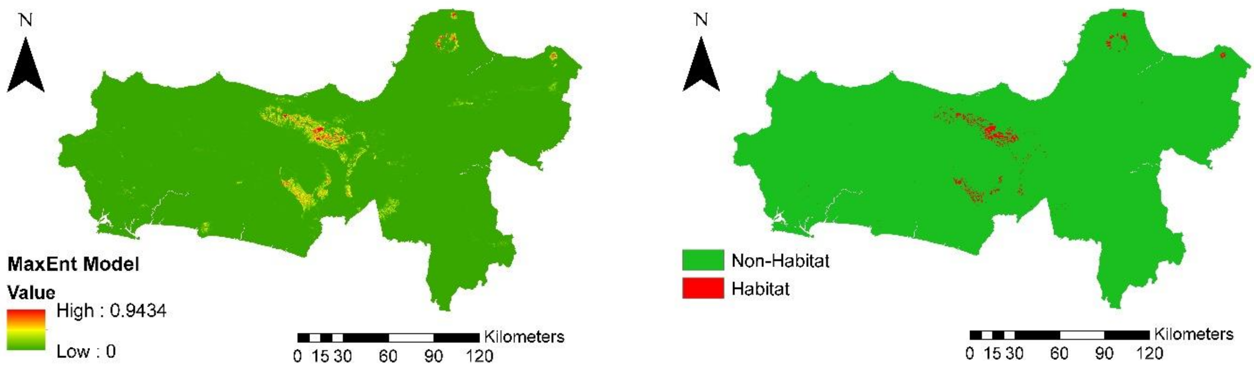
A **B**

Figure 1. Performance model based on AUC value (A) and Omission Rate Value (B)



A **B**

Figure 2. The result of Jackknife test of regularized training gain (A) dan jackknife of AUC for *Nictycebus javanicus* (B)



A **B**

Figure 3. The result of the spatial distribution modeling of Javan slow loris *Nictycebus javanicus* use MaxEnt SDM (A) Suitable - unsuitable area classification based on threshold rule value (B)

Table 4. Potential distribution area of *Nictycebus javanicus* based on land cover types. Percentage (%) represents the land cover intersect with suitable habitat of *N. javanicus*

Landcover types	Suitable area (ha)	Unsuitable area (ha)	% suitable area within each landcover type	% unsuitable area within each landcover type
Airport	0	265.05	0	100
Fishpond	0	45170.19	0	100
Paddy field	0	1055866.14	0	100
Mixed dryland agriculture	31.68	499430.43	0.006342823	99.99365718
Dryland Agriculture	141.12	283306.59	0.049786961	99.95021304
Swampy thicket	0	400.41	0	100
Secondary mangrove forest	0	6230.52	0	100
Waterbody	4.05	19395.72	0.020876536	99.97912346
Savanna/Grassland	0	25.02	0	100
Open area	0	7737.93	0	100
Settlement	9.54	397996.11	0.002396951	99.99760305
Farmland	7.02	26896.86	0.026092891	99.97390711
Thicket	0.45	36269.46	0.001240698	99.9987593
Plantation	25518.96	914209.47	2.715567518	97.28443248
Secondary dry forest	2.61	52381.08	0.004982467	99.99501753
Primary dry forest	0	83.97	0	100
Total	25715.43	3345664.95	0.762756708	99.23724329

Table 5. Potential distribution area of *Nictycebus javanicus* based on land forest function

Land forest function	Suitable area (ha)	Unsuitable area (ha)	Suitable area within each of the land forest function (%)	Suitable area of the total land forest function (%)	Location
Conservation Area	563.31	12896.91	4.18	2,2	CA Gunung Celering, Jepara
Protected Forest Area	1196.19	83469.78	1.4	4,6	BH Gunung Lasem, Rembang; BH Gunung Muria, Pati; BH Gombong Selatan, Kebumen; BH Ambarawa, Kendal.
Other landcover types	23955.93	3249298.26	0.73	93,2	Rembang, Blora, Grobogan, Wonogiri, Jepara, Pati, Batang, Kendal, Temanggung, Wonosobo, Cilacap, Magelang, Banjarnegara, Banyumas, Purworejo, Kebumen, Kota Semarang, Kota Magelang, Klaten, Boyolali, Kudus,
Total	25715.43	3345664.95	0.76	100	

Our study confirms that Javan slow loris habitat in Central Java was predominantly present within small fragmented habitat. Therefore, the potential action is needed, firstly, to increase the forest coverage of the small fragmented habitat and build corridors to connect them as the Javan slow loris is unable to cover large distances (Nekaris and Bearder 2007). Similiar Maxent research result showed that brown bear that lives in small and isolated population needs increasing the connectivity between the current area occupied and the area of potential range expansion in order to facilitate proactive conservation and management strategies towards promoting a further recovery of the brown bears (Zarzo-Arias et al. 2019). Furthermore, since 93.2% of the Javan slow lorises potentially suitable habitat was situated outside of conservation areas and protected forest areas, the conservation of this species is strongly dependent on the support of local communities. Therefore, empowering and educating local communities about local biodiversity and the Javan slow loris is imperatively important to species survival.

Distribution of *Nictycebus javanicus* under conservation area, protected forest area, and forest production area and other land use type

Protected area

Potential *N. javanicus* habitat was situated within the protected areas which makes up a small fraction of land forest functions in Central Java. The potential habitat comprises both about 563.31 ha (2.2%) in conservation areas, and 1196.16 ha (4.6%) in protected forest areas within Central Java (Table 5). The distribution of *N. javanicus* in conservation area was found in Cagar Alam (CA). Gunung Celering, Jepara District. It also can be found in forest protected areas including in Bagian Hutan (BH) Gunung Lasem, Rembang District; BH Gunung Muria, Pati District; BH Gombong Selatan, Kebumen District; BH Ambarawa, Kendal District (Table 5). Protected areas indeed provide a higher chance of survival for *N. javanicus* populations as land conversion, illegal logging, hunting/poaching, and other human activities that threaten the species survival are forbidden within this area.

Therefore, the existence of protected areas is crucial for the long-term conservation of this species.

However, the condition of the protected areas within Central Java is in small size and in fragmented situation (Sulistyari 2013). This condition depicts that the conservation area in Central Java cannot currently give maximum support to the conservation of this species. Sulistyari (2013) argued that the conservation areas within Java are regarded as too small relative to the total area of Java. However, enlarging the protected area size is hardly feasible within Central Java Province because of the significant increase in human population. Thus, one of the solutions is to build a comprehensive conservation area which includes the forest area adjacent to the protected areas.

Protected areas in Central Java are under the management of the Ministry of Forestry of Indonesia. The Indonesian Government, especially the Ministry of Forestry, is one of the key stakeholders that is responsible for conserving this species. The Indonesian government has established Law No. 5 1990 concerning Conservation of Natural Resources, and Forestry Law No. 41/1999 that replaced the Basic Forestry Law (Law No. 5 of 1967), which had focused mainly on timber management rather than conservation. In contrast, the 1999 Law includes some conservation-oriented policies. It divides forests into three categories, including: Conservation Forests, Protection Forests, and Production Forests. Another regulation established was the Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.92/ MENLHK/ SETJEN/ KUM.1/ 8/2018 dated 5 September 2018 on Types of Protected Plants and Animals, to highly protect the Javan Slow Loris. However, the *N. javanicus* population is still decreasing. This depicts that the role of protected areas and the Indonesian government are not enough to protect this species in Java.

Forest production area, and other landcover types

The potential habitat of *N. javanicus* also intersects with forest production, agricultural areas, and other types of landcover. Around 93.2% (23,955.93 ha) of the Javan slow loris habitat can be found in forest production, agricultural areas, and other types of landcover in which the former land type was the dominant habitat (Table 4). The distribution of *N. javanicus* in forest production area among other land cover types were found in some districts in Central Java, including Rembang, Blora, Grobogan, Wonogiri, Jepara, Pati, Batang, Kendal, Temanggung, Wonosobo, Cilacap, Magelang, Banjarnegara, Banyumas, Purworejo, Kebumen, Kota Semarang, Kota Magelang, Klaten, Boyolali, and the Kudus district. This indicated that the bigger part of the Javan slow loris habitat in Central Java exhibits many human disturbances such as land conversion into agricultural areas, settlements, roads, and other industrial purposes.

The forest plantations within Java fall mostly under management of the authority of Indonesian State Forest Company (PERUM PERHUTANI), and the other types of landcover are managed by local government. These two stakeholders are key players, and have the highest responsibility to conserve the species outside of the protected forest. Since the most dominant suitable habitat areas were in forest plantation areas, the role of local government and Perhutani to support conservation of this species is crucial. One of the solutions is possibly establishing wildlife ecotourism. Maccoll and Tribe (2017) argued that the wildlife ecotourism development approach can be used as an alternative solution for the areas located outside protected and agricultural areas. This approach serves as not only a way to conserve wildlife and its habitat, but also as an economical boosting factor for the surrounding community. Another approach to conservation is through empowerment of local communities, in which the local government is expected to be able to convey the importance of conserving *N. javanicus*. By increasing local awareness, it is expected that poaching, wildlife trading, and habitat destruction due to land conversion within Central Java can be prevented.

In addition, vital areas for the conservation of threatened species especially the Javan slow loris within production forest and agriculture areas could be better protected and restored via the establishment of High Conservation Value (HCV) approach (Brown and Senior 2014). Perum Perhutani, as the only company operating within the *N. javanicus* range, has introduced green policies for the management of its concession, and those managed by the adoption of HCV approach. Considering the importance of the Javan slow loris distribution for the species conservation both at the regional level and international level, and especially for the continued reduction of Javan slow loris habitat, the greatest percentage of potential Javan slow loris habitat within commercial concession would fall under HCV management. It should, therefore, be managed in ways that facilitate the survival of the species. Furthermore, habitat management within commercial areas should also include the restoration and protection of forest in the potential distribution areas of the Javan slow loris.

Implications for the conservations of Nictycebus javanicus

Habitat protection and restoration are crucial for the survival of *N. javanicus* in Java. With the population of the Javan slow loris predicted to continue decreasing, it is imperative that the protection of potentially suitable habitat is a high priority. A population of *N. javanicus* is also known to exist in the Temanggung sub-district, Central Java Province (Sodik et al. 2019) in small population size and fragmented habitat, therefore, further surveys to establish whether *N. javanicus* is required to determine whether any additional population exists in the suitable habitat within Central Java Province.

The map of the *N. javanicus's* distribution (Figure 3) showed that the current distribution probability overlaps with conservation areas, protected forest areas, production forest areas, plantation land, or agricultural areas. Therefore, the scenario proposed by this study provides a potential solution for sustaining the species survival in the long term. The researchers advise building a comprehensive protected area that is connected to surrounding forest areas that support the preservation of *N.*

javanicus. Expanding existing wildlife areas by including adjacent forest areas is not only beneficial for *N. javanicus*, but also other species (Imron et al. 2011). Connectivity is very crucial in this case since some suitable habitats in small size without linked among them, which do not allow ecological processes like gene flow, migration, re-colonization of areas with threatened populations, the suitable habitat areas cannot meet their conservation goals (Rudnick et al. 2012). Similar research reported that connectivity is mainly applied to facilitate movement among resource patches (Taylor et al. 1993) since isolation of areas with high conservation value limits the capacity of the system to maintain ecological processes (Rudnick et al. 2012). Mammals, including primates, are able to adapt to fragmented habitats (Luckett et al. 2004). For primate tree-dwelling species such as slow lorises, artificial wildlife corridors, such as green bridges, could provide a solution to improving connectivity in fragmented habitats (Birot et al. 2019). Birot et al. (2019) reported that artificial canopy bridges in a fragmented agroforest environment in West Java allowed slow lorises to include areas in their home ranges that were previously disconnected. This condition resulted in expanded their home ranges, created access to newly habitable areas and feeding resources, and reduced time spent on the ground after the installation of bridges.

Another option is to create corridors for habitat connectivity of the Javan slow loris. Corridors could be used to connect between natural forest areas in degraded habitats. Nevertheless, forest corridors are not always easy to implement in Java, as they may cross privately owned properties thus requiring permission and cooperation from the landowners. Therefore, least-cost corridors (LCC) could be an option in this case. Beier et al. (2009) stated that LCC is more realistic representation of a conservation goal as it represents the accumulated cost gradient, which makes them stronger to being areas to link habitats. LCC could create corridors between habitat patches with the least cost accumulation based on the type of land cover that exists between these habitat patches as the main consideration (Aryam et al. 2016). An example of this corridor is a planted tree corridor that also has value for local communities or land-owners. The Javan slow loris can benefit from these corridors by using them for traveling, resting, and as a new food source (Birot et al. 2019).

The establishment of these corridors has to be accompanied by an active role and support from all involved stakeholders, including the Ministry of Forestry of the Republic of Indonesia, local government and Perhutani, the surrounding community, and all related parties affected by the corridors. These corridors may be detrimental to entrepreneurs; nevertheless, the preservation of the adjacent protected area has high ecological benefits. Furthermore, since 93.2% of potentially suitable habitat for the Javan slow loris is both outside of conservation area and forest protected area within a fragmented area shape, the conservation of this species is strongly dependent on the support of locals. Therefore, these strategies in combination with increasing the implementation of local conservation education are very important to conserve this species.

In conclusion, our results showed that 0.76% (25,715.4 ha) of the total area of Central Java Province was suitable for *N. javanicus* habitat. The researchers revealed that 2.2% of the suitable habitat was in conservation areas, 4.6% was in protected forest area, and 93.2% was outside the protected area. The Javan slow loris was predicted to be mostly scattered in the northern part of Central Java Province. The Javan slow loris was widely distributed in plantations, which was the most dominant habitat that able to support their resource needs. The findings of this study show that the small percentage of suitable habitat present within protected forest and conservation areas cannot sustainably maintain the extant Javan slow loris population due to a large number of threats for the species. Thus, it is important for the Indonesian government and other key related stakeholders working together in combination with educating local communities to preserve the habitat and population of *N. javanicus*. The expectation is that the results of this study can enrich the literature in this field, especially for *N. Javanicus* in Central Java areas.

ACKNOWLEDGEMENTS

We convey our gratitude to The Ministry of Environment and Forestry Republic of Indonesia, PERHAPPI, and Simposium dan Kongres Primata Indonesia 2019 in Yogyakarta, Indonesia for sponsoring our research. We also thank BPKH Yogyakarta, BAPLAN Jakarta, Perhutani KPH Kedu Utara, Arif Setyawan (Swara Owa), and Dr. Wirdateti (LIPI) for providing us with data. We want to thank all people who contribute for all the help and support with the fieldwork along with this study, to name among them are Ryan Adi Satria, Arif, Febriyanto I. Nugroho, Dona Susanti, Bejo, Carik Kemuning, Bayan, Dikun, Make, Dayat, Budi, Kunting, and Edwar. We are also grateful to the Wildlife Conservation Centre, Faculty of Forestry, Universitas Gadjah Mada, Yogyakarta for providing the proofread of this manuscript.

REFERENCES

Al-Doski J. 2013. NDVI differencing and post-classification to detect vegetation changes in Halabja City, Iraq. IOSR J Appl Geol Geophysics 12: 1-10. DOI: 10.9790/0990-0120110.

Araujo MB, Pearson RG, Thuiller W, Erhard M. 2005. Validation of species-climate impact models under climate change. Glob Chang Biol 11: 1504-1513.

Arroyo-Rodriguez V, Cuesta-del Moral E, Mandujano S, Chapman CA, Reyna-Hurtado R, Fahrig L. 2013. Assessing habitat fragmentation effects on primates: the importance of evaluating questions at the correct scale. In: Marsh LK, Chapman CA (eds) Primates in Fragments: Ecology and Conservation. New York, Springer.

Aryam CAC. Mendoza ME, Etter A, Salicrup DRP. 2016. Habitat connectivity in biodiversity conservation: A review of recent studies and applications. Prog Phys Geogr 40 (1): 7-37. DOI: 10.1177/0309133315598713.

Austin M. 2007. Species distribution models and ecological theory: A critical assessment and some possible new approaches. Ecol Model 200: 1-19.

Balen SV. 1999. Birds on Fragmented Islands Persistence in The Forests of Java and Bali. [Dissertation]. Wageningen University and Research Centre, The Netherlands.
Beier P, Majka DR, Newell SL. 2009. Uncertainty analysis of least-cost modeling for designing wildlife linkages. Ecol Appl 19: 2067-2077.
Benchimol M, Peres C.A. 2014. Predicting primate local extinctions with 'real-world' forest fragments: A pan-Neotropical analysis. Am J Primatol 76: 289-302.
Birot H, Campera M, Imron M, Nekaris K. 2019. Artificial canopy bridges improve connectivity in fragmented landscapes: The case of Javan slow lorises in an agroforest environment. Am J Primatol 2019;e23076. DOI: 10.1002/ajp.23076
Brown E, Senior MJM. 2014. Common guidance for the management and monitoring of high conservation value. HCV Resource Network.
Dormann CF, Elith J, Bacher S, Buchmann C, Carl G, Carré G, Lautenbach S. 2013. Collinearity: A review of methods to deal with it and a simulation study evaluating their performance. Ecography 36 (1): 027-046. DOI: 10.1111/j.1600-0587.2012.
Elith J, Graham CH, Anderson RP, Dudıìk M, Ferrier S, Guisan A, Zimmermann NE. 2006. Novel methods improve prediction of species' distributions from occurrence data. Ecography 29: 129-151. DOI: 10.1111/j.2006.0906-7590.
Elith J, Phillips SJ, Hastie T, Dudik M, Chee YE, Yates CJ. 2011. A statistical explanation of Maxent for ecologists. Divers Distrib 17: 43-57. DOI: 10.1111/j.1472-4642.2010.00725.x.
Estrada A, Garber PA, Mittermeier RA, Wich S, Gouveia S, Dobrovolski R, Nekaris KAI, Nijman V, Rylands AB, Maisels F, Williamson EA, Bicca-Marques J, Fuentes A, Jerusalinsky L, Johnson S, Rodrigues de Melo F, Oliveira L, Schwitzer C, Roos C, Cheyne SM, Martins Kierulff MC, Raharivololona B, Talebi M, Ratsimbazafy J, Supriatna J, Boonratana R, Wedana M, Setiawan A. 2018. Primates in Peril: The significance of Brazil, Madagascar, Indonesia and the Democratic Republic of the Congo for global primate conservation. PeerJ 6: e4869: 10.7717/peerj.4869.
Fawcett T. 2006. An introduction to ROC analysis. Pattern Recogn Lett 27 (8): 861-874. DOI: 10.1016/j.patrec.2005.10.
Franklin J. 2009. Mapping Species Distribution: Spatial Inference and Prediction. Cambridge University Press, New York.
Guissan, Zimmermann. 2000. Predictive habitat distribution models in ecology. Ecol Model 135 (2000): 147-186.
Hair, Joseph F, William CB, Barry JB, Rolph EA. 2010. Multivariate Data Analysis (7th Ed.). Englewood Cliffs, Prentice-Hall, NJ.
Higginbottom TP, Collar NJ, Symeonakis E, Marsden SJ. 2019. Deforestation dynamics in an endemic-rich mountain system: Conservation successes and challenges in West Java 1990-2015. Biol Conserv 229: 152-159. DOI: 10.1016/j.biocon.2018.11.017.
Hijmans RJ, Cameron SE, Parra JL, Jones PG, Jarvis A. 2005. Very high resolution interpolated climate surfaces for global land areas. Intl J Climatol 25: 1965-1978.
Hijmans RJ, Elith J. 2019. Spatial Distribution Models. DOI: 10.1016/b978-008045405-4.00677-7.
Imron MA, Herzog S, Berger U. 2011. The influence of agroforestry and other land-use types on the persistence of a Sumatran tiger (Panthera tigris sumatrae) population: An individual-based model approach. Environ Manag 48 (2): 276-288.
IUCN 2013. The IUCN Red List of Threatened Species. Red List 2013: Threatened Species Across The Regions of The World. www.iunc.org
Jerina K, Debeljak M, Dzˇeroski S, Kobler A, Adamič M. 2003. Modeling the brown bear population in Slovenia: A tool in the conservation management of a threatened species. Ecol Modell 170 (2-3): 453-469.
Jiang Z, Huete AR, Chen J, Chen Y, Li J, Yan G, Zhang X. 2006. Analysis of NDVI and scaled different vegetation index retrievals of vegetation fraction. Remote Sens Environ 101 (3): 366-378. DOI: 10.1016/j.rse.2006.01.003.
Krisanti AA, Widiyani T, Imron MA. 2017. Species diversity and population distribution of arboreal mammals in Kemuning Forest, Temanggung, Central Java, Indonesia. Biodiversitas 18 (3): 1190-1195. DOI: 10.13057/biodiv/d180342
Luckett J, Danforth E, Linsenbardt K, Pruetz J. 2004. Planted trees as corridors for primates at El Zota Biological Field Station, Costa Rica. Neotrop Primates 12 (3): 143-146. DOI: 10.1896/ 1413-4705.12.3.143
Maccoll M, Tribe A. 2017. Wildlife Tourism and Conservation: The Hidden Vale Project. Springer, Australia.
MacKenzie DI, Nichols JD, Lachman GB, Droege S, Royle JA, Langtimm CA. 2002. Estimating site occupancy rates when detection probabilities area less than one. Ecology 83 (8): 2248-2255.
Malone N, Purnama AR, Wedana M. 2002. Assessment of the sale of primates at Indonesian bird markets. Asian Primates 8: 7-11.
Marsh LK, Chapman CA. 2013. Primates in Fragments: Complexity and Resilience. Springer, New York.
Marshall AJ. 2009. Are montane forests demographic sinks for Bornean white-bearded gibbons? Biotropica 41: 257-267.
Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being, Synthesis, Summary for Decision-Makers. www.millenniumassessment.org
Mittermeier RA, Rylands AB, Wilson DE. 2013. Handbook of The Mammals of The World. Vol. 3, Primates. Lynx Editions, Barcelona.
Nekaris A, Bearder SK. 2007. The Lorisiform Primates of Asia and Mainland Africa. In: Primates in Perspective. Oxford University Press, New York.
Nekaris KAI, Blackham GV, Nijman V. 2008. Conservation implications of low encounter rates of five nocturnal primate species (*Nycticebus* spp.) in Asia. Biodivers Conserv 7 (4): 733-747. DOI: 10.1007/s10531-007-9308-x.
Philipps SJ, Dudık M. 2008. Modeling of species distributions with Maxent: New extensions and a comprehensive evaluation. Ecography 31: 161-175. DOI: 10.1111/j.2007.0906-7590.
Phillips SJ, Anderson RP, Schapire RE. 2006. Maximum entropy modeling of species geographic distributions. Ecol Model 190 (3-4): 231-259. DOI: 10.1016/j.ecolmodel.2005.
Phillips SJ, Research A. 2017. A Brief Tutorial on Maxent. http: //biodiversityinformatics.amnh.org/open_source/maxent/.
Redon M, Luque S. 2010. Presence-only modelling for indicator species distribution: Biodiversity monitoring in the French Alps. 6th Spatial Analysis and Geomatics International Conference (SAGEO 2010) 1: 42-55.
Reinhardt KD, Wirdateti, Nekaris KAI. 2016. Climate-mediated activity of the Javan slow loris, *Nycticebus javanicus*. AIMS Environ Sci 3 (2): 249-260. DOI: 10.3934/ environsci.2016.
Rode-Margono EJ, Nijman V, Wirdatet, Nekaris KAI. 2014. Ethology of the critically endangered Javan slow loris *Nycticebus javanicus* É. Geoffroy Saint-Hilaire in West Java. Asian Primates J 4 (2): 27-38.
Rondinini C, Stuart S, Boitani L. 2005. Habitat suitability models and the shortfall in conservation planning for African vertebrates. Conserv Biol 19 (5): 1488-1497.
Rudnick D, Ryan S, Beier P, et al. 2012. The role of landscape connectivity in planning and implementing conservation and restoration priorities. Issues Ecol 16: 20-20.
Schneider L, Pontius Jr. RG. 2001. Modeling land-use change in the Ipswich Watershed, Massachusetts, USA. Agric Eosyst Environ 85: 83-94.
Sodik M, Pudyatmoko S, Yuwono PSH, Imron MA. 2019. Resource selection by Javan slow loris *Nycticebus javanicus* E. Geoffroy, 1812 (Mammalia: Primates: Lorisidae) in a lowland fragmented forest in Central Java, Indonesia. J Threatened Taxa 11 (6): 13667-13679. DOI: 10.11609/jott.4781.11.
Sulistyari D. 2013. Sejarah Penunjukan Kawasan Konservasi. [Master Thesis]. Universitas Gadjah Mada, Yogyakarta.. [Indonesian]
Taylor PD, Fahrig L, HeneinK, et al. 1993. Connectivity is a vital element of landscape structure. Oikos 68: 571-73.
Thorn JS, Nijman V, Smith D, Nekaris KAI. 2009. Ecological niche modelling as a technique for assessing threats and setting conservation priorities for Asian slow lorises (Primates: Nycticebus). Divers Distrib 15 (2): 289-298. DOI: 10.1111/j.1472-4642.2008.00535.x.
Undang-Undang Republik Indonesia Nomor 5 Tahun 1990. Tentang Konservasi Sumber Daya Alam Hayati dan Ekosistemnya. [Indonesian]
van Gils HAMJ, Kayijamahe E. 2010. Sharing natural resources: Mountain gorillas and people in the Parc National des Volcans, Rwanda. Afr J Ecol 48: 621-627.
Voskamp A, Rode EJ, Coudrat CNZ, Wirdateti, Abinawanto, Wilson RJ, Nekaris KAI. 2014. Modelling the habitat use and distribution of the threatened Javan slow loris *Nycticebus javanicus*. Endangered Species Res 23 (3): 277-286. DOI: 10.3354/esr00574.
Voss DS. 2004. Multicollinearity. Encyclopedia of Social Measurement.
Wardatutthoyyibah, Pudyatmoko S, Subrata SA, Imron MA. 2019. The sufficiency of existed protected areas in conserving the habitat of

proboscis monkey (*Nasalis larvatus*). Biodiversitas. 20 (1). DOI: 10.13057/biodiv/d020101
Whitten A, Soerjaatmaja RE, Afiff A. 1999. Ekologi Jawa dan Bali. Prenhallindo, Jakarta. [Indonesian]
Winarti I. 2011. Habitat, Populasi, dan Sebaran Kukang Jawa (*Nycticebus javanicus* Geoffroy 1812) di Talun Tasikmalaya dan Ciamis, Jawa Barat. [Thesis]. Institut Pertanian Bogor, Bogor. [Indonesian]
Wisz MS, Hijmans RJ, Li J, Peterson AT, Graham CH, Guisan A. 2008. Effects of sample size on the performance of species distribution models. Divers Distrib 14: 763-773.
Xu D, Guo X. 2014. Compare NDVI extracted from Landsat 8 imagery with that from Landsat 7 imagery. Am J Remote Sens 2 (2): 10-14. DOI: 10.11648/j.ajrs.20140202.11.
Zarzo-Arias A, Penteriani V, Delgado MdM, Peon Torre P, Garcıa-Gonzalez R, Mateo- Sanchez MC, et al. 2019. Identifying potential areas of expansion for the endangered brown bear (*Ursus arctos*) population in the Cantabrian Mountains (NW Spain). PLoS ONE 14 (1): e0209972. DOI: 10.1371/journal. pone.0209972