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Correlation between landscape structure and distribution of Javan Pangolin (*Manis javanica*) in an extreme landscape

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Abstract. *Withaningsih S, Parikesit, Nasrudin A. 2021. Correlation between landscape structure and distribution of Javan Pangolin* (Manis javanica) *in an extreme landscape. Biodiversitas 22: 920-932.* The Javan Pangolin (*Manis javanica*) is a unique mammal with hard scales and can roll over when threatened. However, the study of Javan pangolin ecology, particularly using an ecological landscape approach, is limited. Here, a spatial analysis of the presence and distribution of Javan pangolins living in an extreme landscape in Rongga Sub-district, West Bandung District was conducted and was correlated to the landscape structure using a landscape metric approach. A descriptive method was used in conjunction with quantitative statistical analyses using simple linear regressions based on the Pearson correlation coefficient. The variables were features of the extreme landscape structure and the number of Javan pangolin animal signs at the sampling sites. The seven sample sites had variations in land cover classes, and the landscape structure affected the distribution of the Javan pangolins. The pangolin distribution showed a strong, negative correlation with the number of patch types ($R^2 = 0.628$) and a weak, negative correlation with both the landscape heterogeneity ($R^2 = 0.012$) and the percentage of forest cover ($R^2 = 0.136$). Together, the landscape heterogeneity, the number of patch types and the percentage of forest cover negatively affected the distribution of Javan pangolins, showing a strong correlation ($R^2 = 0.799$).

Keywords: Extreme landscape, landscape metric, landscape structures, pangolin distribution

INTRODUCTION

The Javan pangolin (*Manis javanica*) is a pangolin species with a home range distributed in the Southeast Asian islands of Sumatra, Java and Kalimantan (Sompud et al. 2019). This is the only remaining pangolin species in Indonesia after *Manis palaeojavanica* was declared extinct in the wild (Manshur et al. 2015). These mammals are unique because their entire bodies are covered with keratinized scales; they have long tongues (half a body length, approximately 25-30 cm), and are without teeth (Takandjandji and Sawitri 2016).

Javan pangolins are classified as critically endangered by the International Union for Conservation of Nature and Natural Resources (IUCN) are included in the Appendix I category based on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). They are vulnerable to extinction and are prohibited from being traded freely (Challender et al. 2019). Manshur et al. (2015) state that this condition is caused by four main factors, namely, illegal trade, limited and special feed (insects such as ants and termites), low reproductive potential and minimal anti-predator adaptation mechanisms. Moreover, illegal poaching has caused pangolin populations to decline by more than 50% over the past 15 years (Withaningsih et al. 2018). This practice is triggered by the high black-market demand for pangolin parts, such as scales, tongues, bile and meat, as the main commodities of the pangolin trade. The scales, tongues and bile are used as raw materials for traditional Chinese medicine, while pangolin meat is considered a symbol of luxury that indicates the social status of the consumers (Andini and Purnaweni 2019).

Many studies related to pangolins have been carried out, but most have focused on anatomical and morphometric analysis (Nisa' et al. 2010; Zhou et al. 2012), histology (Pongchairerk et al. 2008; Meyer et al. 2010) and pangolin biotechnology (Maryanto et al. 2013). To date, pangolin ecological studies have investigated the home range areas, daily ecological behaviors (Lim and Ng 2008), population distribution (Karawita et al. 2018) and habitat characteristics (Manshur et al. 2015). However, practical studies, particularly using a landscape ecological approach, is limited.

A landscape ecological approach can be used as a conceptual framework for analyzing the long-term impacts of developmental activities on the biodiversity caused by landscape changes. Landscape management and planning require a sustainable approach based on the spatial dimensions involved (Withaningsih et al. 2019). Scientific advances in remote sensing and geographic information systems are useful for identifying landscape ecological patterns and structures (Wu et al. 2015). Landscape ecology can be used to assess habitat quality at a certain spatial scale. Heterogeneous landscapes affect ecological processes such as animal mobility and distribution, population numbers, and species interactions (Ardian and Haryono 2018).

One of the remaining Javan pangolin habitats on Java Island is located in the extreme landscape area of Rongga Sub-district, West Bandung District where Cisokan hydropower plant is located. The study of Withaningsih et al. (2018) suggests this area to be the Javan pangolin habitat. Extreme landscapes have extreme biophysical characteristics, such as steep to very steep topographical conditions, and prone to natural disasters like landslides, floods, droughts, and earthquakes. Even though, this landscape supports many natural ecosystems such as secondary forests, production forests, agroforestry and orchards, shrubland, burnt fields, rice fields, fish ponds, settlements and yards. Stress upon environment comes as baggage with infrastructure development projects. Therefore, it is speculated that the hydropower plant construction and human activities in Rongga Sub-district might have a damaging effect on the activities and habitats of Javan pangolins, which may lead to their population decline. In order to propose conservation measures for Javan pangolin, the present study aims towards their comprehensive ecological study through correlation between the landscape structure and their habitat distribution in Rongga Sub-district using a landscape ecological approach.

MATERIALS AND METHODS

This study used a descriptive method with a quantitative statistical analysis approach utilizing simple linear regression analysis based on Pearson correlation coefficients. The variables were the extreme landscape structures in Rongga Sub-district, Bandung District, West Java Province, Indonesia, and the estimated abundance and distribution of Javan pangolins in the sampling sites. The landscape structure variations of the proportion of landscape classes were determined by correlation analysis.

Collection of secondary data included the location of nesting sites and the signs of pangolin existence. These data informed the *M. javanica* distribution in the vicinity of the Cisokan hydropower plant construction site and were based on the findings of Withaningsih et al. (2018). The study area was delineated based on the pangolin sampling sites and they were projected onto a distribution map in Google Earth Pro. Subsequently, each sample site was digitized to determine the types of land cover at that site. The digitization results were then analyzed using the following landscape metrics: the largest patch index (LPI), the number of patches (NP) and the Shannon diversity index (SHDI). Fragstats 4.2 software was used to compute the selected landscape metrics. The values of the landscape measurements were then statistically analyzed by a simple linear regression based on the Pearson correlation test to assess the relationship between the landscape structure and the Javan pangolin distribution.

The Largest Patch Index (LPI) shows the type of land cover that has the largest proportion in the landscape, so it can be assumed that this land cover type has the most influence on the processes that occur in the landscape (Wu and Hobbs 2007). LPI equals the area (m^2) of the largest patch in the landscape divided by total landscape area (m^2), multiplied by 100 (to convert to a percentage); in other words, LPI equals the percent of the landscape that the largest patch comprises. Note, total landscape area (A) includes any internal background present. The equation used to calculate the LPI value (McGarigal 2014) is:

$$LPI = \frac{\max_{j=1}^{n} (a_{ij})}{A} (100)$$

Where, a_{ij}: area (m^2) of patch ij, A: total landscape area (m^2).

Number of Patches (NP) is a parameter that indicates the total number of different patches in the landscape. The number of patches can indicate the intensity of the interaction between each spot that can create or eliminate processes that occur in the landscape (Farina 1998). The NP value is the same as the number of patches identified in the landscape. NP can indicate the heterogeneity of a landscape in the study area.

Shannon's Diversity Index (SHDI) shows the value of patch diversity which can be interpreted as the level of variation in the patches that make up the landscape in each research site, the higher the value of the diversity of patches, the more varied the components of the landscape are. The SHDI value is commonly used to see the effect of the diversity of patches on processes that occur in the landscape and to compare one landscape to another or the same landscape at different times (Farina 1998). SHDI is calculated in a landscape determined by the number of spot types and a proportional distribution in the area of each patch type with the following equation:

$$H = -\sum_{i=1}^{m} \text{pi} \ln(\text{pi})$$

Where: m is the total number of patch types and pi is the proportion of landscape area occupied by patch type (class) i.

Determination of the blocks to be analyzed using the buffering method based on Nomura and Nakagoshi (1999), which is one of the main spatial analysis methods that use a geographic information system (GIS) application with a circular center (buffer radius) as an area that has a direct relationship with the main focus of the study, in this case, are several locations in the Rongga Sub-district area which are the sampling points for Javan pangolins distribution. Then a circle with a radius of 500 m (area of 78.5 ha) was created, which was the radius for structural analysis at the micro-landscape level (Warren et al. 2005). The 500 m radius was chosen because it covered the home-range area of the Javan pangolin, which ranges from 6.97-43.3 ha (Lim and Ng 2008; Jackson and Fahrig 2012). The landscape analysis sample points were determined based on 45 pangolin sampling points as the midpoint of the circular block by randomly selecting the intersecting points within a radius of 500 m, so that seven non-intersecting points were sampled for the landscape analysis (Figure 1).

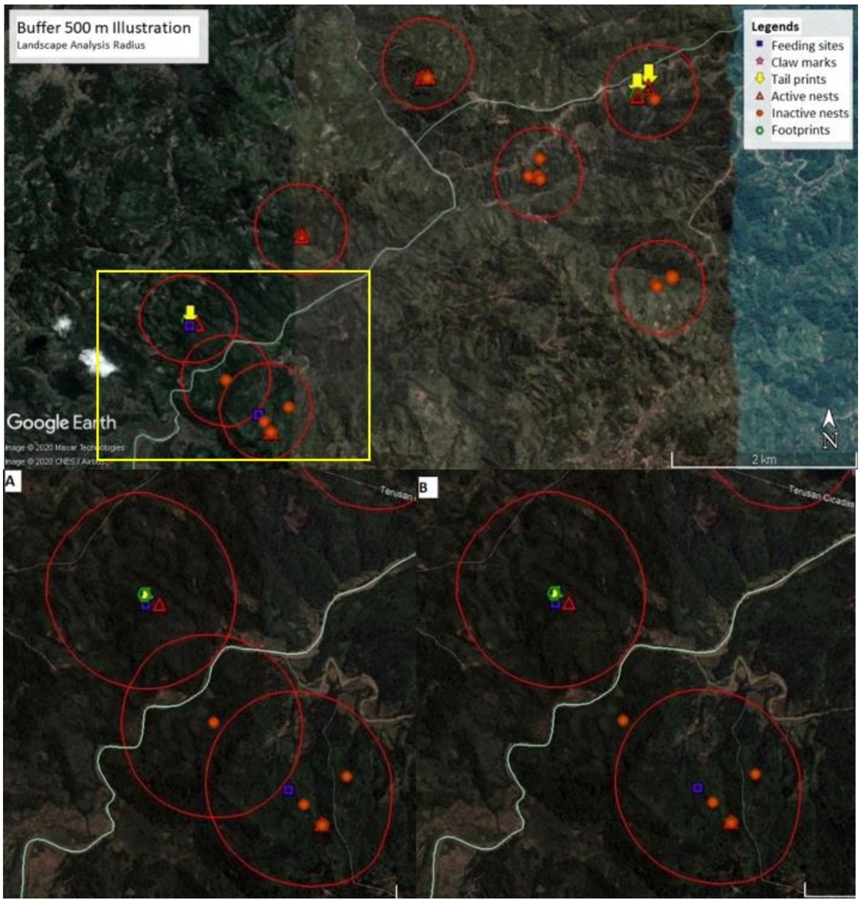


Figure 1. The 500 m radius buffers at the sample sites. Study sample determination: A.Three Javan pangolins sampling sites in Tegalega, Lamajang Village where two sampling sites intersect each other in a 500 m radius area, B. One sample site was randomly chosen as landscape analysis sample. The differences of symbols indicate Javan Pangolins' signs at the sampling sites, such as feeding sites, claw marks, tail prints, active nests, inactive nests, and footprints (Google Earth 2020)

Satellite imagery was taken at the data collection stage by selecting images without cloud cover or less than 10% cloud cover so that the object could be seen clearly. Satellite imagery was obtained from the Landsat 8 OLI/TIRS C1 satellite Level 1 path 122 / row 65 30 m spatial resolution with the recorded date of 17 August 2016 which was downloaded for free from the page of The United States Geological Survey (USGS) http://earthexplorer.usgs.gov.

After the satellite image data were obtained, then digitizing the land cover was carried out based on the images obtained with the QuantumGIS software version 3.4.6-Madeira with The Semi-Automatic Classification Plugin (SCP) (QGIS Development Team 2019) to determine the type of land cover, then analyzed to determine the characteristics of each point. Then, rasterization is carried out at each point so that an image is in the form of a Temporary Instruction File Format/TIFF (.tiff /.tif) raster which was then analyzed the landscape with the Fragstats 4.2.1 software (McGarigal et al. 2012) (Figure 2).

RESULTS AND DISCUSSION

Pangolin distribution and land cover in the research area

This study was conducted in an extreme landscape in Rongga Sub-district, West Bandung District, Indonesia. A total of seven sample sites within the Javan pangolin habitat area were analyzed for their landscape structure. Details of the sample sites are presented in Table 1. The land cover in the extreme landscape was divided into eight types based on Google Earth satellite imagery, Landsat 8 imagery, 2016 digitization maps, and previous related studies. These land cover types were forests, pine forests, mixed-species plantations, shrubland/drylands/fields, open fields, settlements, rice fields, and water bodies. Land cover identification features are presented in Table 2.

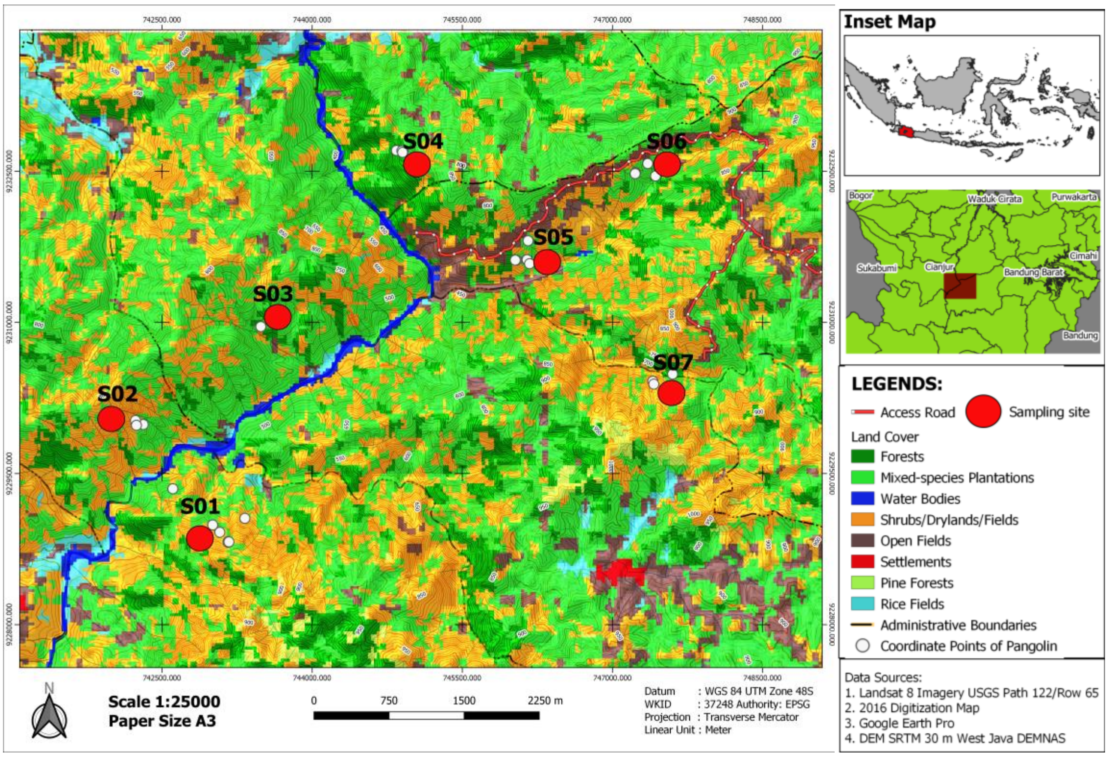


Figure 2. Distribution map of Javan pangolins in an extreme landscape in Rongga Sub-district, West Bandung District, West Java, Indonesia (Withaningsih et al. 2018)

Table 1. Details of sample sites

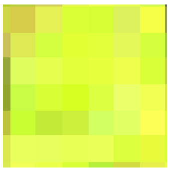
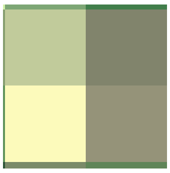
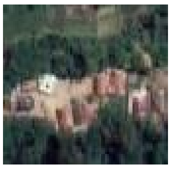
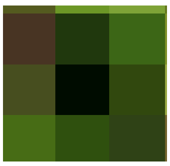
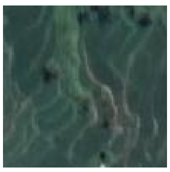
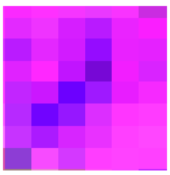
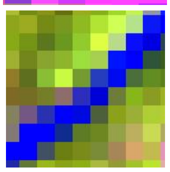
Sample code	Trail	Coordinate (UTM/48S)		Location	Alt. (m)	Community type
		Latitude	Longitude			
S01	Footprints	742235	9230027	Pasir Gagak	660	Shrublands/Drylands/Fields
S02	Inactive burrows/ nests	743161	9228817	Batu Wulung	750	Shrublands/Drylands/Fields
S03	Inactive burrows	744896	9232703	Hutan (forest) Gowek (Batu Tumpeng)	744	Mixed-species Plantations
S04	Inactive burrows	747430	9232454	Pongpok	675	Forest
S05	Inactive burrows	747600.28	9230486.72	Curug (waterfall) Japarana	728	Open Fields
S06	Inactive burrows	746140.9	9231623.16	Cadas Gantung	550	Mixed-species Plantations
S07	Inactive burrows	743486.67	9230958.53	Batu Sahulu	608	Shrublands/Drylands/Fields

Source: Withaningsih et al. (2018)

Satellite imagery was taken by selecting images without cloud cover or less than 10% cloud cover so that the object could be seen clearly. Satellite imagery was obtained from the Landsat 8 OLI/TIRS C1 satellite Level 1 path 122 / row 65 30 m spatial resolution with the recorded date of 17 August 2016 which was downloaded for free from the page of The United States Geological Survey (USGS) http://earthexplorer.usgs.gov. After the satellite image data were obtained, then digitizing the land cover was carried out based on the images obtained with the QuantumGIS software version 3.4.6-Madeira with The Semi-Automatic Classification Plugin (SCP) (QGIS Development Team 2019) to determine the type of land cover, then analyzed to determine the characteristics of each point.

Data processing includes several stages, namely: (i) Registration process, registration was carried out for geometric correction with a resampling process based on a spatial coordinate system or control point (Ground Control Point/GCP) using the Earth Map and 2016 digitization maps as a reference. (ii) Image cropping, with the boundaries of the research area. (iii) Color composite image processing to combine channels at once. This aimed to sharpen the objects in the image for a specific purpose, making it easier to manage the objects in the image. Create a composite and RGB (Red, Green, Blue) of the multispectral Landsat 8 to follow up with the 4-3-2 channel plan to check every visible object in the image. (iv) Determining the sample in class selection, taking the training area based on the land cover class which was divided into 8 classes, namely forests, pine forests, mixed-species plantations, shrubland/drylands, or drylands/fields, open fields, settlements, rice fields, and water bodies. (v) Image classification was carried out in a supervised classification. Classification method with maximum similarity (*Maximum Likelihood*) with deliberate sample selection (sample class) based on the display on the monitor with the help of a composite image that has been made. Sampling was done with polygons, where each sample is taken must be completely homogeneous. According to Manandhar et al. (2009) (the minimum level of interpretation accuracy in the identification of land use and LULC categories from remote sensing data should be at least 85%. Map created in this research has an accuracy above 85%, exactly 88.9%.

Table 2. Land cover class of the sample sites

Land cover class	**Citra - Satellite images**		**Identification features**
	Google earth	**Composite 3-2-1/5-4-3**	
Forests			Green-to-black colour plant community canopies with various shapes and densities
Mixed-species Plantations			Vegetable fields interspersed with tree canopies
Shrubland/ Drylands/ Fields			Land area that is dominated by understory vegetation such as shrubs, bushes, and grasses. Yellow to light green in color, rough texture, and irregular patterns
Open fields			Non-vegetation, non-settlement and non-water body areas. Brown or soft yellow in color
Settlements			Housing areas; roofs of houses are medium pink to soft pink
Pine Forests			Canopy shapes similar to "Forests", with relatively less density. Dark green, smooth texture
Rice Fields			Land planted with rice including irrigated rice fields, cultivation paddy fields and rainfed rice fields. Pink and blueish in color, smooth texture with regular patterns
Water Bodies			Land completely covered with river water; light-dark blue color, smooth texture with regular patterns

Source: Google Earth (2020), Landsat 8 OLI USGS (2016)

Trails of Javan pangolins are reported to be found in forest ecosystems (natural and production forests), shrub areas, and orchards. Pangolins can live in several habitat types, including primary forests, secondary forests, rubber, and palm oil plantations, and even in open spaces near human settlements (Lekagul and McNeely 1977; Nowak 1999; Challender et al. 2014).

Based on animal tracks and signs, habitats of pangolins were found to be scattered across five areas (Figure 3). The first area comprised Pasir Gagak (Block 1), Cigintung, Batu Sahul and Batu Nunggul (Block 2); the second area comprised Batu Wulung (Block 3). Curug (waterfall) Japarana and Curug Walet (Block 4) comprised the third area. The fourth area comprised Hutan (forest) Gowek and Gantung Cadas (Block 5), and the fifth area comprised Pongpok (Block 5). The area was grouped based on the range of Javan pangolins, which is reportedly around 4.5-7 km per night, with a total range of 6.97-43.3 ha (Lim and Ng 2008). Some areas are separated by large rivers, such as the first and second areas. The third and fourth areas are separated by the Cisokan River, while the Cilengkok River separates the fourth area from the second and third areas. The strong currents of these two rivers can wash away pangolins if they try to cross. Therefore, the areas separated by heavy river flows are assumed to be distinct home ranges (Withaningsih et al. 2018). Javan pangolins generally prefer steep slopes because such areas provide isolation and security. In this study, signs of Javan pangolins were found at an altitude of 531-757 masl.

The 45 identified signs of Javan pangolins in five different areas revealed a clumped distribution pattern, strongly influenced by barriers, such as food availability, area size, and topographic conditions such as extreme landscapes. Clusters of the animals shared the same living areas and formed large groups because of their basic reliance on the same ant and termite food sources.

Landscape structure at the sample sites

The landscape class metrics at the seven sample sites revealed eight land cover classes. The sample sites varied in the number of land cover classes that compose it (3 or 4 land cover classes), as indicated by the landscape class metric values in Table 3.

At the class level, the landscape metrics (i.e., number of patches (NPs), class area (CA), the percent of landscape (% LAND), and total edge (TE)) highlight the features of each class (Table 3). The landscape class structure differences at each sample site indicate variations in the landscape processes. A comparison of the composition of the land cover classes that make up each sampling site is illustrated in Figure 4. Three other land cover classes (settlements, pine forests, and rice fields) were not represented in the bar chart because they were not included in the sampling sites.

The NP value indicates the number of patches on each land cover class in a landscape. It includes the landscape metric parameters e.g., the number of patches that can determine the number of subpopulations in a spatially dispersed population or metapopulation for species that are specifically associated with a particular habitat type (McGarigal 1994). Forest fragmentation at the micro-landscape level is indicated by NP ≥ 1 (Ji et al. 2020) and all study sample sites showed forest fragmentation, with an NP value ≥ 1. The two sample sites with the lowest forest NP values were S04 (Pongpok) and S07 (Batu Sahulu). Sample 5 in Curug Japarana had the highest NP value, with 8 forest patches. The highest NP score was from the mixed-species plantation class in sampling site 5 (NP = 14). A higher NP value means a more diversified landscape, thus indicating an enhanced fragmentation process (Withaningsih et al. 2020). Patches in mixed-species plantations were found among the seven sites and had an NP value greater than 1. This indicated forest fragmentation and conversion of considerable amount of forest land for agricultural use.

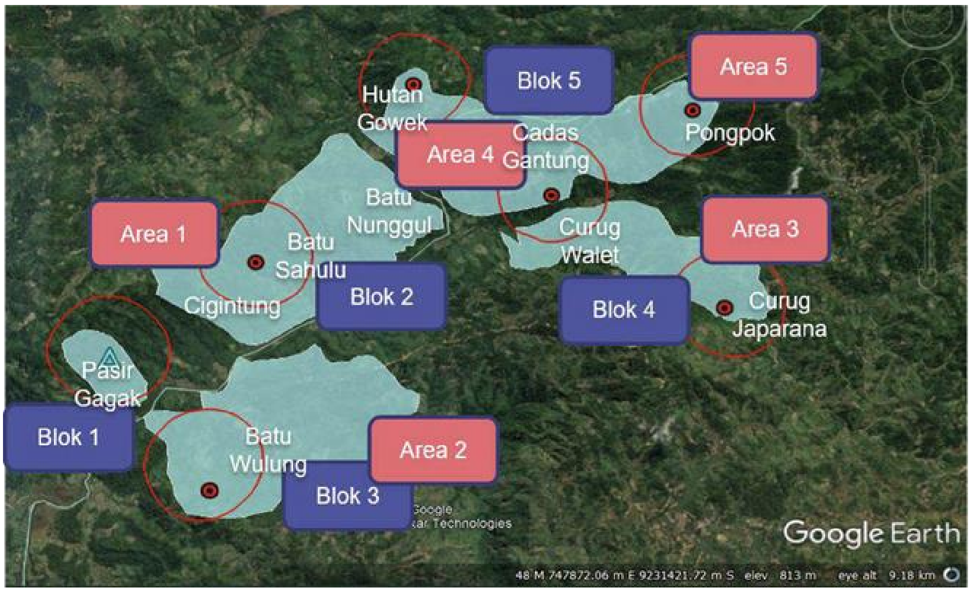


Figure 3. Distribution of Pangolin signs in the study area

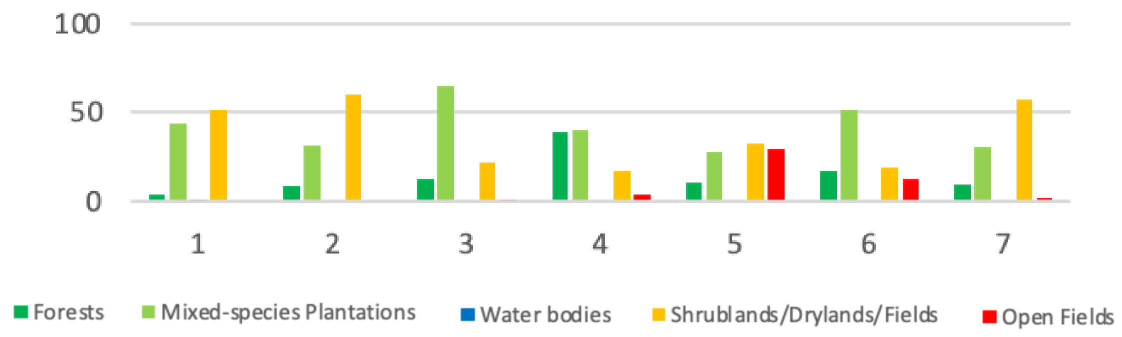


Figure 4. Land cover class proportions in the seven sampling sites of the study area

Table 3. Landscape features in sampling sites based on class metrics

Sample code	Name of sampling site	PR	Class	Class metrics				Landscape metrics			
				NP	CA (ha)	%LAND	TE (m)	TA (ha)	SHDI	LPI (%)	LP
S01	Area 2 (*Batu Wulung*)	4	Shrubland/ drylands/ fields	8	39.6	51.522	9960	76.86	0.8785	39.344	Shrubland/ drylands/ fields
			Mixed-species plantations	10	33.39	43.443	9300				
			Forests	4	3.15	4.098	1770				
			Water bodies	1	0.72	0.937	330				
S02	Area 1 (*Pasir Gagak)*	3	Mixed-species plantations	7	24.57	31.744	9120	77.4	0.879	56.860	Shrubland/ dryands/ fields
			Shrubland/ drylands/ fields	4	46.35	59.884	9900				
			Forests	5	8.3721	8.372	2940				
S03	Area 1 (*Cigintung, Batu Sahulu, Batu Nunggul)*	4	Mixed-species plantations	4	50.04	65.029	9570	76.95	0.9187	63.509	Mixed-species Plantations
			Shrubland/ drylands/ fields	11	16.74	21.754	7260				
			Forests	5	9.27	12.047	4350				
			Open fields	1	0.9	1.170	420				
S04	Area 4 (*Hutan* (forest) *Gowek)*	4	Mixed-species plantations	5	30.6	40.094	8070	76.32	1.1664	38.326	Forests
			Open fields	3	3.15	4.127	1530				
			Shrubland/ drylands/ fields	11	12.96	16.981	6540				
			Forests	2	29.61	38.797	4980				
S05	Area 4 (*Cadas Gantung)*	4	Shrubland/ drylands/ fields	13	24.84	32.318	9570	76.86	1.3178	16.510	Open fields
			Mixed-species plantations	14	21.33	27.752	8490				
			Forests	8	8.1	10.539	3780				
			Open fields	3	22.59	29.391	5700				
S06	Area 5 (*Pongpok*)	4	Mixed-species plantations	5	39.6	51.522	8100	76.86	1.218	33.138	Mixed-species Plantations
			Open fields	4	9.54	12.412	3060				
			Forests	6	13.14	17.096	5130				
			Shrubland/ drylands/ fields	13	14.58	18.970	7170				
S07	Area 3 (*Curug Japarana, Curug Walet*)	4	Shrubland/ drylands/ fields	4	43.65	57.193	9780	76.32	0.9965	55.542	Shrubland/ drylands/ fields
			Mixed-species plantations	11	23.49	30.778	8370				
			Forests	2	7.38	9.670	2700				
			Open fields	1	1.8	2.359	630				

Note: PR: Patch Richness, NP: Number of Patches, CA: Class Area, PLAND: Percent of Landscape, TE: Total Edge, TA: Total Landscape Area, SHDI: Shannon Diversity Index, LPI: Largest Patch Index, LP: Largest Patch

The NP value of habitat can also reflect the distribution of disturbances across a landscape. In particular, highly divided patch types may be more resistant to the spread of disruptions and, as a result, are more likely to persist in a landscape than adjacent patch types. Conversely, fragmented habitats may experience higher levels of disturbance (such as strong winds) than adjacent habitats (McGarigal 1994).

Mixed-species plantations including shrublands/ drylands/fields were found at all sample sites, which indicates occurrence of substantial human activity in each study block. Only in Hutan Gowek (Block 5) there was absence of mixed-species plantations, rice fields, and commercial crops, however, there were shrubs that signified past clearing for smallholder plantations. Javan pangolins occupied four of the eight land cover types in the study area. There are three land covers that are not inhabited by Javan pangolins, namely pine forests, settlements, and rice fields. This is due to the high human activity intensity.

The area of each land cover class can be assessed using the class area (CA) landscape metric. The CA represents the total amount of land covered by a landscape element and a large CA value indicates these landscape elements dominate a landscape. Therefore, the matrix of S03 (mixed-species plantations with CA=50.04 ha) is the most distinct homogeneous area in a landscape, as indicated by the largest CA value in a landscape (Withaningsih et al. 2020).

The landscape structure at the class level can also be analyzed based on the percentage of the land cover class measured by the %LAND metric. Regarding the proportion of land cover classes at each sample site, four of them had shrublands/drylands/fields as the land cover class with the largest proportion, while mixed-species plantations were the largest in three sites. As outlined in the ordination diagram (Figure 5), the proportion of land cover type at each sample site revealed that most land cover types were clustered, which explains the considerable similarity among the sample sites.

Based on the correspondence ordination diagram, three sample sites (S01, S02, and S07) were clustered around the coordinate point (-0.537, 0.186), the sample sites (S03, S04, and S06) were clustered around the coordinate point (0.719, -0.258), while the sample site S05 alone was located further away (-1,001, -1.006). As the coordinate point distances among sample sites indicate differences based on the land cover percentage in a given landscape, the site of the land cover coordinate point is influenced by the percentage of each land cover type at the sample site and the number of sample site that have a particular land cover. The ordination diagram shows that the variation in land cover percentage was relatively similar among six sample sites and different for one site (S05).

Another class-level landscape metric is the total edge (TE). TE is a measurement of the total length of the edge of a particular patch type. The TE value can be used to interpret the amount of connectivity between two land cover types. The highest TE values were observed for the shrublands/cleared land/field classes, and the lowest was for the water body classes. While lower TE values indicate the shape of a patch to be more rounded, the higher TE values are indicator for the patch shape to be more elongated (Withaningsih et al. 2020).

All sample sites consisted of shrublands/drylands/fields, forests and mixed-species plantation land cover types (Figure 5; Table 3). Based on the TE values of mixed-species plantation land cover, site S02, S05 and S06 had TE values of 9,120 m, 8,490 m and 8,100 m, respectively. This implies that the greatest connectivity between mixed-species plantations and natural forests was for sites S02 and S05, and the lowest connectivity was for site S06. The connectivity to natural forests affects the number of pangolin signs-more pangolin tracks are found in areas of higher connectivity to natural forests. However, in the current study, the number of signs did not differ much among the sample sites.

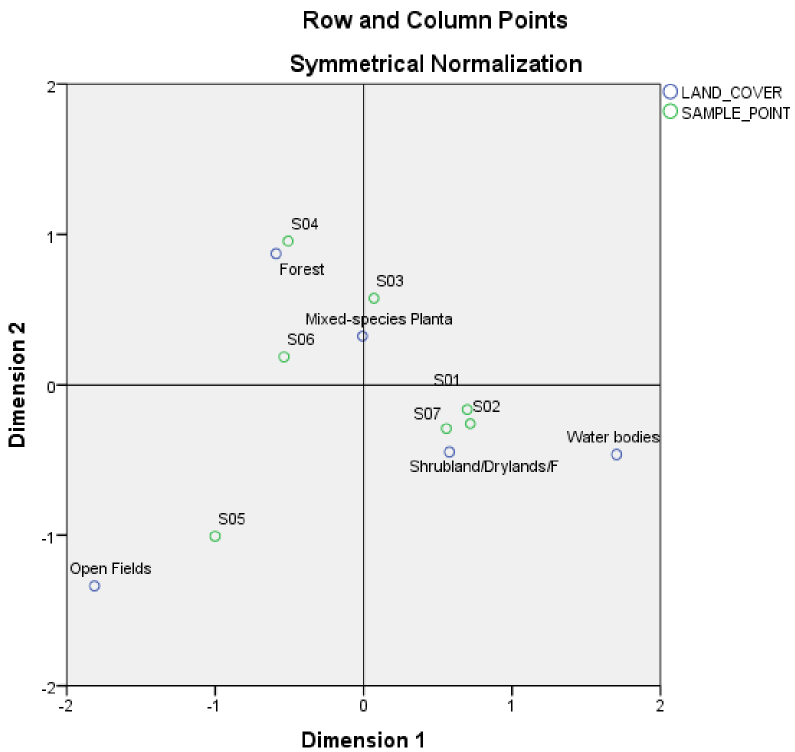


Figure 5. Correspondence Between sample sites and proportions of landscape classes

High total edge values between forest and mixed-species plantation land covers can increase the habitat connectivity and cause increase in contrast between a patch and its surrounding environment. Consequently, this increased contrast may affect several important ecological processes in Javan pangolin habitats, one of which is the edge impact (Forman and Godron 1986). Actively managed forest stands can form new forest edges. When allowed and uncontrolled over time and across space, forest exploitation such as clear-cutting will create complex networks of forest edges. The newly formed edges will change the landscape and may affect many environmental factors. These changing environmental factors have various impacts on forest growth and structure and can alter wildlife habitats. Additionally, forest edges may threaten the interior forest habitat of wildlife and expose sensitive species to harmful processes such as nest predation or parasitism (Ross and Tóth 2016). The correlation between each site based on the length of the class TE is shown in Figure 6.

After calculating several metrics at the landscape class level, measurement of the landscape level metrics for each sample site was also carried out. Landscape metrics such as SHDI, PR and LPI are used to compare landscape structures between sample sites.

PR is the landscape metric applied to measure variability in the sample sites. The PR value represents the richness of the number of patches in a landscape. A large PR value indicates more land cover classes within a landscape. Sample site S02 had the lowest PR value, consisting of 3 land cover classes, while the other sites had PR values of 4 (Table 3).

The total landscape area (TA) often does not provide much interpretive value when evaluating landscape structures, but this landscape metric is important for determining landscape size. Additionally, the total landscape area is used in calculations of many other class and landscape metrics. Sample sites S02 had the highest TA value (77.4 ha), while the lowest TA value (76.32 ha) was found for sample sites S04 and S07. The TE value in meters indicates the size of the edge. The highest TE value was found for sample site S05 (13,770 m), while the lowest value was for site S02 (10,560 m). The landscape structure metrics are presented in Table 3.

The SHDI values shown in Table 3 indicate the level of diversity and landscape heterogeneity and ranged from 0.8785 to 1.3178. The SHDI values of the sample sites are related to the number of classes, as assessed by the PR landscape metric, with decreasing SHDI values associated with decreasing NP and PR scores. The degree of landscape heterogeneity indicates the class variation within a landscape, and the LPI measures the dominance of the landscape class with the largest patch. Sites S02, S05 and S06 had SHDI values of 0.879, 1.3178 and 1.218, and LPI values of 56.86, 16.51 and 33.138, respectively. These three locations had PR values of 3, 4 and 4, and the SHDI value increased as the LPI value decreased. However, this trend was different in other sample sites with the same PR values, where the SHDI was greater in sites with larger LPI values.

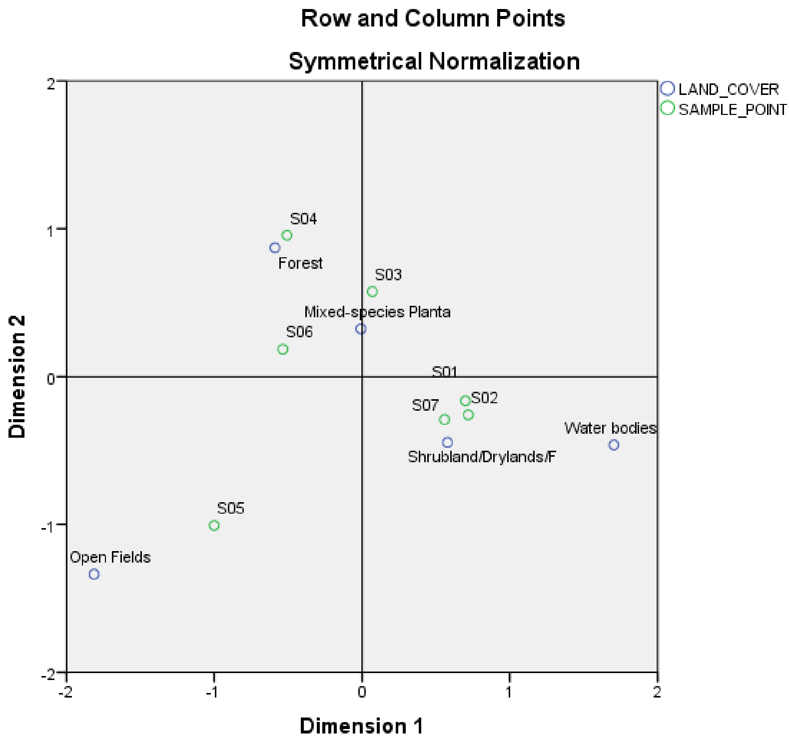


Figure 6. Correspondence between sample sites and total edge landscape class

Relationship between landscape structure and Javan pangolin distribution

A simple linear regression test was performed to determine the relationship between the landscape structure and the Javan pangolin distribution. The landscape structure variables tested were the SHDI, NP and the proportion of forest land cover at the sample sites. The Javan pangolin distribution data used were the number of trails obtained from the sign survey method as well as the number of signs of pangolins in the form of burrows (active and inactive), footprints, tail tracks, scratches and food scraps (Table 4). The data were then processed by linear regression analysis, and the results are shown in Table 5.

The simple linear regression results for the landscape structure and Javan pangolin distribution based on the number of signs found at each site indicate that the independent variable (X) PR and the proportion of forests are correlated to the distribution, while the SHDI is not. The SHDI, PR and the proportion of forests simultaneously do not have a significant relationship with the dependent variable (Y) (i.e., the Javan pangolin distribution). A large correlation value is based on the significance of F-change, where if the significance of F-change is less than 0.05 then the variables have a significant relationship (Sudjana 2013). The strength of correlation between the independent variable and the dependent variable is indicated by the R coefficient based on the magnitude of the Pearson correlation. The correlation coefficient of the independent variable PR was 0.792, indicating a strong correlation, while the three independent variables simultaneously showed a very strong correlation (R = 0.894). The SHDI and forest cover proportion showed weak correlations, with R values of 0.108 and 0.369, respectively.

The three landscape structure variables showed a greater degree of correlation with the dependent variable of the Javan pangolin distribution when they were tested simultaneously. The correlation between the three landscape structure variables and the Javan pangolin distribution is illustrated in Figure 7.

As shown in Table 5, the SHDI, PR and forest percentage have R^2 values of 0.012, 0.628 and 0.136, respectively. Figure 7 also illustrates the relationship between the independent and dependent variables (positive or negative value), which is indicated by the beta coefficient value.

The three landscape structure variables tested (i.e. SHDI, PR and the percentage of forest cover) were negatively correlated with the distribution of Javan pangolins, which means that increasing the values of SHDI, PR and forest percentage will reduce the likelihood of finding signs of Javan pangolins. This is because there are a variety of land cover classes (5) around the extreme landscape sample sites. While most of the sites had 4 land cover classes, site S02 had the lowest (Table 3). The other sample sites revealed a smaller number of Javan pangolin traces, ranging from 4-7 signs in the form of burrows/nests, footprints, tail tracks, scratches and food scraps, while site S02 which was located in the Batu Wulung area dominated by shrublands/drylands/fields, had 10 of the 45 Javan pangolin signs (9 burrow/nest traces and 1 food scrap sign). These suggest that increase in landscape diversity due to forest land conversion into open fields and high levels of human activity might reduce the likelihood of Javan pangolins in the area.

The decreasing forest patch percentage due to land conversion to cultivated land and shrublands/drylands/ fields does not significantly affect the existence of Javan pangolins. This is because they are adaptive animals that can live in various land cover types at different altitudes and with various climatic gradients. The extreme landscape, the habitat of Javan pangolins, is an area with steeply sloping topography and a variety of land cover types. Living in such habitat is a defense mechanism of Javan pangolins that protects them against predators and helps guarantee the availability of food sources, such as ants and termites (Withaningsih et al. 2018). This proves that Javan pangolins are able to live in different plant communities, except in areas of intense human activity.

Although Javan pangolins are adaptive animals that can live in various habitats, female Javan pangolins require intact forest cover. This is consistent with Lim (2008)'s study stating that the adaptation rate of female Javan pangolins during the reproductive period is low compared to male pangolins. During the nursing period, female Javan pangolins occupy only large tree trunks that have a diameter of over 50 cm. Therefore, intact forests are important for Javan pangolins during the breeding period, and the presence of this landscape type will be closely related to the future existence of Javan pangolins (Lim 2008).

Table 4. Number of Javan Pangolin traces at sample sites

Sample code	Trail/Sign	Quantity	Number of sign types	Total
S01	Burrows	4	4	7
	Footprints	1		
	Food Scraps	1		
	Tail Tracks	1		
S02	Burrows	9	2	10
	Food Scraps	1		
S03	Burrows	4	1	4
S04	Burrows	5	1	5
S05	Burrows	6	2	7
	Scratches	1		
S06	Burrows	3	3	7
	Tail Tracks	3		
	Footprints	1		
S07	Burrows	5	1	5

Source: Withaningsih et al. (2018).

Table 5. Linear regression of landscape structure and Javan Pangolin distribution

Independent variable (X)	Correlation coefficient (R)	Coefficient of determination (R^2)	Sig. F change
SHDI	0.108	0.012	0.818
PR	0.792	0.628	0.034
Forest Cover Proportion	0.369	0.136	0.415
SHDI, PR, Forest Cover Proportion	0.894	0.799	0.143

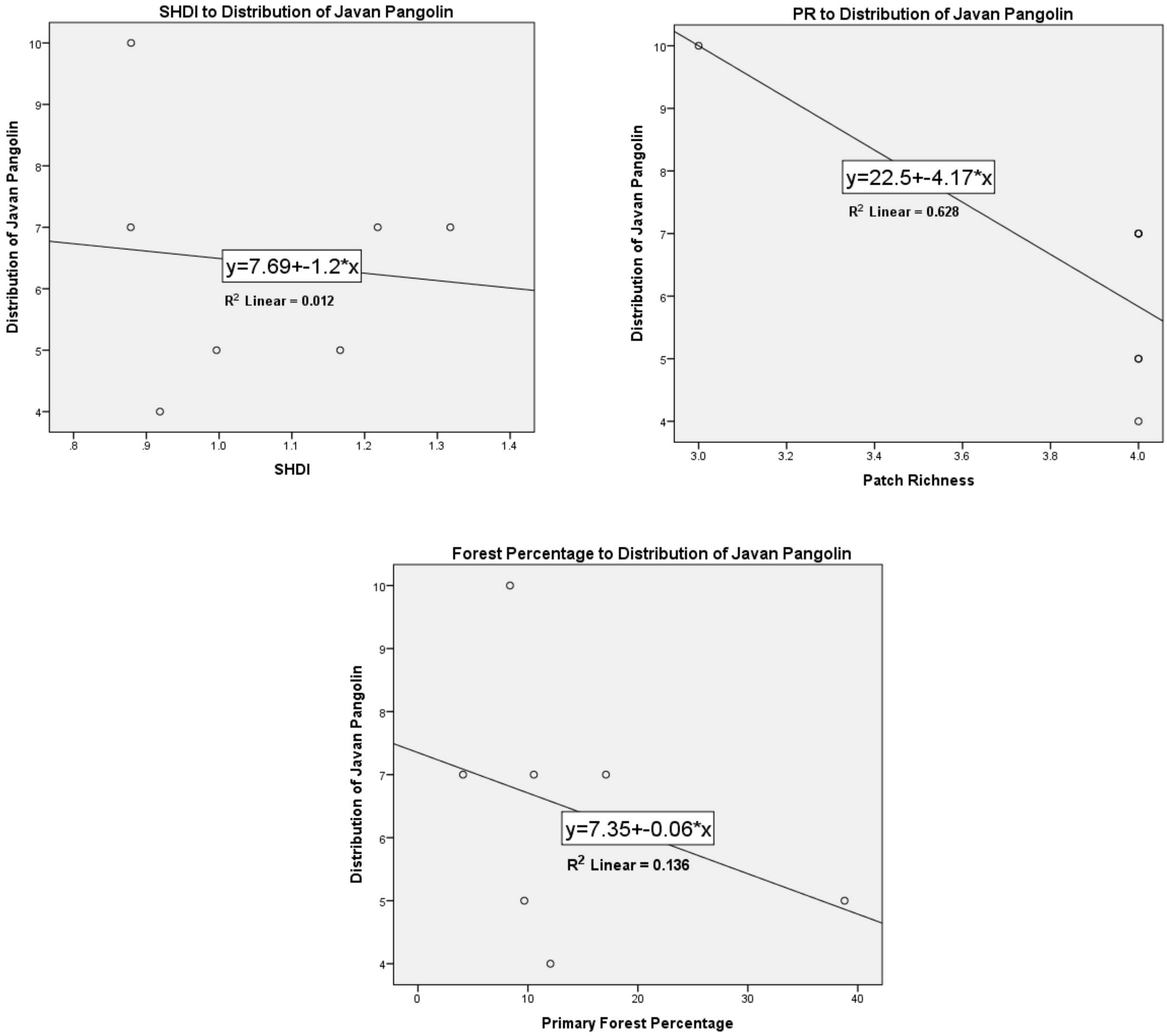


Figure 7. Linear regression of landscape structure metrics (%Forest, PR, SHDI) and Javan Pangolin distribution

A landscape structure has two qualities, namely, composition and configuration. The landscape composition is a good indicator to assess the environmental suitability of a species. The distribution of Javan pangolins is influenced by the composition of the landscape as seen from the Javan pangolins' response to the availability of habitat and food sources in the landscape.

According to Lim (2008), Javan pangolins are found in secondary forests, agricultural areas and settlements due to the availability of their primary food source, ants and termites, which is available in these habitats. Many burrows/nests were found in locations where food was abundant near the burrows. Based on the study of Withaningsih et al. (2018), the existence of Javan pangolins was extrapolated from the presence of their nests/burrows, most of which are rock burrows. Pangolins also bore soil burrows for resting and for accessing food and soil burrows are easier to construct because of the soft soil texture and cost them less energy compared to build other types of burrows.

The availability of habitats and each element of a landscape affects the distribution of Javan pangolins. These animals respond differently to various landscape compositions. According to Kuswanda and Setyawati (2016), Javan pangolins will not forage or nest in certain habitats, and they tend to use various types of land cover that are suitable for them. These habitat preferences likely occur because Javan pangolins are insectivorous animals and tend to spread according to their food sources.

The preferred habitats of Javan pangolins are secondary and mixed forests with limited vegetation at the seedling and understory levels and close to a normal soil pH. Such habitats make it easier for Javan pangolins to detect ant holes and mounds because of the more open forest floor. Primary forests and community plantations are less preferred because of humid soil conditions (low temperatures) and the presence of predators (Kuswanda and Setyawati 2016). This may be a limiting factor in the pangolin distribution due to fewer such forest land types and presence of larger agricultural areas that use pesticides, which can reduce the soil pH.

The percentages of natural land cover and cultivated land also affect the distribution of Javan pangolins. Javan pangolins are adaptive animals that can live in various types of habitats, but they are also sensitive and have a low tolerance for living in proximity to humans (reportedly also due to low tolerance of pangolins to noise (Sawitri et al. 2012). The increased percentage of cultivated land cover due to land clearing for agriculture (where human activity is very high) can disturb Javan pangolins, resulting in their inability to nest and forage in the disturbed locations (Withaningsih et al. 2018).

Withaningsih et al. (2018) identified 45 signs of Javan pangolins; 36 signs were of active and inactive burrows/nests discovered on land cover types dominated by shrublands/drylands/fields. Javan pangolins are also found in the production and secondary forests in the districts of Tanggamus and West Lampung (Wirdateti et al. 2013). In the current study, burrow/nest traces were found at all sample sites, while there were few footprints, tail tracks, food scraps and scratches. These findings may be because Javan pangolins are nomadic animals that tend to move their burrow/nest locations every day, hence many burrows can be found in different places. In addition, burrows/nests are the easiest signs to find because they are more durable than other traces such as footprints, tail tracks, and scratches, which can be easily washed away by rainwater (Withaningsih et al. 2018).

The three tested landscape structure variables, SHDI, PR and percentage of forest cover, were negatively correlated with the pangolin distribution. However, based on an F-change significance value of <0.05, only the PR was significantly correlated with the distribution and had a strong correlation coefficient ($R=0.792$). This finding was supported by the number of signs of the Javan pangolin presence. The statistical analysis indicated that a greater PR value was correlated with fewer signs of Javan pangolins. Additionally, the low correlation coefficient for the SHDI and for the percentage of forest cover could have been caused by the somewhat lacking and irregularly distributed data. As a result, these data could not be processed by a linearity test even though they were normally distributed, and they eventually fell far from the regression line. Similarly, Withaningsih et al. (2019) assert that the connectivity with other land cover types causes confusion in the correlation between the forest cover percentage and the distribution of Javan pangolins. This may also be due to other characteristics of the forest such as the number of patches and the total length of the edges at each sample site, which may indicate forest fragmentation.

The present study aimed to propose conservation measures for Javan pangolins, which were categorized as critically endangered by the IUCN, by using comprehensive ecological study through correlation between the landscape structure and their habitat distribution in Rongga Sub-district using a landscape ecological approach. The relationships between the habitat landscape structure and the presence and distribution of Javan pangolins were investigated and showed mixed results: the correspondence analysis of the forest cover percentage and the total edges of each landscape class indicated that the characteristics of six sites tended to be similar, while one site was different.

The results from the landscape diversity of the sample locations based on the SHDI and the number of landscape class types calculated using the PR metric indicated a forest fragmentation level. Forest fragmentation alters the distribution of Javan pangolins, as seen by the number of pangolins signs. The distribution is also affected by the tolerance to habitat disturbance and human activities. Additionally, the increase in landscape diversity due to forest land conversion into open fields and high levels of human activity might reduce the likelihood of Javan pangolins in the area. The statistical analysis results indicated that a greater patch richness was correlated with fewer signs of Javan pangolins.

Lastly, the forest cover percentage indicates the level of connectivity between the Javan pangolin natural habitats and other land cover types, especially cultivated land. Habitat fragmentation increases the connectivity among habitats, allowing the movement of Javan pangolins from natural land cover types to cultivated lands. Threats and disturbances to Javan pangolin habitats are increasing and will limit their existence and distribution in the study area. Therefore, more consolidated study is required to increase tolerance of pangolins to human disturbances (Wirdateti et al. 2013) and increase data sampling for strengthening statistical relationships among landscape metrics such as SHDI and percentage of forest, in terms of Javan pangolin distribution.

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