Spatial distribution pattern of *Tarsius Lariang* in lore lindu national park

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ABSTRACT

Tarsius lariang (T. lariang) is an endemic species in Lore Lindu National Park (LLNP). Available information regarding T. lariang is limited to only morphological, anatomical, cytogenetic, and voices issues. Knowledge for its geospatial characteristics such as spatial preferences and spatial distribution is rare. The main objective of this study is to identify the spatial distribution pattern of T. lariang in LLNP. An additional objective is to identify the environmental factors affecting its spatial distribution patterns. Field observation for distribution pattern was done at the observation plot that were using systematic sampling with random start. Furthermore, the density estimation in each point was calculated using Triangle Count and Concentration Count method, while insect abundance was estimated using light traps sample data. Finally, spatial pattern was estimated using nearest neighbor index, while the environmental affecting factors were identified by using spatial analysis and correlation analyses. From 45 observation points, the T. lariang distribution pattern was clumped. It is also recognized that the significant factors affecting the spatial distribution were insect abundance, proximity from the commercially utilized land, and land surface temperature.

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1. INTRODUCTION

The Lore Lindu National Park (LLNP) is one of the most important tropical rain forest conservation areas located in the eastern part of Indonesia. Geographically, the LLNP is located within the Wallacea region that blending Asian and Australian flora fauna has high species endemicity. *Tarsius lariang* (*T. lariang*) is one of the endemic animals found in LLNP which has the smallest body size compared to other primate species [1, 2]. There are three species of *T. lariang* in the TNLL, i.e., *T. pumilus, T. dentatus and T. lariang*. Based on a series of morphological, anatomical, cytogenetic, and voice research in 2006 [1], *T. lariang* was recognized as a "new primate species from western Central Sulawesi" [1].

The recognition of *T. lariang* as a new species has been very important step for its conservation. According to the IUCN [3], currently the status of the conservation of *T. lariang* is "data deficient" or lack of data. Up to now, no scientific publication has been found related to geospatial information of *T. lariang* in LLNP, while the information about *T. lariang* is crucial in this area. So far, the available research on *T. lariang* outside of TNLL has been reported in 2006 [1], however, the study is limited only on the morphological, anatomical, cytogenetic, as well as voices. Another issue that also should be considered in the area, is the pressure that the national park has from various land utilization, such as land for coffee and cocoa plantations, bamboo and rattan collection activities, which may affect the status of *T. lariang* population.

By considering the above issues, efforts for conserving the *T. lariang* have been undertaken through appropriate conservation programs, collecting information on distribution patterns as well as the environmental factors like habitat preference of *T. lariang*. The utilization of spatial knowledge, *i.e*., geospatial information system (GIS) in various fields of natural resource management has been widely applied, particularly by using various spatial modeling [4-8]. Now, the GIS technology has been proven as effective tools and methods to monitor management activities, analysis and visualization of wild animal's data, including habitat requirements and ranges, population patches and linkages, disease levels within populations, progress of management activities and historical and present wildlife densities [9].

In this study, the GIS technology was applied for estimating the spatial characteristics and analyzing the spatial pattern of *T. lariang* in TNLL, by integrating the spatial capability analysis of GIS software and field-based data inventory. The main objective of the study *is to identify the spatial distribution* and spatial pattern of *T. lariang* in TNLL, while the additional objective is to identify the environmental factors affecting its distribution pattern. The environmental factors considered were biophysical and anthropogenic factors.

2. RESEARCH METHOD

2.1. Date and Site

The field data collection was conducted from April 2011 to March 2012 within a part of the TNLL area. Research data was located within the working area of Toro and Moa resorts.The area is located within Kulawi and Southern Kulawi, Sigi and Poso Regencies Central Sulawesi Province.

2.2. Tools, Software, Hardware, and Data

For Field data collection, the equipments used were global positioning system (GPS) tracking device, clinometer, and altimeter. For insect observation, the study used light trap, white cotton fabric 3 m long and width 2 m, and ethyl acetate. The spatial analysis was carried out using *ArcGIS version 10.1*. The main spatial data was Landsat Thematic Mapper (TM) image path 114 / row 61 of 2011; while the supporting data include administrative maps, LLNP area maps, contour maps and Indonesian landform map at a scale 1: 250,000 sheets 2014–64 (Maranata), 2114–43 Kamarora, 2014–62 (Kulawi), 2114–41 (Langko), 2114–42 (Wuasa), 2114–13 (Lawua), 2114–14 (Doda), and 2114–11 (Gintu); boundary map of TNLL forest area.

2.3. Data Collection and Analysis

2.3.1 Data Collection

T. lariang distribution data was collected through field surveys by exploring areas of *T. lariang* concentration in various habitat types. The sample unit of observation was laid out by using systematic sampling with random start with 1 km x 1 km interval, processed spatially using extension IHMB version.34 [10]. Each direct encounter of *T. lariang* was recorded in habitat type and linked with other data such as temperature, humidity, slope, altitude and its geographic coordinates using the GPS tracking device. Data collection for relative density of individual population of *T. lariang* was done by using Triangle Count and Concentration Count [11, 12]. The calculation of relative density of individual *T. lariang* was using the formula developed by O'Brien and Duma [13, 14]. The calculation of the abundance of insects was done by trapping insects at each point of *T. lariang* encounter. Trapping insects was done by using a light trap. For analysis, the considered insects were those only have a body length longer than >1 cm.

2.4. Data Analysis

2.4.1 Identification of *T. lariang* concentration area

Spatial distribution of *T. lariang* was obtained based on the number of individuals encountered in the field, by marking the geographic coordinate using GPS tracker. Furthermore, the spatial distribution and the concentration area of *T. lariang* were analyzed using Inverse Distance Weigted (IDW), interpolation method available in *ArcGis version 10.1*. The result of *T. lariang* density interpolation was used later on, as the basis for determining the location spatial pattern and identifying the affecting environmental factors.

2.4.2 *T. lariang* spatial distribution pattern

Spatial distribution patterns were analyzed to determine the relationship between the distribution of *T. lariang* and the factors that might affect it.The method used in estimating spatial distribution pattern was Nearest Neighbor Index (NNI), calculated by using the following formula:

$$NNI = \frac{DO}{DE};\ \mathrm{DO} = \frac{\sum_{i=1}^{n} di}{N};\ DE = \frac{0.5}{\sqrt{\frac{N}{A}}}$$

DO is Observed Distance, while DE is the Expected Distance. The spatial distribution pattern will be categorized as clumped when the NNI<1; as random when the NNI≈1; and as dispersed (uniform) when the NNI >1 [15, 16].

2.4.3 Environmental factors affecting the spatial pattern

The environmental factors considered in this study include proximity from settlement, commercial areas (cacao, coffee, and mixed garden), and proximity from the road. Those factors were derived from the spatial operation using the GIS software for obtaining spatial distribution of the insect abundance, then the IDW was applied. The statistical parameters for each environmental factor are summarized in Table 1.

Table 1. Environmental factors and disturbance area used in analysis

Environmental factors	Minimum	Maximum	Total data	Interval
Insect abundance (ind/hour/km^2)	1.1	63.4	80	0.8
Distance from road (m)	50	7300	138	53
Distance from settlement area (m)	100	7300	73	99
Distance from commercial area (m)	100	4800	48	98
Altitude (asl)	369	1653	42	30.6
Slope (%)	1	52	36069	0
Temperature (^{0}C)	22.5	27.1	93	0.05
Humidity (%)	77.2	86.0	102	0.09

2.4.4 Determination of environmental factors on spatial patterns

For selecting the most affecting factors, the study analyses the correlation among the dependent variable (density of *T. lariang*) and all the independent variables (environmental factors) as mentioned above. The steps for selecting the most significant variables are as follows:

1. All independent variables, i.e. abundance of insects (X1), distance from road (X2), distance from settlement (X3), distance from commercial area (X4), elevation (X5), slope (X6), temperature (X7), and the humidity (X8) were examined.
2. All variables except insect abundance (X1) were examined. The X1 is excluded since this variable is relatively difficult to obtain.
3. Insect abundance (X1), commercially unit areas (X4), and temperature (X7) where examined due to their close correlation with the density of *T. lariang*.
4. Variable distance from commercial area (X4) and temperature (X7) were examined. These two variables are easily derived from the existing remote sensing technology and considered to have a high correlation with the density of *T. lariang.*
5. Only variable insect abundance (X1) was examined. This to assess the capability of this variable to estimate the spatial distribution pattern of *T. lariang*.

These variables were used to classify the density of *T. lariang* using the clustering method, where the dendogram was developed using the complete linkage algorithm.

3. RESULTS AND ANALYSIS

3.1. Location identification of *T. lariang* spatial distribution area

From the 45 observation points of *T. lariang,* in Figure 1, the study shows that *T. lariang* is distributed in transitional areas between primary and secondary forest. This indicates that *T. lariang* is the *edge species* animal. High abundance of insect feeds in edge area or ecotone has been closely correlated with the density of *T. lariang*. This is in line with the study of Mansyur *et. al*. [17] that *T. tarsiers* in the Lambusango Forest of Buton Island are found in the forest edge area habitats.

The edge forest area has a unique microhabitat vegetation structure with more vegetative species and more seedlings [18, 19]. Low canopy cover on these edges causes an increment in insect-feed biomass [19]. From the spatial data of the location and density of *T. lariang,* the spatial analysis shows that spatial distribution pattern of *T. lariang* in LLNP is clumped with NNI = 0.2 or <1. The spatial distribution pattern of *T. lariang* is related to its behaviour to maintain its survival, and closely related to environmental conditions, such as bio-physical and anthropogenic factors. This clumped distribution of *T. lariang* might be influenced by its behaviour, as territorial animal, competing with other Tarsius species, such as *T. dentatus*. Homogeneity of habitat, and other factors (such as prey, biomass-feed, and other suitable factors) are also suspected in affecting the spatial distribution of *T. lariang* [19-21].

Most of the field observation points belong to the primary forest (40 points) while only a few points (5 points) belongs into secondary forest. Primary forest has a good quality for habitat of *T. lariang*. In primary forest land cover, there are many *ficus sp*. trees and large trees that have holes for shelter and rest, whereas secondary forests are preferred as feeding places. This case was similar to the *T. tarsier,* found in Tangkoko-Batu Angus Nature Reserve area of North Sulawesi, that uses *ficus* spp tree as its nest [22]. Other allegations that cause spatial distribution of clustered *T. lariang* are kinship, gregarious behavior, similarity of interest in the utilization of resources (feed and space) and anti-predator [23].

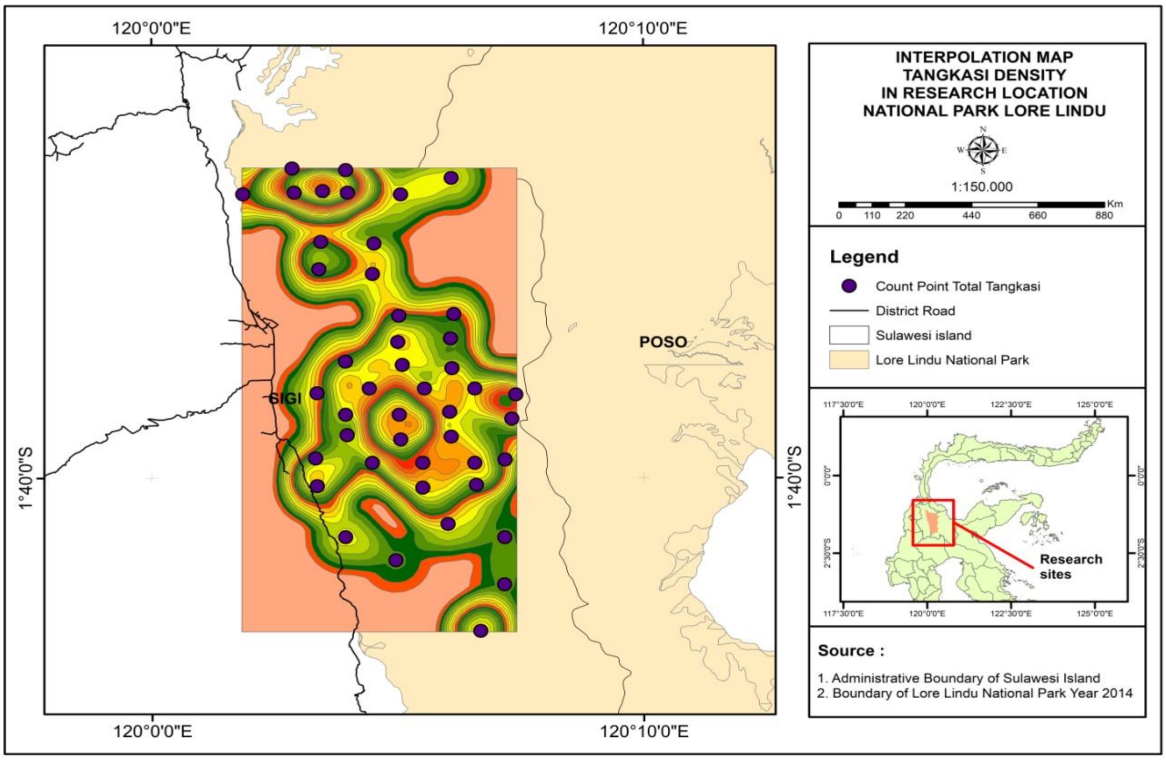

Figure 1. Spatial distribution of *T. lariang* developed using IDW interpolation result in Lore Lindu National Park

3.2. The environmental variables that influence spatial distribution pattern of *T. lariang*

Based on the results of analysis, there are 7 variables that have high contribution to the spatial distribution pattern of *T. lariang*. They are the abundance of insects, followed by the distance to commercially utilized area, humidity, temperature, distance from the road, distance to settlement and altitude. Slope variable within the study area do not significantly contribute in the spatial distribution pattern of *T. lariang*, having very small R^2 value of only 32.3%.

3.2.1 Correlation of *T. lariang* density with source of feed

Tarsius is a small primate which is classified to the first primitive insectivore category that makes the staple food [24, 25]. Tarsius uses hearing sensors to catch insects from their rustling voices and flutter of its wings [25, 26]. Tarsius takes 58-–141 grams of insects per day to meet their feeding needs [27]. The result of the analysis in Figure 2, shows that there is a very close correlation between density of *T. lariang* and the insect density with R value close to 1. This means the increasing of insect density has significant effect on the increasing of the density of *T. lariang*. The increasing of insect density is proportional to the density of *T. lariang* population due to the need of feed of *T. lariang*. Insects provide a variety of nutrients for the needs of insectivore primates including protein, fat, carbohydrates, chitin, enegy, vitamins and minerals [28]. The distribution pattern of *T. lariang* is significantly influenced by the abundance of insects to fulfill their daily needs (feeding) in performing their daily activities. Habitats that have a high abundance of insects affect significantly the high spread of density. Abundance of feeding sources is a factor that affects the distribution and density of animal populations [29].

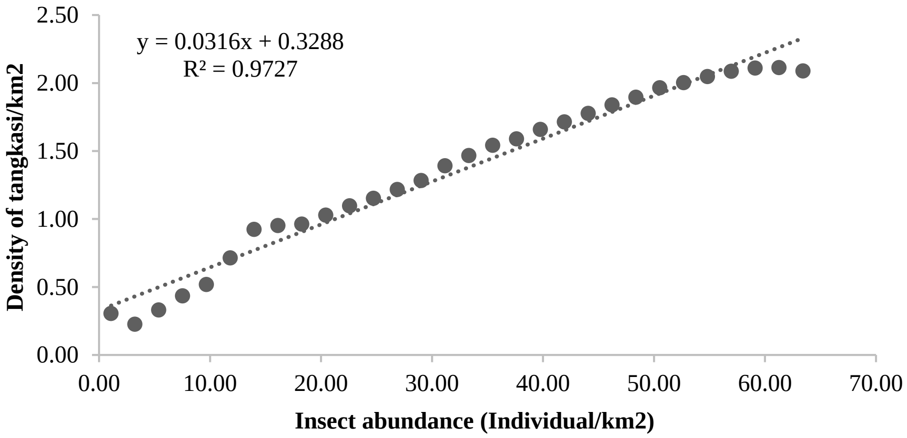

Figure 2. Correlation between the density of *T. lariang* and insect abundance

3.2.2 Correlation of T. lariang density with physical factors

Analysis of correlation between *T. lariang* density with physical factors consisted on the analysis of correlation between *T. lariang* density with temperature, humidity, altitude and slope. Air temperature and air humidity are closely correlated when the increasing of one unit of air temperature will affect the change of humidity. Each species of animals has different respond on different temperature and humidity values. Environmental temperature has a significant role in influencing the pattern of wildlife spatial distribution. So that temperature and humidity are included as limiting factors for wildlife survival. The results showed that the air temperature of *T. lariang* habitat was found in the ranges 22.5^{0}C–27.5^{0}C and humidity ranged between 75–87% (Figures 3.a and 3.b). The *T. lariang* abundance seems to increase when the environmental temperature increases up to 27.5^{0}C with 79% air humidity. *T syrichta* in captive breeding will die if the air temperature reaches below 18^{0}C. The preferred temperature ranges from 25^{0}C to 30^{0}C, while the preferred humidity to prevent dryness of the skin is about 80% [29, 30]. The regression line form of *T. lariang* density with temperature is power shape with high R^2 of 72%. Since there is a very close correlation between the air temperature and air humidity (r = 0.95), therefore, to simplify the model, only one variable would be selected, either humidity or temperature. The correlation between air temperature and humidity with *T. lariang* is quite high, larger than 0.7 so that air temperature and humidity have significant effect to the increasing of *T. lariang* abundance. This shows that temperature has significant impact to the abundance of *T. lariang* in Figure 3a).

The highest level of *T. lariang* abundance occurs in areas with altitude between 800–1000 masl (Figure 3.c) and will decrease along with the increase on altitude. The altitude of 2000 masl has the highest insect diversity and will decrease along with the increasing of altitude [31-33]. This is in line with the general theory of ecological changes, when altitude of the site increases, the temperature decreases, the density of flora is linearly decreased and the diversity of both flora and fauna decreases [33]. Another factor in decreasing the density of *T. lariang* is the increasing of altitude, the higher the altitude, the lower the insect species diversity, which represents the source of *T. lariang* feeding [33, 34]. The altitude also affects *T. pumilus* when the altitude of the site decreases the feed source, which affects its behavioral change, morphology and body size [31]. Regression analysis of the *T. lariang* density with the slope shows the R^2 value of only 32.27% in Figure 3d. This shows that there is no significant effect of slope variation to the *T. lariang* density.

T. tarsier in Buton island was found at most on the slopes >40% which belong to the category of very steep slopes [17]. Tarsius on Selayar Island and TWA Patunuang South Sulawesi are more commonly found on topographic ramps up to 20% slopes [35] and *T. fuscus* in Bantimurung Bulusaraung National Park at low slopes ranging from 0–25% [34]. This study differs from the study of *T. tarsier* in Buton where the *T. tarsier* was more commonly found at the slopes steeper than 40% [17].

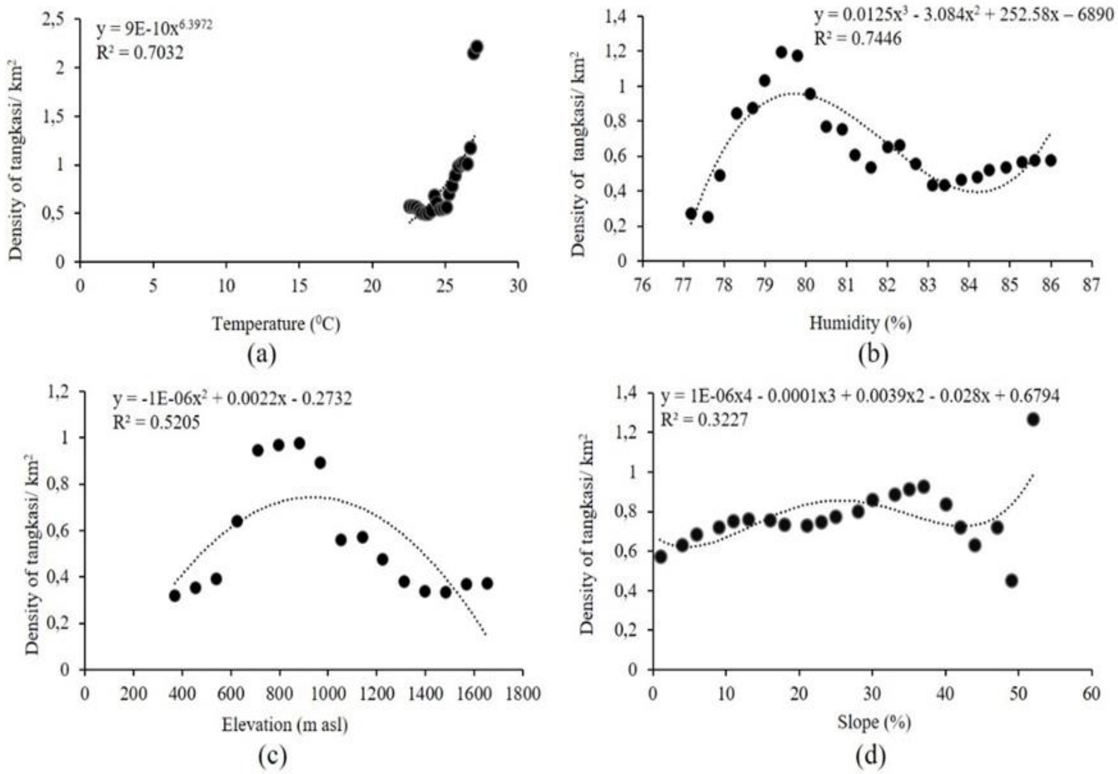

Figure 3. Correlation of *T. lariang* density with (a) temperature; (b) humidity; (c) elevation; (d) slope

3.2.3 Correlation between density of *T. lariang* with human disturbance

T. lariang is an animal that has different responses to human presence, depending on the types of contact and *T. lariang's* interaction with humans. For *T. dianae* located in Kamarora TNLL, high dense populations are mostly found in the areas with high disturbance [1, 36]. This study examined three disturbance factors that affect the density of *T. lariang*, namely the distance from commercially utilized area, the distance from settlement and the distance from road. The regressions between *T. lariang* and distance from road, settlement, and commercial area show high coefficients of determination of 61.4%; 60.7%; and 79.9%, respectively. The R^2 value between *T. lariang* and all human disturbance factors is >50%, indicating that all factors influence the density of *T. lariang*. The *T. lariang* density also has a very close correlation with proximity from commercial area, in Figure 4.a, where the highest density was occurred at the 4000 m distance. The highest density of *T. lariang* was also found at the distance of 4000 from the settlement area in Figure 4.b and the highest abundance of *T. lariang* were found at the distance of 4000 m from the road in Figure 4.c. The maximum distance between *T. lariang* density and all three disturbance factors is indicated as the edge area, this is identified by the tendency of the dropping back density after the maximum density increases. In these areas, it is possible that human disturbances are not very high, have sufficient feed abundance and allow *T. lariang* to hide into the primary forest area. The size of the *T. dianae* group decreases with increasing levels of disturbance and *T. pumilus* has an increased abundance in line with the abundance of insects at the edge area [1, 31].

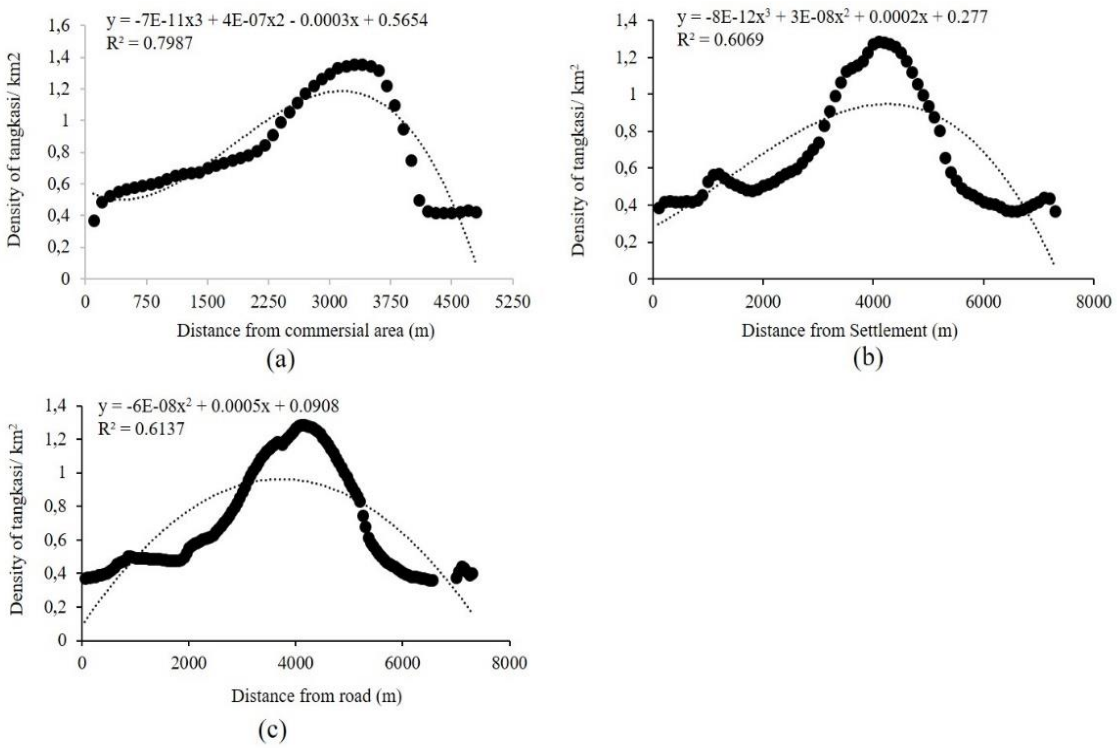

Figure 4. Correlation of *T. lariang* density with (a) commercial areas; (b) settlement areas; (c) distance from road

3.3. Selection of determinant variables

This research uses 8 variables X as mentioned previously independent of *T. lariang* such as namely (a) abundance of insect (X1), (b) distance from road (X2), (c) distance from settlement (X3), (d) distance from commercial area (X4), (e) altitude (X5), (f) slope (X6), (g) temperature (X7), and (h) humidity (X8), while the dependent variable is the density of *T. lariang* (indicator Y). Table 2 shows that the highest correlation occurs between the density of *T. lariang* with the abundance of insects with a R^2 value of 97.3%. Except for slope (X6), there is a close correlation between density of *T. lariang* and affecting factor with R^2 >50% (R >0.7).

Table 2 Determination coefficient value among the variables

Variables	Determinant coefficient (R^2) (%)							
	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7
X_1	97.3							
X_2	61.4	31.4						
X_3	60.7	32.3	96.8					
X_4	79.9	40.8	80.5	87.3				
X_5	52.1	22.3	58.9	73.0	67.0			
X_6	32.3	3.6	11.5	12.5	9.3	2.3		
X_7	70.3	12.1	30.9	36.5	5.6	33.3	4.9	
X_8	74.5	15.9	30.4	30.9	11.2	5.5	0.2	89.6

Information: Y: density of *T. lariang*, X_1: insect abundance, X_2: distance from road, X_3: distance from settlement areas, X_4: distance from commercial areas, X_5: altitude, X_6: slope, X_7: temperature, X_8: humidity

Among independent variables, temperature (X7) and humidity (X8) have a quite high R^2 value of 89.6%. This relationship shows that the higher the temperature the lower the humidity. In addition, the distance from the road (X2), distance from the settlement (X3), and the distance from the commercially utilized area (X4) have a very high correlation, more than 80% (see table 2). Furthermore, for developing the *T. lariang* density class, into 2 or 3 classes, the clustering analysis was performed, where the class was grouped using complete linkage approach. The classification used several combinations that are related with the density of *T. lariang* (Y).The three types of combinations were examined, namely (1) all X variables were used, (2) three X variables, i.e., insect abundance (X1), distance from commercial area (X4), and temperature (X7), with Y. (3)

The distance from the commercial area (X4) and the temperature (X7) with Y. Then variable combinations in each determinant variable was chosen based on accuracy value assessment.

3.3.1 Classification of spatial distribution variable

By using the clustering method with the complete linkage dendrogram, the spatial distribution of the *T. lariang* was classified into 2 dan 3 classes. Within all examined combination, the obtained accuracy assessment is summarized in Table 3. It is shown that the overall accuracy of 3 classes is very high (90%). When the classes was merged into only 2 classes, the overall accuracy (OA) of the classes was even higher, i.e. 96%, with 94% producer's accuracy (PA) and 97% user's accuracy (UA).

To avoid multicollinearity and simplify the clustering process, only X1, X4 and X7 were examined. When the independent variables were X1, X4 and X7 then the obtained overall accuracy was about 87%. Furthermore, when the number of variable was reduced, where only the X4 and X7 were considered then the OA decreased to 83.5%. This study recognized that the variable X4 and X7 provide much better accuracy as well as more practical implementation, in comparison with the use of the variable X1 alone. Although, the variable X1 alone provides an OA of 76.9%. The use of variable X1 (insect abundance) would be more difficult due to the limitation of the insect abundance.

Table 3. Accuracy assessment using with 2 and 3 classes

	Accuracy of 2 classes (%)	Accuracy of 3 classes (%)
Variable all		
OA	96.2	90.0
Avg PA	94.4	89.3
Avg UA	97.7	89.0
Variable X1, X4, X7		
OA	96.6	86.7
Avg PA	97.4	85.7
Avg UA	95.8	91.7
Variable X4, X7		
OA	93.3	83.5
Avg PA	96.7	75.0
Avg UA	96.6	92.0
Variable X1		
OA	88.3	76.7
Avg PA	90.7	62.5
Avg UA	68.8	80.5

Information: OA = *overall accuracy*, Avg PA = *average producers accuracy*, Avg UA = *average user accuracy*

4. CONCLUSION

From the forgoing discussion, the study concludes that *Tarsius lariang* species has a clumped spatial distribution pattern. The clumped pattern of *T. lariang* is empirically influenced by some environmental factors. The most significant environmental factor affecting the density of *T. lariang* is insect abundance (X1), followed by distance to commercial area (X4), humidity (X8), temperature (X7), distance from the road (X2), distance to settlement (X3), and altitude (X5). These ones significantly affect *T. lariang* density with coefficients of determination (R^2) larger than ≥50%. The slope variable (X6) does not affect the spatial pattern significantly. For classifying the spatial distribution of the *T. lariang*, the classification into 3 classes with all variables provides excellent accuracy of 90% OA, 89.3% PA, and 89.0% UA. Meanwhile, analysis with X1, X4, and X7 provides 86.7% OA, 85.7% PA and 91.7% UA. The use of only X4 and X7 for density classification provides about 83.50% OA, 75.0% PA, and 92.0% UA.The variable X1 (insect abundance) is not recommended since the variable is technically impratical.

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