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Original article

Biophysical and anthropogenic factors affecting human and Tapanuli orangutan (*Pongo tapanuliensis*) conflict in Sumatran tropical rain forest, Indonesia

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ABSTRACT

Tapanuli orangutan (*Pongo tapanuliensis*) is a critically endangered species that must be conserved. One of the locations where it is found is Dolok Sipirok Natural Reserve. The threat to this species arises from land use of agriculture and accessibility to the area, resulting in *human-orangutan* conflict. Identification of conflict areas is necessary. Information on the contributing factors to conflicts between humans and orangutans is also important. This research analyzed the relationship between spatial characteristics with conflict location. The factors including distance to the forest boundary, road, and the river, slope, altitude, and land cover were analyzed. Statistical analysis was performed using Rank Spearman correlation coefficient was. The results showed that distance to farmland and altitude were the main factors affecting the conflict, while the weakest factor was distance from the road. Arse Nauli village was the place where most conflicts occurred. The most robust relationship with conflict was altitude.

KEY WORDS: agriculture, altitude, Batang Toru, Dolok Sipirok nature reserve, human-wildlife conflict, Tapanuli orangutan

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1. Introduction

Human settlements, farming roads, and other structures that encroach on forest reserves can be a severe problem, especially in areas where economic growing fast and nature reserves are underdeveloped (YANG ET AL., 2019). Deforestation (DE OLIVEIRA ET AL., 2017), land clearance for agricultural production (DE MORAES ET AL., 2017), and human settlement increase (BAILEY ET AL., 2016) are all factors that contribute to wildlife habitat destruction and degradation. The growth of human settlements within nature reserves causes wildlife habitat loss and forest fragmentation (HE ET AL., 2014; MERLN-URIBE ET AL., 2013; SAMSURI ET AL., 2014). A new road had prompted encroacher to come in and remove the remaining forest, resulting in a big area of rubber, coffee, and oil palm plantations with intensive management (KUSWANDA, 2014). Human inhabited areas along the borders of protected areas can lead to conflict with wildlife since orangutans enter the farming fields to look for food. The situation can pose a significant threat to the existence of endangered species (NYHUS & TILSON, 2004). Conflicts between animals and humans destroy their mutual well-being and pose a growing risk to the conservation of many of the species involved (SHILONGO ET AL., 2018).

Human–animal conflict is common when human–inhabited areas and wildlife habitats meet. Human

lived surrounding the forest reserve where has also served as an orangutan habitat. The habitat of the orangutan is directly impacted by human population growth (KUSWANDA, 2014). It destroys orangutan habitat, resulting in a decrease in orangutan numbers. Meanwhile, low orangutan populations and ecological conditions has proved the existence of human–orangutan conflict occurred (HILL & OBUA, 2005; WALLACE & HILL, 2012).

In Sumatra, observations on conflict occurrence have been made in villages around the Dolok Sibual–Buali forest reserve area by PASARIBU & HARAHAP (2017) who found evidence of conflict between humans and the Sumatran orangutan. Humans throw stones at orangutans when they are seen in agricultural fields near the village. Some people deliberately hunt orangutans to serve them as food at some traditional cafes. This shows that the existence of orangutans and their habitats are threatened. Another threatened area for the Tapanuli orangutan is the Dolok Sipirok Nature Reserve. Tapanuli orangutans can find abundant food in their habitat in the reserve. The study team discovered a new species of orangutan in 2017 (NATER ET AL., 2017), which they nicknamed Tapanuli orangutan. However, the threat to the Tapanuli orangutan's habitat has intensified. Due to agricultural encroachment into orangutan habitats, the Tapanuli orangutan's living space is becoming constrained (KUSWANDA, 2014).

As PASARIBU & HARAHAP (2017) and KUSWANDA (2014) stated, the situation causes the orangutan population heading to decrease in its existence. These threats are the cause of conflict between orangutans and humans. As a measure to handle and anticipate future conflicts, research was conducted by SIREGAR ET AL. (2015). This research mapped areas prone to conflict between orangutans and humans in the Dolok Sipirok Nature Reserve, including the conflict spots distribution and data compilation affecting conflict incidents.

Research on orangutan conflicts, particularly the Tapanuli orangutan and humans living adjacent to the nature reserve, is necessary in order to carry out post-conflict orangutan and human resolutions and to reduce future conflict situations. Information on locations where orangutans and humans are likely to interact is useful in helping local authorities make policies while still addressing the long-term viability of orangutans and their habitats and preventing future conflicts.

This research aimed to (1) identify spatial patterns of conflict-prone areas between Tapanuli orangutans *(Pongo tapanuliensis)* and the community of villages around the DS-NR nature reserve and (2) analyze the factors that support the occurrence of conflict between Tapanuli orangutans and the communities in the villages around the nature reserve.

2. Materials and methods

2.1. Study site

This study was carried out in the villages of Ramba Sihosur, Luat Lombang, Aek Batang Paya, Nanggarjati, Lancat, and Arse Nauli surrounding DS-NR. Dolok Sipirok Nature Reserve is located in the Batang Toru natural landscape, which is mountainous tropical rain forest with an elevation of 600–1,200 metres above sea level (masl). This nature reserve is one of the areas where Tapanuli orangutan are found.

The data were analyzed at University of Sumatera Utara's Forest Management Laboratory, which is part of the Faculty of Forestry in the Department of Forest Management. Figure 1 depicts the locations of the six villages. The nature reserve is located in the Sipirok sub district alongside Silangge and Ramba Sihosur villages; and Arse sub-district, Tapanuli Selatan district. A part of nature reserve area in the Simangumban sub-district, Tapanuli Utara district, which is only 360 kilometers from Medan's city center. Access to the research site is limited to motorbikes or two-wheel drives from Sipirok city to Ramba Sihosur village.

The Natural Resources Conservation Agency of North Sumatra manages the nature reserve region. The topography is generally mountainous, with a 90 percent slope (also known as a steep hill). This nature reserve is included in the Batang Toru forest ecosystem precisely in the eastern section of Sarulla. The nature reserve is a fragmented orangutan habitat that is not connected to each other habitat. The preservation of the nature reserve's vegetation is continuing, encompassing a potential diversity of fifty distinct tree species. The nature reserve area is surrounded by twelve communities that are directly close to it and due to this closeness to villages, the nature reserve is subject to wildlife disturbances.

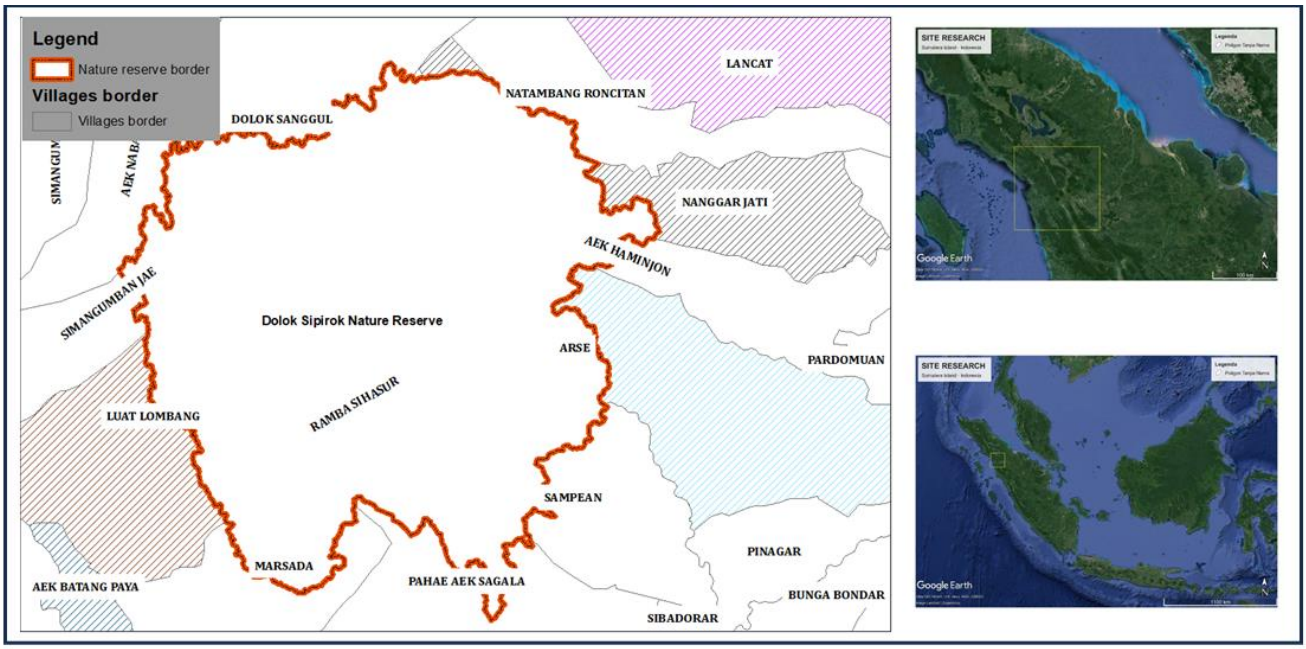


Fig. 1. Research location map of Dolok Sipirok Nature Reserve

2.2. Tools and materials

ArcGIS 10.3 software (ESRI), a Global Positioning System (GPS), a Digital Camera, statistical software, stationery, and questionnaires were all utilized in the research. An administrative map of the Tapanuli Utara and Tapanuli Selatan districts, village administration maps, land cover maps, and nature reserve area maps were used in this study. In addition to secondary data, there are empirical data on the occurrence of orangutan–human conflicts in the research region and ground checks for human–orangutan conflict were used (HOC). The method used to collect data on the conflict location was a direct observation by purposive sampling and required respondents to fill out questionnaires and included the criteria of the community who owned the land where the conflict occurred.

2.3. Data collecting

The research stages were: tool preparation and collection of materials, field surveys, data analysis, and conflict analysis. For the preparation stage this included, data collection was from several sources (institutions or agencies related to the management of nature reserve), books and the internet, data from wildlife surveys from patrol activities, and monitoring surveys by patrol officers include data on orangutan existence.

Human orangutan conflicts (HOCs) as the focus of this research take into account the damage of crops within the conflict area. Due to the prevalence of crop-raiding conflicts between humans and primates (Siljander, 2020), three types of research methodologies have been used: (i) farmers are interviewed about crop damage (Hill &Webber, 2010; Marchal & Hill, 2009; Saj et al., 2001; Tweheyo et al., 2005); (ii) crop damage and loss economics are assessed over time (Hill, 2000; Priston et al., 2011) and (iii) observing wildlife behaviour in farm land (Priston et al., 2011).

Spatial data collection. The Central Statistics Agency provided village administration maps for the Tapanuli Selatan and Tapanuli Utara districts of North Sumatra. The land cover map and nature reserve map area were obtained from the Directorate General of Forestry Planning and Environmental Governance Region I - Medan. The land cover map provides information on the various types of land cover. It is classified into six categories: forest, plantation, settlement, grass, open land, and water bodies (SNI 7645, 2010). Other spatial data used were road, contour, altitude, and river maps which were also available from the Geospatial Information Agency (BIG). All spatial data were used as inputs to create a map of conflict-prone areas.

Community interview. The core data collection consisted of gathering two types of information: (1) the type and degree of crop damage on conflict hotspots and (b) community knowledge and response on HOCs.

In addition, the research used a set of questionnaires for chosen respondents. Several questions were posed to the community in order to obtain information regarding (1) the location of the conflict, (2) the time of crop destruction, (3) the frequency of disturbances to community land or plants, (4) the types of plants damaged by orangutans, (5) the volume or number of damaged plants or fruit, and (6) techniques used for controlling, or preventing, conflict by the community.

The respondents were chosen through purposive sampling. Individuals, or communities, living in conflict areas were interviewed. Furthermore, private or community farmlands raided by Tapanuli orangutan have also been listed as respondents. Questionnaires were given in the six villages that were regarded as the study's main focus area. The questionnaire instrument provides respondents with a basic understanding of the Tapanuli orangutan's unique characteristics and how the community deals with conflict.

Verification of human orangutan conflict spots. Several occurrence spots of conflicts between orangutans and humans were categorized as field data types. The number of crops damaged in the research region related to conflicts was derived from the ground check results of human orangutan conflict points. Conflict locations were chosen based on a set of criteria. Where the conflict between orangutans and humans occurred was determined by looking at the apparent disturbance in the field. Moreover, the study verified the HOC location obtained from community interviews and determined crop damage type in farmland. The HOC verification gained data, i.e., what part of the crop, crop species, and fruit were destroyed or eaten by Tapanuli orangutan.

2.4. Data analysis

Slope Map. The slope map included specific information about the slope class at the research site. The six villages that were the focus in the research area had 4 out of the 5 slope classes; only slope class 5 was not present at the research site. The slope map was used to see the spread of conflict spots in the slope classes. Classification of the slope class follows Table 1.

Altitude Map. The altitude class map obtained from secondary data was sourced from BPKH Region I Medan. The altitude class at the research site was divided into five classes, these were 1500 metres above sea level (masl), 1 200–1 500 masl, 900–1 200 masl, 600–900 masl, and 300–600 masl. Altitude maps are used to view the topographic profile of conflict spots. The classification of altitude classes is shown in Table 1.

Distance from roads, nature reserve boundaries, and rivers. Distance determination from biophysical factors utilizing buffer facilities yields a shapefile (feature) or graphical object as the result of the distance determination performed on the biophysical factor. The buffer, for spatial analysis purposes, usually represents a range of services, or an assumed extent, with a certain distance. Buffer class divisions follow Table 1.

Table 1. Altitude class classification (Source: Directorate General of Forestry Planology Regulations, 2014)

Class	Slope (%)	Information
I	>40	Very steep
II	25–40	Steep
III	15–25	Moderate
IV	8–15	Gentle slope
V	0-8	Flat
Altitude (meters above sea level)		
I	> 1 500	
II	1 200–1 500	
III	900–1 200	
IV	600–900	
V	300–900	
Buffer – rivers and roads (meters)		
I	> 1 200	
II	900–1 200	
III	600–900	
IV	300–600	
V	0–300	
Buffer area boundary (meters)		
I	4 000–5 000	
II	3 000–4 000	
III	2 000–3 000	
IV	1 000–2 000	
V	0–1 000	

Overlay map. The HOC spot map was overlain with the administration map, land cover, slope, altitude, river buffer, and road buffer map (Fig. 2). Composite maps have attributed data regarding biophysics and anthropogenic factors.

2.5. Correlation analysis of the HOCs and affecting factors

The overlay analysis conducted to HOC spot data and factor affecting HOC. Correlation analysis examined all of the attribute data. Correlation analysis aims to determine the degree of the relationship between two or more affecting nature reserve factors with HOC. The correlation will determine which biophysical factors are related to orangutan conflict with humans in the village around nature reserve. The conflict determined using crop-damage data caused by orangutans in community fields. The trace and footstep of crop damage in the farmland, and even the identification of the finding, serve as evidence for crop loss caused by orangutan conflict with humans.

Rank Spearman's statistical test looks at the relationship between biophysical factors and anthropogenic factors with HOC. Biophysical factors include altitude, land cover, and slope; anthropogenic factors include the distance from the river, distance from the road, and distance from the boundary of the nature reserve. The correlation is carried out against all biophysical and anthropogenic factors. The class division of the factors refers to research conducted by SIREGAR ET AL. (2015) and KUSWANDA (2013) state that the presence of orangutans in lowland and declining mountainous areas. Spearman Rank Correlation is used to determine influence when each variable is related in the form of ordinal and data sources between variables are not necessary to be the same (DĄBROWSKA & SOŁTYSIAK, 2015) or examine the significance of associative hypotheses (SUGIYONO, 2013). MARTONO (2010) states *Rank Spearman* test score is symbolized by ρ (read: rho). Therefore, before data processing, quantitative data to be analyzed needs to be compiled in rankings. Ordinal data is input in Spearman Rank correlation analysis by the system before the *output* is generated.

This correlation determines the degree of tightness of the relationship between dependent variables and independent variables as expressed by the coefficient R. The higher the scale is close to '1', with a positive sign, then the relationship between these two variables is more robust, and vice versa. The correlation is lower if the scale is in the direction of '0' or neutral. If the scale shows '0' or neutral, then the correlation relationship is lower. We interpreted the strength of the relationship based on Rank Spearman's correlation analysis using an interpretation guide. These guidelines can be found in Table 2. The research framework for this final task can be seen in the form of a flowchart (Fig. 2).

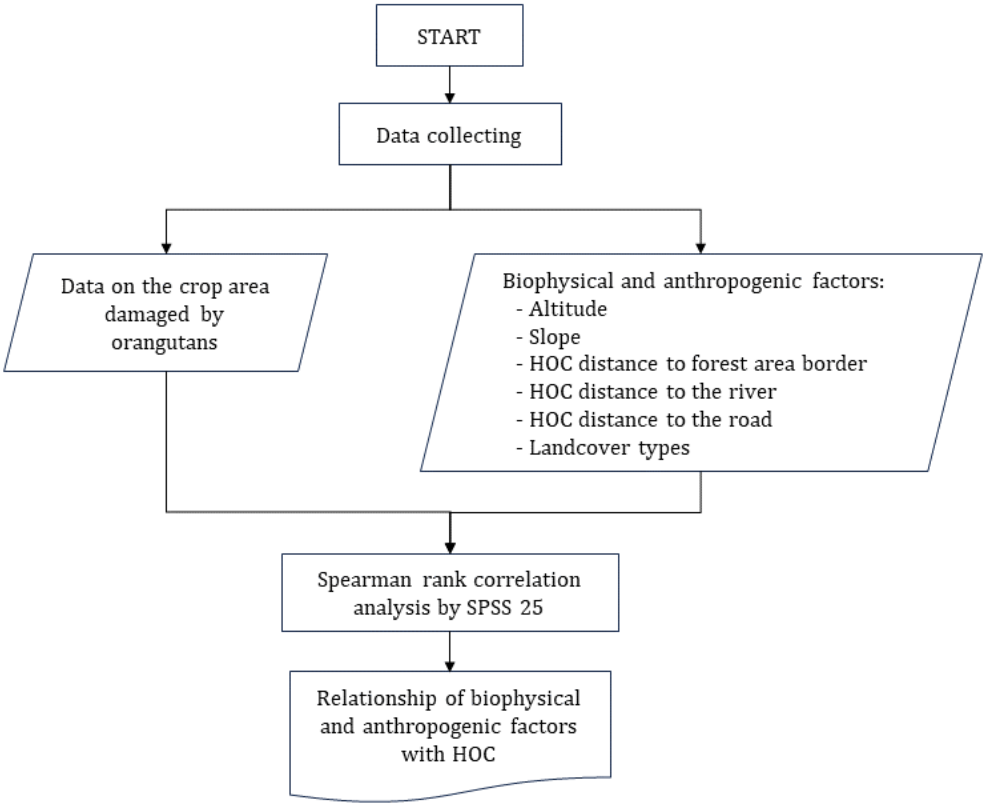


Fig. 2. Flowchart of research stages

Table 2. The correlation coefficient classes (Source: Siregar et al., 2015)

Correlation coefficient value	Degree of correlation
0.00 – 0.199	No correlation
0.20 – 0.399	Low correlation
0.40 – 0.599	Moderate correlation
0.60 – 0.799	Strong correlation
0.80 – 1.00	Very strong correlation

3. Results and discussion

3.1. Pattern of HOC spots

The orangutan human conflict-prone research area was conducted in four villages with two being adjacent to the nature reserve: Aek Batang Paya, Nanggarjati Ramba Sihosur, and Luat Lombang, Lancat, and Arse Nauli villages. The six locations were chosen based on the number of community reports to the Natural Resources Conservation Agency Section V regarding orangutans entering their farmlands. In addition, these six locations are the places that most often report incidents of HOCs in their fields. SIREGAR'S (2014) stated that physical factors affect conflicts such as location height, location slope, land landcover type, HOC distance from the river, and HOC distance from the boundary of the nature reserve and HOC distance from the road.

Based on the map (Fig. 3), the research location is at an altitude of 300–1200 meters above sea level (masl). The HOC spots are mainly spread at an altitude of 600–900 m above sea level, 15 points were within Arse Nauli, Nanggarjati, and Lancat villages. HOC is also widely spread at an altitude of 300–600 meters above sea level. Ten HOC spots in Aek Batang Paya and Luat Lombang village are at an altitude of 900–1200 meters above sea level, and five spots are in Ramba Sihosur Village. Distribution of HOC spots based on altitude can be seen in Fig. 3.

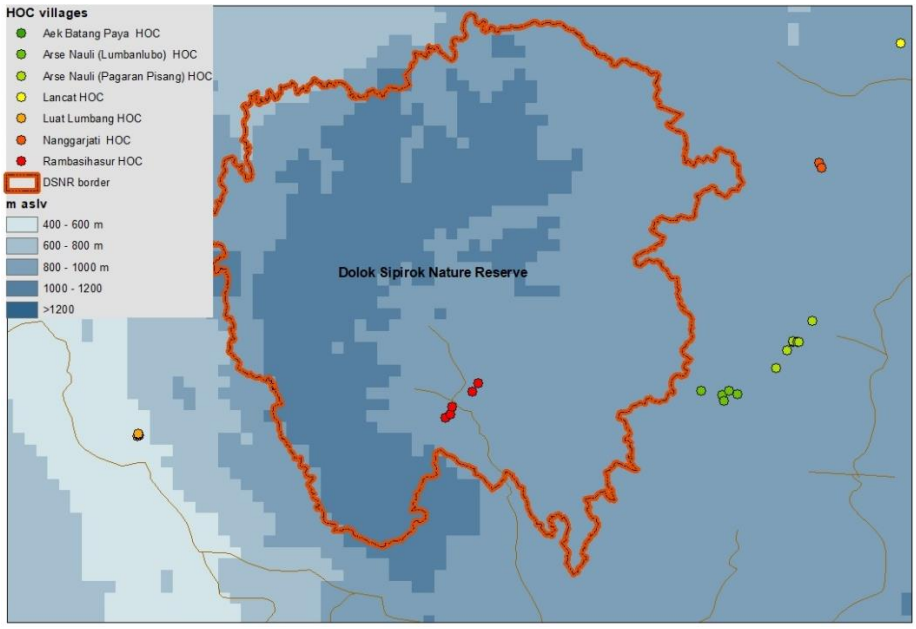


Fig. 3. Altitude class map and HOC point deployment at Dolok Sipirok Nature Reserve

Overlay of altitude class maps with HOC spots in the field; most HOC occurences were at altitudes between 600–900 m above sea level. RIJKSEN & MEIJAARD (1999) state that the population of Sumatran orangutans is mostly limited to lowland rainforests. The Sumatran orangutan is mostly found in locations below 500 meters above sea level, with only a few exceptions reaching higher than 1,500 meters. Furthermore, field data show that the spread of HOC locations is dominant between 300 and 900 meters above sea

level, with a tiny percentage of HOC between 900 and 1200 meters above sea level. KUSWANDA (2013) states that in lowland areas, there is estimated to be approximately five individuals/km^2 and this decreases in mountainous areas to two individuals/km^2. Then this decreases again to an altitude of 1 000–1 500 meters above sea level to 0.5 individuals/km^2, and above 1 500 meters above sea level, there are no orangutans. The feed type abundance in each altitude affects the distribution of orangutan populations. In the primary forests, there are many types of feed plants, fruit producers, such as species in the family Moraceae.

Figure 4 shows the spread of HOCs at an altitude of 600–900 metres above sea level. The community fields around the nature reserve are at an altitude of 600–900 meters above sea level, such as Arse Nauli village. Arse Nauli has 12 HOC spots which are spread across altitudes of 600–900 meters above sea level. Most Arse Nauli people grow *Durio zibethinus* and *Parkia speciosa*, species of orangutan feed plants which attract the Tapanuli orangutan to come into farmland to find food.

Slope is one factor influencing the occurrence of HOC. Based on the overlay analysis of HOC spot and a slope class-map, HOC spots dominated the slope class 0–8% with 15 spots of the number of HOC found. It is followed by ten spots within slope class 25–40% and five spots within slope 8–14%. It means the community do farming activities in many ranges of slope, including the area where there are orangutan corridors. It is also in line with KUSWANDA'S (2014) remark that the nature reserve area is between 600 and 1,200 meters above sea level. The topography of the forest area has a rather steep to steep slope with a slope above 40%, relatively the same as Nature Reserve of Dolok Sibual-Buali. The distribution of HOC spots based on the slope class map is illustrated in Fig. 5. The slope of a region strongly influences the existence of orangutans. The slope condition is an area that individual orangutans often encounter with the intensity of many areas that orangutans often encounter because many are overgrown by feed trees.

The community lands that were the subject of this study are generally located within a 300–600-meteres radius of the river. Farmlands within a radius of 0–300 meters from the river dominate the HOC spots with 16 spots, and nine spots are within a radius of 300–600 meters. This characteristic is significant because orangutans will create nests close to water sources, rivers, and tributaries. This is in line with DALIMUNTHE'S (2009), research which stated that the large number of nests found along a transect was due to better vegetation conditions, and there were more and varied feed trees. HOC distribution based on the river buffer map is shown in Fig. 6.

The river network is an essential GIS input when looking at the spread of HOC spots. Rivers are vital because they are one of the abiotic components that affect the quality of habitat and the source of livelihood for humans. People usually farm near water sources, and orangutans also build nests near water sources, according to DALIMUNTHE (2009). Research by PERBATAKUSUMA ET AL. (2006), found that Sumatran orangutans, especially those in the forest area of Batang Toru, were more activite (eating, moving, and making nests), within strata of tree layer B (middle canopy) where tree height can reach 20 m and generally having diameter between 10–20 cm such as *Syzigium sp*. Nest trees located in Aek Batang Paya Village have an average height of 10 meters.

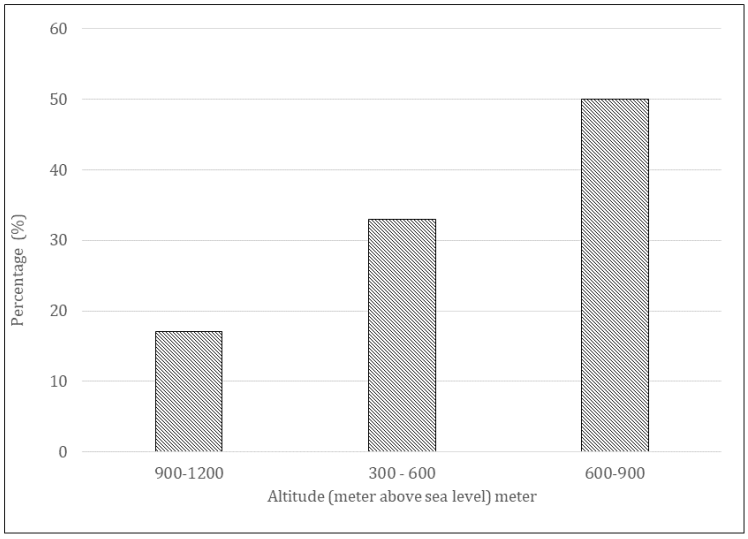


Fig. 4. Percentage of HOC which occurred by altitude class

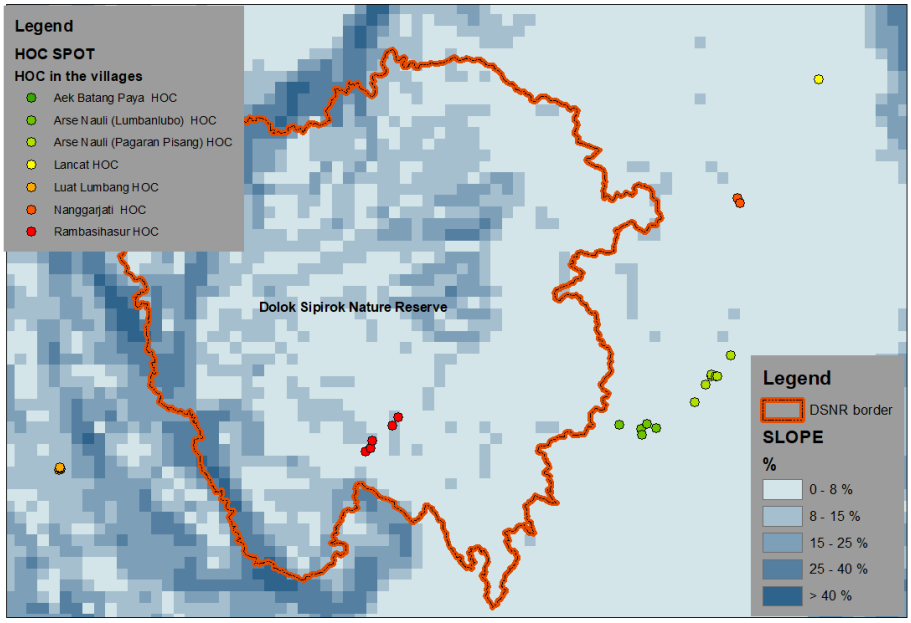


Fig. 5. Map of HOC type distribution within slope class in Dolok Sipirok Nature Reserve

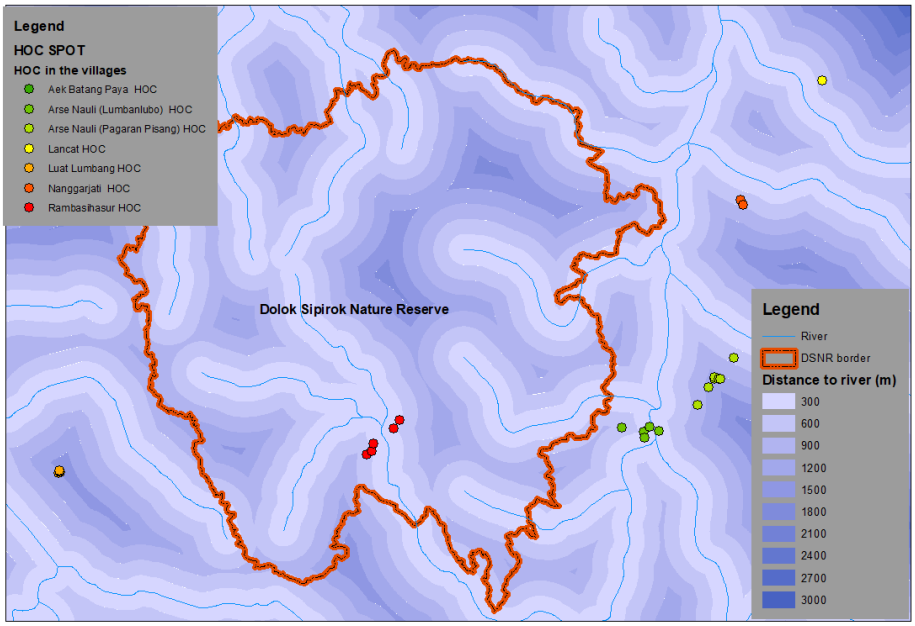


Fig 6. Map of HOC distribution based on river *buffer* in Dolok Sipirok Nature Reserve

The buffering road map illustrates the distance of HOC spots with road access connecting between villages. Road connectivity will affect the presence of orangutans. It corresponds with (WYNN-GRANT ET AL., 2018; BUCHHOLTZ ET AL., 2020) that roads, farms (TREVES ET AL., 2011) indicate the spatial variance of wildlife conflict in several studies (BROEKHUIS ET AL., 2017; KERTSON ET AL., 2011). The location of HOC is mostly at a very close distance to the road, which is 0–300-meters from the village road. As many as 16 spots are in the 0–300-meter buffer road class. While the remaining part is distributed across the road buffer classes of 300–600 meters and 600–900 meters from the road body, HOC is dominated in the 300–600 meter class. Villages that have HOC in the buffer class 300–600-meters is Ramba Sihosur (2 HOC spots), Luat Lombang (4 HOC spots), and Aek Batang Paya village (2 HOC spots). All HOC spots in the class of 600–900 meters were found in Arse Nauli Village. Arse Nauli is an ideal area for orangutan life HOC distribution based on road buffer map illustrated in map Fig. 7.

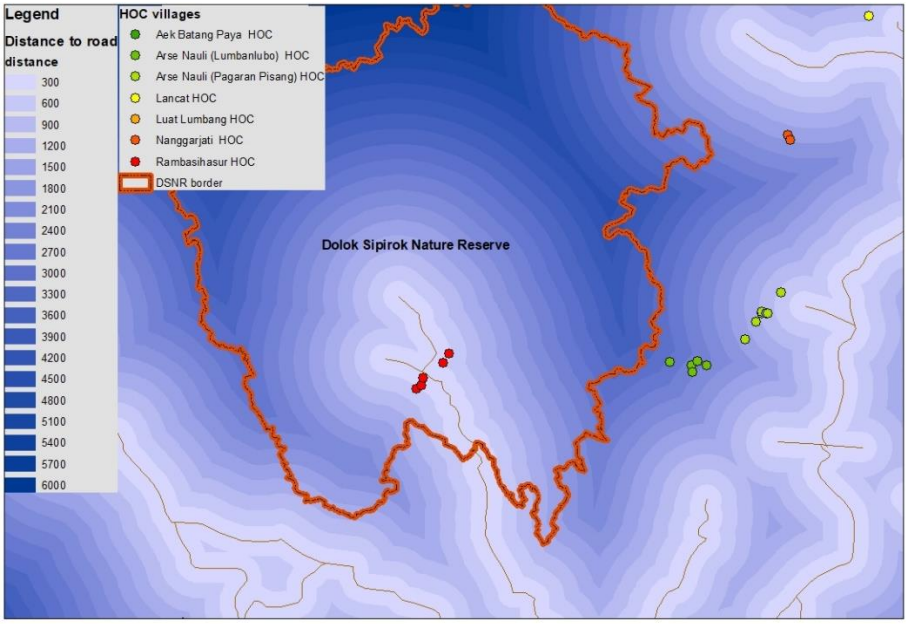


Fig. 7. Map of HOC deployment based on map class *buffer* path around Dolok Sipirok Nature Reserve

The opening and construction of roads around orangutan habitats will allow for easier access to farmland occupancy and expansion. However, it causes orangutan habitat fragmentation (SAMSURI ET AL., 2014) and isolation of orangutan habitats in the population pool. The frequency of conflict occurrences was found to be significantly positively related to connectivity factors (BUCHHOLTZ ET AL., 2020). Interconnected neighborhoods would drive immigrants to come around more frequently, raising the risk of conflict (BUCHHOLTZ ET AL., 2020). Spatially, some areas of the nature reserve area's buffer zone have become community fields, such as in Arse Nauli village, a HOC of 450 m with a forest area bordered of nature reserve. The occupancy of community lands creates severe fragmentation of orangutan habitats and reduces orangutan feed trees, making orangutans enter community lands. Conflict with humans also occurs, especially during *Durio zibethinus* fruit season, because some areas are directly adjacent to the community farmland, and as a result, orangutans will be easily captured. The HOC spots are in Ramba Sihosur village, a village in the enclave area of nature reserve, and a part of the area entered into forest area nature reserve. HOC distribution based on the map buffer boundary area is illustrated on the map in Fig. 8.

Spatially, conflict and potential conflict can be analyzed using field data and factors that affect it. Figure 8 shows HOC occurred closest to the boundary of being in Ramba Sihosur and Arse Nauli while the HOC spots furthest from the forest area are in Aek Batang Paya and Lancat village. It could cause forest boundaries to have more human-carnivore interactions and anthropogenic food attractants (both urban and agricultural foods such as cattle or crops) (TREVES ET AL., 2011). There are six types of land cover: secondary dryland forest, bare land, and ricefields shrubs, and dryland agriculture in nature reserve. The HOC spots in three villages (Nanggarjati, Lancat, and Luat Lombang Village) are in dryland farming type. Most of Arse Nauli village's HOC spots are on dryland farms, and the remaining three spots are on bare land. The Aek Batang Paya village has only one HOC point located in dryland farming. Three spots are in secondary forests, and two spots are in rice fields close to secondary forests. It is also supported by TREVES ET AL. (2011) found wildlife conflict–affected by forest cover type; ZELLER ET AL. (2018) state that factors that affect HOC distribution can be compared with the number of crop damage cases. HOC distribution based on land cover type is illustrated on a map in Fig. 9.

It can be known that most conflicts occur in the dryland agricultural land cover (TREVES ET AL., 2011. The community lands of a village around nature reserve are dominated by coffee and rubber plants. In addition to coffee and rubber crops, community fields are also widely planted tree species such as *Durio zibethinus*, *Parkia speciosa*, *Artocarpus integer*, *Artocarpus heterophyllus*, *Arenga pinnata,* and others. Plants that orangutans eat include *Durio zibethinus* and *Parkia speciosa* have been planted since ancient times and passed on to their inheritance. The number is not much so that the plant has old age and produces abundant fruit.

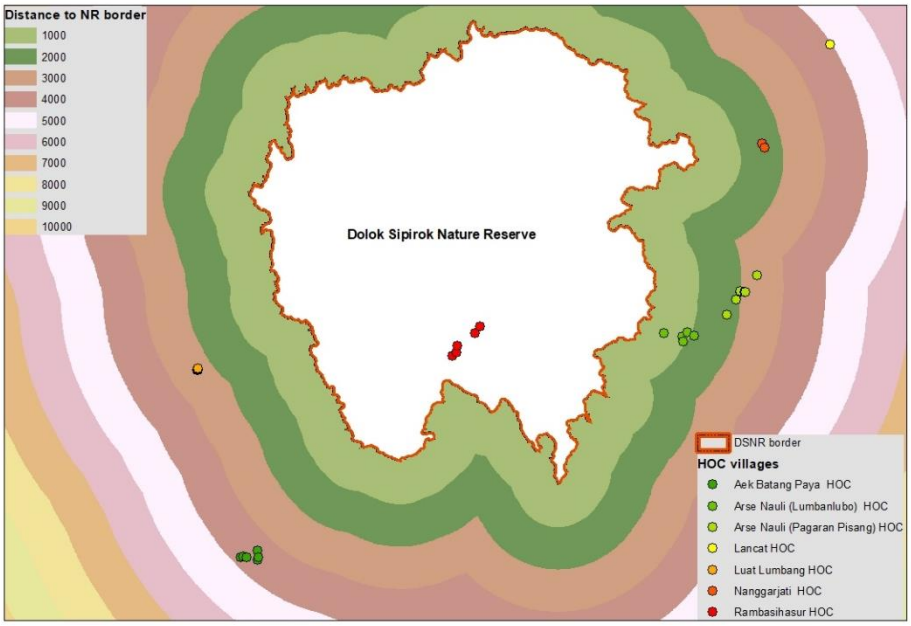


Fig. 8. HOC distribution based on boundary buffer and land cover types of Dolok Sipirok Nature Reserve

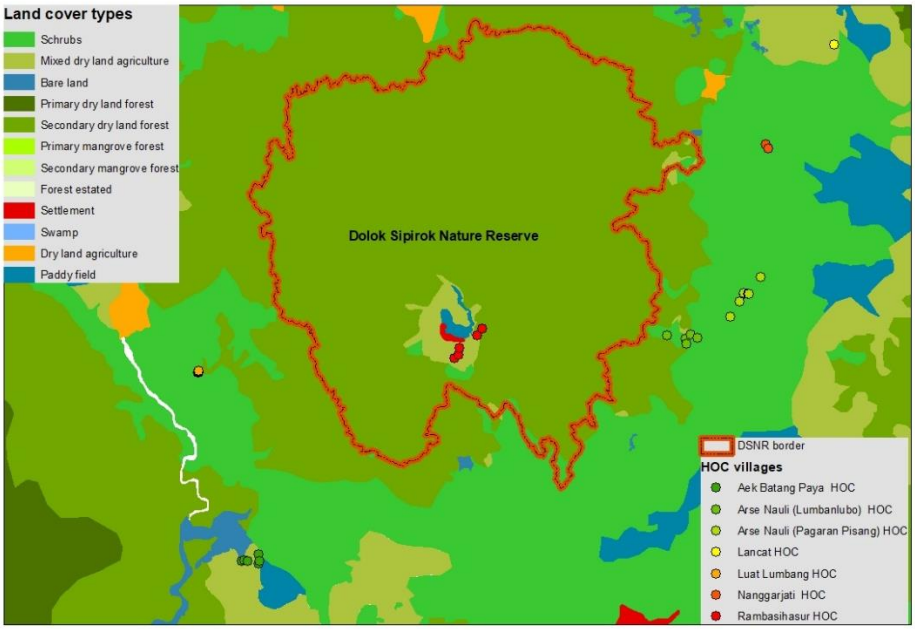


Fig. 9. HOC distribution based on land cover type

3.2. Location altitude and crop damage

The density test results of the relationship between the height of the place and the occurrence of conflict using the *Spearman Rank* correlation test are listed in Table 3. *Spearman Rank* correlation test showed the correlation between the amount of plant damage with the location altitude is 0.603 with a probability value of 0.000<0.05, which can be interpreted to be smaller than 0.01. The correlation between both variables is very significant, meaning the relationship between the height of the location and the HOC that occurred is very strong. ZAR (2005) stated that the correlation results showed that the higher the altitude class, the more damage to plants.

The distance of the HOC from the area boundary is one of the biophysical factors that influence conflict. For example, crop damage is associated with a HOC distance from the area boundary. This is an important factor because nature reserve is the Tapanuli orangutan's habitat. As a consequence, habitats and conflict events are closely linked to orangutan roaming

areas. The correlation relationship of HOC distance from the areal boundary is as in Table 4.

Spearman's rank correlation coefficient (ZAR, 2005) shows the strong correlation between crop damage and HOC distance from forest areas. It is shown with a correlation coefficient of -0.600 and a sig value of 0.000 smaller than 0.05, which means that the relationship between the two variables is significant. The coefficient value's negative sign (–) indicates that the relationship between the amount of damage and the HOC distance from the forest area is inversely proportional. It means, the further away from the farmland location, the greater the damage. It has occurred in Aek Batang Paya village. A strong correlation influences each other indicated by the analysis results of -0.600 and negatively correlated; the further HOC from nature reserve, then the conflict will increase as happened in Aek Batang Paya village.

3.3. Slope class and crop damage (HOC)

The slope factor is one of the weak factors influencing the amount of crop damage caused by orangutans. The slope implies the level of crop damage caused by HOC. The research area's slope varies from 0–40% (KUSWANDA, 2014) and affects the spread of feed trees at the research site. Correlation test analysis can determine the relationship between crop damage caused by conflict and slope. The result of the correlation test is listed in Table 5. Table 5 shows a correlation value of -0.338 and a significance value of 0.067, meaning the Spearman rank correlation (ZAR, 2005) represents a low correlation between the two factors. While a significance value greater than 0.05 indicates a relationship between the two factors has no significant correlation.

Table 3. Correlation between orangutan plant damage rate with altitude

			Amount of damage	Height
Spearman's rho	Amount of damage	Correlation Coefficient	1.000	.603**
		Sig. (2-tailed)	.	.000
		N.	30	30
	Height	Correlation Coefficient	.603**	1.000
		Sig. (2-tailed)	.000	.
		N.	30	30

***At the 0.01 level, correlation is significant (2-tailed)*

Table 4. The correlation between orangutan-induced crop damage with HOC distance from the forest area

			Amount of crop damage	Distance from the boundaries of the region
Spearman's rho	Amount of crop damage	Correlation Coefficient	1.000	-.600**
		Sig. (2-tailed)	.	.000
		N.	30	30
	Distance from the boundaries of the region	Correlation Coefficient	-. 600**	1.000
		Sig. (2-tailed)	.000	.
		N.	30	30

***. At the 0.01 level, correlation is significant (2-tailed)*

Table 5. Correlation between HOC plant damage rate with slope

			Amount of crop damage	Slope
Spearman's rho	Amount of crop damage	Correlation Coefficient	1.000	-.338
		Sig. (2-tailed)	.	.067
		N.	30	30
	Slope	Correlation Coefficient	-.338	1.000
		Sig. (2-tailed)	.067	.
		N.	30	30

3.4. Crop damage (HOC) and distance from the road

The distance of the HOC from the road is one of the weak factors influencing the amount of crop damage caused by orangutans. Table 6 shows the results of the correlation test. According to Table 6, the correlation value is -0.017, and the significance value is 0.927; according to ZAR'S (2005) correlation, there is no correlation between the two factors. A significance value greater than 0.927 indicates that neither factor has a significant correlation. The road allows people to enter the forest, allowing the community plants to be well monitored for animal disturbances.

Table 6. Correlation relationship between orangutan-induced crop damage levels with HOC distance from the road

			Amount of crop damage	Distance from road
Spearman's rho	Amount of crop damage	Correlation Coefficient	1.000	-.017
		Sig. (2-tailed)	.	.927
		N.	30	30
	Distance from road	Correlation Coefficient	-.017	1.000
		Sig. (2-tailed)	.927	.
		N.	30	30

3.5. Crop damage (HOC) and distance from the river

Besides slope, field distance to the road, and the land cover type, HOC distance to the river is one of the weak variables that influence the amount of crop damage caused by orangutans. Table 7 summarizes the output of the correlation test. Table 7 shows a 0.034 and positive correlation between the rate of crop damage caused by an orangutan and the distance from the river. The value is very small. Based on the Spearman's standard rank correlation coefficient, it indicates a weak correlation.

Table 8 shows the correlation between crop damage number and the slope class, the distance to the nature reserve boundary, the distance to the river, and the distance to the road. The Spearman's negative rank correlation is the level of crop damage and distance from nature reserve (-0.600), crop damage and slope (-0.338), crop damage and distance from the river (0.034), and the amount of damage to plants by the distance from the road (-0.17). Spearman's Rank correlation value represents low and very low correlation. The distance factor from the river, distance from the road, and slope are insignificant to HOC spots.

Table 7. Correlation relationship between the amount of plant damage with HOC distance from river

			Amount of crop damage	Distance from river
Spearman's rho	Amount of crop damage	Correlation Coefficient	1.000	.034
		Sig. (2-tailed)	.	.859
		N.	30	30
	Distance from river	Correlation Coefficient	.034	1.000
		Sig. (2-tailed)	.859	.
		N.	30	30

Table 8. Spearman rank test results recapitulation

Biophysical factors	Correlation coefficient	Significance
Altitude	0.603	0.000
Distance from the boundary of the nature reserve	-0.600	0.000
Slope	-0.338	0.67
Distance from the river	0.034	0.859
Distance from the road	-0.17	0.927

Overall the Tapanuli orangutan conflict is caused by a decrease in habitat support due to the expansion of agricultural land and plantations. It confirms that the threat to orangutan habitat is factual. Farmland distance from the nature reserve area has a high correlation with HOC spots. It is related to the degree to which HOC and anthropogenic factors are linked. The frequency of conflict incidences (HOC) was significantly positively linked with connectivity factors (BUCHHOLTZ ET AL., 2020). Interconnected neighborhoods would drive immigrants to come around more frequently, raising the risk of conflict. The connection was linked to reported crop-raiding incidence (BUCHHOLTZ ET AL., 2020). Anthropogenic elements included settlement density, agriculture, distance to villages, and linear features such as fences and roads (BUCHHOLTZ ET AL., 2020; DĄBROWSKA & SOŁTYSIAK, 2015). Predictions of the probability of presence or the animal presence on the landscape are based on habitat or resource selection approaches (BOYCE ET AL., 2002). Anthropogenic and environmental variables linked to conflict and used to forecast geographic distribution are called predictors of conflict. Trail density (WYNN-GRANT ET AL., 2018), farms (TREVES ET AL., 2011), roads (WYNN-GRANT ET AL., 2018), and forest cover (TREVES ET AL., 2011) have all been found to predict spatial variance in a conflict in several studies (TREVES ET AL., 2011; MERKLE ET AL., 2011; KERTSON ET AL., 2011; BROEKHUIS ET AL. 2017). It could be since forest borders have more human–wildlife overlap and anthropogenic food attractants (TREVES ET AL., 2011).

When assessing factors that affect HOC or distribution, one method compares the number of crop damage cases that match each of the listed factors affecting classes (ZELLER ET AL., 2018). Adaptation and mitigation are needed to control the frequency of HOC. Proactive mitigations in communities adjacent to the forest, fencing that restricts both carnivore species, and reduction of rural food attractants should be targeted at potential conflict locations and times (ZELLER ET AL., 2020). However, proactive mitigation can conserve mammals and alleviate negative impacts on humans, such as conflict–related losses, by preventing conflict (MCMANUS ET AL., 2015). Predictors of conflict can be used to identify patterns in conflict occurrences, allowing management costs to be reduced and effectiveness to be increased (BROEKHUIS ET AL., 2017; TREVES ET AL., 2011).

4. Conclusions

HOC is mainly found out in dryland agricultural cover types located at 8–14%, altitudes between 600–900 meters above sea level, field distance from the river 0–300 meters, field distance from the road 0–300 meters then the distance of the field from the forest is 0–1000-meters from the Dolok Sipirok Nature Reserve. The factors that have the most robust relationship to orangutan conflict with humans are the height with a value of 0.603 and significance of 0.000. Factors that have a weak relationship to conflict events are slope, the distance from the road, and the distance from the river. Factors with a strong relationship with HOC events are height (correlation coefficient of 0.603 and significance of 0.000) and regional boundaries (correlation coefficient of 0.600 and significance of 0.000). Based on the factors that have a strong influence on HOC, then reducing HOC can be through reducing access to nature reserve. It is necessary to reduce or eliminate the construction of new roads. Likewise, the use of rivers for access to the habitat of the Tapanuli orangutan needs to be reduced and controlled. These factors also are factors that should be considered in determining the location of patrols. The destruction and reduction of the habitat of the Tapanuli orangutan can be prevented to preserve the existence of the Tapanuli orangutan. Conflict can be reduced through efforts to meet orangutans' needs for food and nesting sites. The function and quality of corridors surrounding natural reserves must be improved. So, the orangutan could meet their needs within the area.

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References

Bailey K.M., McCleery R.A., Binford M.W., Zweig C. 2016. Land-cover change within and around protected areas in a biodiversity hotspot. *Journal. Land Use Science*, 11, 2: 154–176.

Barnes A.D., Allen K., Kreft H., Corre M.D., Jochum M., Veldkamp E., Clough Y., Daniel R., Darras K., Denmead L.H. 2017. Direct and cascading impacts of tropical land-use change on multi-trophic biodiversity. *Nature Ecology & Evolution* 1, 10: 1511–1519.

Boyce M.S., Vernier P.R., Nielsen S.E., Schmiegelow F.K.A. 2002. Evaluating resource selection functions. *Ecological Modelling*, 157, 281–300.

Broekhuis F., Cushman S., Elliot N.B. 2017. Identification of human-carnivore conflict hotspots to prioritize mitigation efforts. *Ecology and Evolution*: 1e10.

Buchholtz E. K., Stronza A., Songhurst A., McCulloch G., Fitzgerald L.A. 2020. Using landscape connectivity to predict human-wildlife conflict. *Biological Conservation*, 248: 108677.

Buchholtz E.K., Fitzgerald L., Songhurst A., McCulloch G., Stronza A. 2019. Overlapping landscape utilization by elephants and people in the Western Okavango panhandle: implications for conflict and conservation. *Landscape. Ecology,* 34, 1411–1423.

Dąbrowska D., Sołtysiak M. 2015. The impact of anthropogenic factors on the natural values of the water reservoirs in Sosnowiec (Poland). *Environmental and Socio-Economic Studies*, 3, 1: 20–25.

Dalimunthe N.P. 2009. *Estimasi Kepadatan Orangutan Sumatera (Pongo abelii) Berdasarkan Jumlah Sarang Di Bukit Lawang Taman Nasional Gunung Leuser Sumatera Utara*. Skripsi. Universitas Sumatera Utara, Medan [in Indonesian].

De Moraes M.C.P., De Mello K., Toppa R.H. 2017. Protected areas and agricultural expansion: biodiversity conservation versus economic growth in the Southeast of Brazil*. Journal of Environmental* Management, 188: 73–84.

De Oliveira S.N., De Carvalho Júnior O.A., Gomes R.A.T., Guimaräes R.F., Mcmanus C.M. 2017. Deforestation analysis in protected areas and scenario simulation for structural corridors in the agricultural frontier of Western Bahia, Brazil. *Land Use Policy*, 61: 40–52.

Distefano E. 2005. *Human-wildlife conflict worldwide: Collection of case studies, analysis of management strategies and good practices*. SARD initiative report Rome.

Fitzherbert E.B., Struebig M.J., Morel A., Danielsen F., Brühl C.A., Donald F., Phalan B. 2008. How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution* [Internet], 23: 538–545.

He C., Liu Z., Tian J., Ma Q. 2014. Urban expansion dynamics and natural habitat loss in China: a multiscale landscape perspective. *Global Change Biology*, 20, 9: 2886–2902.

Hill C.M. 2000. Conflict of interest between people and baboons: Crop-raiding in Uganda. *International Journal of Primatology*, 21, 2: 299–315.

Hill C.M., Webber A.D. 2010. Perceptions of non-human primates in human-wildlife conflict scenarios. *American Journal of Primatology*, 72: 919–924.

Kertson B.N., Spencer R.D., Marzluff J.M., Hepinstall-Cymerman J., Grue C.E. 2011. Cougar space use and movements in the wildland-urban landscape of western Washington. *Ecological Applications*, 21, 8: 2866–2881.

Koh L.P., Wilcove D.S. 2008. Is oil palm agriculture really destroying tropical biodiversity? *Conservation Letters*, 1, 2: 60–64.

Kuswanda W. 2007. Ancaman Terhadap Populasi Orangutan Sumatera (*Pongo abelii* Lesson). *Jurnal Penelitian Hutan dan Konservasi Alam*, 4, 4: 409–417 [in Indonesian].

Kuswanda W. 2014. *Orangutan Batang Toru Kritis di Ambang Punah. Bogor (ID)*. Forda Press, Bogor [in Indonesian].

Kuswanda W., Sugiarti S. 2003. Potensi Habitat dan Pendugaan Populasi Orangutan (*Pongo abelii* Lesson 1827) di Cagar Alam Dolok Sibual-Buali, Sumatera Utara. *Jurnal Penelitian Hutan dan Konservasi Alam*, 2, 6: 555–566 [in Indonesian].

Marchal V., Hill C. 2009. Primate crop-raiding: A study of local perspectives in four villages in North Sumatra, Indonesia. *Primate Conservation*, 24: 107–116.

Martono N. 2010. *Statistik Sosial (Teori dan Aplikasi Program SPSS) Edisi Pertama*. Gaya Media. Jakarta [in Indonesian].

McManus J.S., Dickman A.J., Gaynor D., Smuts B.H., Macdonald D.W. 2015. Dead or alive? Comparing costs and benefits of lethal and non-lethal humane wildlife conflict mitigation on livestock farms. *Oryx*, 49: 687–695.

Meijard E, Rijksen DH, Kartikaari N. 2001. Di Ambang Kepunahan Kondisi Orangutan Liar di Awal Abad Ke-21.: *The Gibbon Foundation*. Jakarta [in Indonesian].

Merkle J.A., Krausman P.R., Decesare N.J., Jonkel J.J. 2011. Predicting spatial distribution of human-black bear interactions in urban areas. *The Journal of Wildlife Management*, 75, 5: 1121–1127.

Merlín-Uribe Y., Contreras-Hernández A., Astier-Calderón M., Jensen O.P., Zaragoza R., Zambrano L. 2013. Urban expansion into a protected natural area in Mexico City: alternative management scenarios. *Journal of Environmental Planning and Management*, 56, 3: 398–411.

Nater A, Mattle-Greminger M.P., Nurcahyo A., Nowak M.G., De Manuel M., Desai T., Lameira A.R. 2017. Morphometric, Behavioral, And Genomic Evidence for a New Orangutan Species. *Current Biology Journal,* 27, 22: 3487–3498.

Nater A., Mattle-Greminger M.P., Nurcahyo A., Nowak M.G., de Manuel M., Desai T., Groves C., Pybus M., Sonay T.B., Roos C. 2017. Morphometric, behavioral, and genomic evidence for a new orangutan species. *Current Biology*, 27, 22: 3487-3498.e10.

Naughton-Treves L., Chapman C., Wrangham R. 1998. Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacent forest. *Journal of Applied Ecology*, 34, 4: 596–606.

Nyhus P.J., Tilson R.L. 2004. Agroforestry, elephants, and tigers: balancing conservation theory and practice in human-dominated landscapes of Southeast Asia. *Agriculture, Ecosystems & Environment*, 104, 1: 87–97.

Pasaribu S.E., Harahap R.E. 2018. Partisipasi Kelompok Pecinta Alam Forester Tapanuli Bagian Selatan Dalam Pelestarian Orangutan Sumatera (*Pongo abelii*) di Cagar Alam Dolok Sibual-buali Kabupaten Tapanuli Selatan. *Jurnal Administrasi Publik*, 7, 2: 136–157 [in Indonesian].

Perbatakusuma E.A., Siregar R.S.S., Ringo J.B., Panjaitan L., Wurjanto D., Adhikerana A., Sitaparasti D. 2007. Membangun Kolaborasi Strategi Konservasi Habitat Orangutan Sumatera di Ekosistem Batang Toru. *Proceeding*. Laporan Lokakarya Para Pihak. 28–30 Maret 2007. Medan: 1–103 [in Indonesian].

Perbatakusuma E.A., Supriatna J., Siregar R.S.E., Wurjanto D., Sihombing L., Sitaparasti D. 2006. *Mengarustamakan kebijakan konservasi biodiversitas dan sistem penyangga kehidupan di kawasan hutan alam Sungai Batang Toru Provinsi Sumatera Utara. (Laporan Teknik Program Konservasi Orangutan Batang Toru).* Kerjasama Conservation International Indonesia Departemen Kehutanan [in Indonesian].

Priston N.E.C., McLennan M.R. 2013. Managing humans, managing macaques: Human–macaque conflict in Asia and Africa. [in:] Radhakrishna S., Huffman M.A., Sinha A. (eds.) *The macaque connection: Cooperation and conflict between humans and macaques*. Springer, New York: 225–250.

Priston N.E.C., Wyper R.M., Lee P. 2011. Buton macaques (*Macaca ochreata brunnescens*): Crops, conflict, and behavior on farms. *American Journal of Primatology*, 73: 1–8.

Saj T.L, Sicotte P, Paterson J.D. 2001. The conflict between vervet monkeys and farmers at the forest edge in Entebbe, Uganda. *African Journal of Ecology*, 39: 195–199.

Samsuri S., JayaI. N.S., Kusmana C., Murtilaksono K. 2014. Tropical Forest Landscape Fragmentation in Batang Toru Watershed, North Sumatra. *Jurnal Manajemen Hutan Tropika*, 20, 2: 77–85.

Shilongo S.M., Sam M., Simuela A. 2018 Using incentives as mitigation measure for human-wildlife conflict management in Namibia. *International Journal of Scientific and Research Publications*, 8, 11: 677–682.

Siex K., Struhsaker T.T. 1999. Colobus monkeys and coconuts: A study of perceived human-wildlife conflicts. *Journal of Applied Ecology*, 36: 1009–1020.

Siljander M., Kuronen T., Johansson T., Munyao M.N., Pellikka P.K.E. 2020. Primates on the farm – spatial patterns of human-wildlife conflict in forest-agricultural landscape mosaic in Taita Hills, Kenya. *Applied Geography*, 117: 102185.

Siregar D.I, Zaitunah A. dan Patana P. 2015. Pemetaan Daerah Rawan Konflik Orangutan Sumatera (*Pongo abelii*) Dengan Manusia Di Desa Sekitar Cagar Alam Dolok Sibual-Buali. *Peronema Forestry Science Journal*, 4, 1: 120–133 [in Indonesian].

Sugardjito J. 2009. Characterizing Social Interactions and Grouping Patterns of Sumatran Orangutans (*Pongo abelii*) in the Gunung Leuser National Park, Sumatra. *Biodiversitas Journal of Biological Diversity*, 10, 2: 94–97.

Sugiyono. 2010. *Metode Penelitian Bisnis*. Alfabeta, Bandung [in Indonesian].

Treves A., Martin K.A., Wydeven A.P., Wiedenhoeft J.E. 2011. Forecasting environmental hazards and the application of risk maps to predator attacks on livestock. *Bioscience*, 61: 451–458.

Treves A., Wallace R.B., Naughton-Treves L., Morales A. 2006. Co-managing human–Wildlife conflicts: A review. *Human Dimensions of Wildlife*, 11, 6: 383–396.

Tweheyo M., Hill C.M., Obua J. 2005. Patterns of crop-raiding by primates around the Budongo forest reserve, Uganda. *Wildlife Biology*, 11, 3: 137–147.

Wallace G.E., Hill C.M. 2012. Crop damage by primates: quantifying the key parameters of crop-raiding events. *PLOS ONE*: 0046636.

Wich S.A. Fredriksson G., Usher G., Kühl H.S., Nowak M.G. 2019. The Tapanuli orangutan: Status, threats, and steps for improved conservation. *Conservation Science and Practice*, 1: e33.

Wich S.A., Meijaard E., Marshall A.J., Husson S., Ancrenaz M., Lacy R.C., Van Schaik C.P., Sugardjito J., Simorangkir T., Traylor-Holzer K., Doughty M., Supriatna J., Dennis R., Gumal M., Knott C.D., Singleton I. 2008. Distribution and Conservation Status of The Orang-Utan (Pongo spp.) on Borneo and Sumatra: How many remain? *Oryx,* 42, 30: 329–339.

Wich S.A., Singleton I., Nowak M.G., Atmoko S.S.U., Nisam G., Arif S.M., Putra R.H., Ardi R., Fredriksson G., Usher G. 2016. Land-cover changes predict steep declines for the Sumatran orangutan (*Pongo abelii*). *Science Advances*, 2, 3: e1500789.

Wynn-Grant R., Ginsberg J.R., Lackey C.W., Sterling E.J., Beckmann J.P. 2018. Risky business: modeling mortality risk near the urban-wildland interface for a large carnivore. *Global Ecology and Conservation*, 16: e00443.

Yang J., Yang J., Luo X., Huang C. 2019. Conghong HuangImpacts by expansion of human settlements on nature reserves in China. *Journal of Environmental Management*, 248: 109233.

Zaitunah A., Ras S., Samsuri. 2020. Change vegetation density analysis of Sumatran orangutan (Pongo abelii) habitat in Bukit Lawang and Sub-district of Bahorok. *IOP Conference Series: Earth and Environmental Science*, 454: 012087.

Zaitunah A., Samsuri, Ras S. 2021. Vegetation structure of sumatran orangutan (Pongo abelii) habitat in north Sumatra, Indonesia. *Biodiversitas*, 22, 2: 633–639.

Zar, JH. 2005. *Spearman rank correlation*: *Encyclopedia of Biostatistics*. John Wiley & Sons, Ltd. New York.

Zeller K.A., Jennings M.K., Vickers T.W., Ernest H.B., Cushman S.A., Boyce W.M. 2018. Are all data types and connectivity models created equal? Validating common connectivity approaches with dispersal data. *Diversity and Distributions*, 24: 868–879.