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Analysis of the relationship between the population size of Kalimantan orangutan (*Pongo pygmaeus*) and land cover changes in Central Kalimantan, Indonesia

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Abstract. *Openg EBL, Santosa Y, Jaya INS. 2024. Analysis of the relationship between the population size of Kalimantan orangutan (*Pongo pygmaeus*) and land cover changes in Central Kalimantan, Indonesia. Biodiversitas 25: 3468-3475.* Land cover change, a major driver of habitat change, significantly influences the distribution of wildlife species, including the Kalimantan orangutan (*Pongo pygmaeus* Linnaeus, 1760) in Central Kalimantan, Indonesia. This analysis, aimed at quantitatively assessing the relationship between changes in land cover and the population of Kalimantan orangutans in 2014-2019, underscores the urgent need for orangutan conservation. Using data on the population of Kalimantan orangutans and updated Landsat images with land cover data from the Indonesian Ministry of Environment and Forestry, we conducted a multiple linear regression analysis to unveil the relationship between the two. The research results from three specific conservation area locations reveal a decrease in the orangutan population in Lamandau, with the largest increase in open land cover types, a trend largely influenced by anthropogenic factors. Conversely, an increase in population was observed in Sebangau, with the largest increase in the swamp land cover type, and population fluctuations occurred in Tanjung Puting, with the largest increase in the open land cover type. The decline in the orangutan population is attributed to anthropogenic factors and natural predators, while the population increase occurs naturally and through orangutan reintroduction activities. The analysis concludes that secondary swamp forests, bushes, and open land cover are closely related to the size of the Kalimantan orangutan population at the research location, thereby highlighting the urgency and concern for orangutan conservation.

Keywords: Conservation area, forest cover, multiple linear regression, orangutan population

INTRODUCTION

Indonesia is a mega biodiversity country with tropical rainforest ecosystems in several regions, including Kalimantan, Sumatra, Sulawesi, and Papua (Nurbaya et al. 2022). As one of the largest provinces in Indonesia, Central Kalimantan has an area of 1,153,564.5 km^2 (Statistics Indonesia 2020), covering 13 districts and one city, with a forest area of up to 1,256,868 ha, including 1,344,391 ha of protected forest, 3,881,655 ha of permanent production forest, 3,326,812 ha of limited production forest, 2,125,388 ha of convertible production forest, and 1,611,602 ha of nature reserves and conservation (Statistics Indonesia 2018).

Borneo's rainforests are home to one of Asia's great primates, the orangutan. Orangutans are the only great apes living in Asia, while three of their relatives, the chimpanzee, gorilla, and bonobo, live in Africa. In Indonesia, the distribution of orangutans is limited to the islands of Sumatra (*Pongo abelii* Lesson, 1827 and *P. tapanuliensis* Nurcahyo, Meijaard, Nowak, Fredriksson & Groves, 2017) and Borneo or Kalimantan (*P. pygmaeus* Linnaeus, 1760) (Nater et al. 2017). Based on the 2017 IUCN (International Union for Conservation of Nature and Natural Resources) red list of threatened species, all three orangutan species are listed as Critically Endangered (CR). The main threat to this species is caused by human activities that lead to habitat loss and fragmentation (Santosa et al. 2012). The existence of habitat is very important for the survival of wildlife, including orangutans. Kalimantan, one of the orangutan's habitats apart from Sumatra, is home to endemic primates protected by the country, as stated in the attachment to Permen LHK No. P.106/Menlhk/Setjen/Kum.1/12/2018 on protected plant and animal species.

Kalimantan orangutans (*P. pygmaeus*), an endemic species of Kalimantan, continue to be threatened. The wild orangutan population continues to decline. The results of the 2016 Orangutan Population and Habitat Viability Assessment (PHVA) estimated that 71,820 orangutans were remaining on the islands of Sumatra and Borneo (Kalimantan, Sabah, and Sarawak) in a habitat area of 181,773 km^2 (SRAK 2019). The Kalimantan orangutan population was estimated at 57,350 individuals across 160,139 km^2 of habitat in 41 metapopulations, there are 26 metapopulations in Indonesia, 12 metapopulations in Malaysia, and 3 metapopulations in both countries (cross-country) (Atmoko et al. 2017).

In their study, Wich et al. (2012) found that the geographic distribution of Kalimantan orangutans overlaps

with protected areas, logging concessions, and plantations. Only 22% of Kalimantan orangutan distribution is in protected areas, and 78% was distributed outside protected areas and concessions. Forest conversion and habitat degradation, including wildfires, have contributed to a 64% decline in Kalimantan orangutans (Ancrenaz et al. 2010; Mang 2017). In 1973, when large-scale commercial logging began, an estimated 76.4% of Borneo was covered by forest. By 2010, approximately 30% of the forest had been logged, and 31.6% of the economically valuable trees had been cut (Wich et al. 2012).

The decline of an estimated 100,000 Kalimantan orangutans between 1999 and 2015 (Milne et al. 2021) may have been driven by rapid land cover change, especially forest conversion due to land-based economic development (Sharma et al. 2018), population growth, fragmentation, fire, and hunting. The above studies have found that changes in land cover cause changes in orangutan population size due to forest conversion, illegal logging, etc. However, quantitative research has yet to be conducted regarding the relationship between changes in land cover and the population size of Kalimantan orangutans in several protected areas regions in Central Kalimantan. Therefore, by first knowing the size of the orangutan population and the rate of land cover change, it is necessary to study the extent of the influence of land cover change on orangutan population size.

MATERIALS AND METHODS

Study area

Lamandau Wildlife Reserve, Tanjung Puting National Park, and Sebangau National Park are some examples of conservation areas in Central Kalimantan, Indonesia, natural habitats for Kalimantan orangutans. Lamandau Wildlife Reserve before being designated as a wildlife reserve in 1998, was initially a permanent production forest area and converted production forest in several forest groups. Lamandau Wildlife Reserve is the only conservation area with wildlife reserve status in Central Kalimantan, previously a Permanent Production Forest (*Hutan Produksi Tetap* /HPH) area. This nature reserve is located in two districts, West Kotawaringin District and Sukamara District. It is under the Central Kalimantan Natural Resources Conservation Center management. Until recently, Lamandau Wildlife Reserve was home to both natural and reintroduced Kalimantan orangutans. This study examined orangutan populations from four sites within Lamandau Wildlife Reserve: Hulu, Buluh, Teringin, and Mangkung.

Sebangau National Park is one of the largest peat swamp protected areas in Indonesia, which has the main function according to the Law of the Republic of Indonesia No. 5 of 1990 on the Conservation of Biological Natural Resources and Ecosystems, namely, to protect life support systems, conserve plant and animal diversity and their ecosystems, and sustainable use of biological natural resources and their ecosystems (Sebangau National Park Office 2014). Administratively, the Sebangau National Park area covers three regencies/cities: Palangka Raya City, Katingan District, and Pulang Pisau District. Before becoming a national park, it was a Production Forest and Convertible Production Forest area, and in 2004 it was declared a national park by a decree of the Minister of Forestry because it is one of the habitats of the Kalimantan orangutan (Sebangau National Park Office 2014). This makes Sebangau National Park the area with the largest orangutan population in Central Kalimantan. This research focused on two of the eight sites in Sebangau National Park, the Mangkok and Baun Bango Resorts.

Tanjung Puting National Park is located on a promontory on the south coast of Kalimantan, which is administratively divided into West and East Kotawaringin Districts. Before becoming a National Park in 1984, it was a protected area consisting of nature reserves and wildlife sanctuaries, and it became the first orangutan rehabilitation center in Indonesia. The presence of freshwater swamp forests and mangrove forests make this National Park a Ramsar site, which are areas designated to protect and preserve the function of wetlands worldwide. This research focused on three of the nine resorts in Tanjung Puting National Park, Camp Leakey, Baung, and Tanjung Rengas (Figure 1).

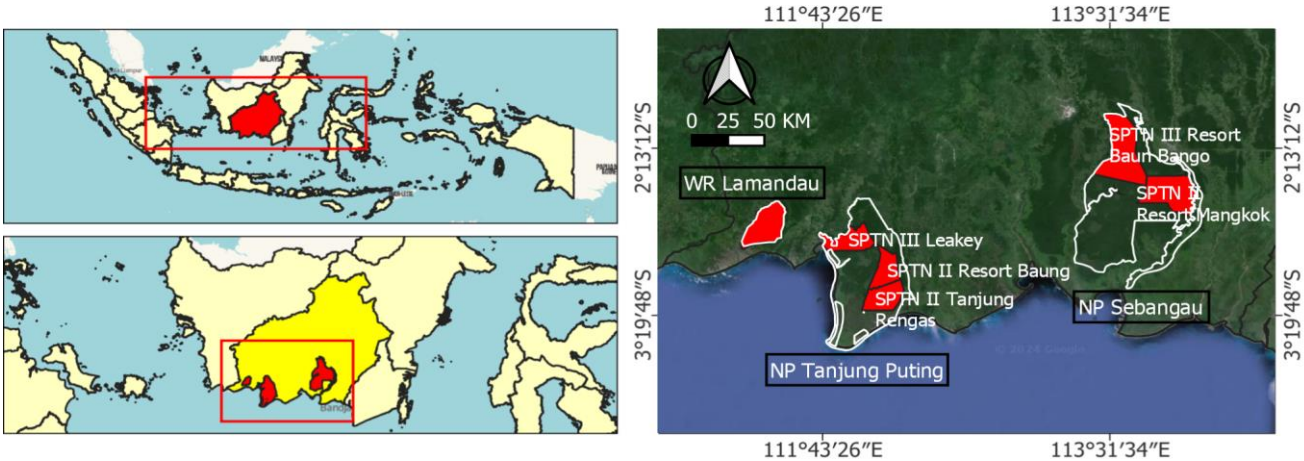

Figure 1. Map of the study areas in Central Kalimantan, Indonesia. Note: WR: Wildlife Reserve, NP: National Park

Data collection and analysis

The research was conducted in nine specific locations from March to December 2023. The selection of the three locations was adjusted according to the availability of population data from each research area's Technical Implementation Unit; it was only valid from 2014 to 2019. The locations are Lamandau Wildlife Reserve Area, specifically at the Hulu, Buluh, Teringin, Mangkung sites, Tanjung Puting National Park at Baung Resort, Tanjung Rengas, Camp Leakey, and Sebangau National Park, specifically at Mangkok Resort and Baung Bango Resort, with field observation time in October 2023 in the Lamandau Wildlife Reserve Area to find out are the Landsat image results look like in the field, to make sure the decisions about the type of land cover. This research only took specific locations on these sites because it was adjusted to the availability of orangutan population data from data representatives, in this case from Central Kalimantan Natural Resources Conservation Center for the Lamandau Wildlife Reserve, as well as from the National Park's office for Sebangau National Park and Tanjung Puting National Park. Data on the orangutan population taken by each office uses the same method, namely nest calculation method. The orangutan population data is used to determine the development of the orangutan population in the area.

The tools used in this research are a camera, GPS (Global Positioning System), with software, ArcGIS 10.8, and SPSS Statistics 20 for data processing. Instruments in the research are shape files of the research area, spatial data of Landsat 8 OLI satellite images in 2014-2019, Ministry of Environment and Forestry land cover map from 2014 to 2019 for the Central Kalimantan region and Kalimantan orangutan population data from 2014 to 2019. These data were obtained from the Directorate General of Forestry Planning and Environmental Management, Ministry of Environment and Forestry, Sebangau National Park Office, Tanjung Puting National Park Office, and Central Kalimantan Natural Resources Conservation Center. The relationship between the dynamics of the Kalimantan orangutan population size and land cover change was carried out using multiple linear regression analysis. Multiple linear regression was carried out to determine the relationship between the independent variable (X) and the dependent variable (Y) or in this case to look for the influence between which types of land cover have the most influence on the size of the Kalimantan orangutan population. The variable used as the dependent variable is the size of the orangutan population, while the variable used as the independent variable is the type of land cover. The method for data collection is summarized in Table 1.

RESULTS AND DISCUSSION

Population dynamics of Kalimantan orangutans in their natural habitats

Some examples of conservation areas in Central Kalimantan that provide natural habitat for Kalimantan orangutans are Lamandau Wildlife Reserve, Tanjung Puting National Park, and Sebangau National Park. Borneo's total population of orangutans is estimated to be 57,350 individuals across 160,139 km^2 of habitat in 41 metapopulations (SRAK 2019). The population of Kalimantan orangutans in the three conservation areas for the years 2014 to 2019 can be seen in Table 2.

Table 1. Data type and research methodology

Data type	Method of data collection	Methods for data analysis
Purpose 1. Determine population size dynamics of Kalimantan orangutans in Central Kalimantan 2014-2019		
2014-2019 Kalimantan orangutan population estimates	1. Data sharing from data representative (Central Kalimantan Natural Resources Conservation Center, Sebangau National Park Office, Tanjung Puting National Park) 2. Literature Study	Analysis of descriptive statistics
Purpose 2. Determine the rate of forest cover development in the natural habitat of Kalimantan orangutans in Central Kalimantan 2014-2019		
1. Landsat multi-temporal imagery data of the study area from 2014-2019 2. 2014-2019 KLHK land cover data 3. Study area shape file	Downloading Landsat using the Google Earth Engine Data sharing from data representative (Directorate General of Forestry Planning and Environmental Management)	1. Qualitative classification (visual interpretation) 2. Post classification comparison 3. Interpretation of Landsat images
Purpose 3. To determine the relationship between Kalimantan orangutan population size dynamics and the rate of land cover change in Central Kalimantan 2014-2019		
1. Landsat image interpretation based on land cover type 2014-2019 2. Kalimantan orangutan population size data 2014-2019	1. Interpretation of Landsat images 2. Data sharing from data representative	Analysis of multiple linear regression $Y = a + b1x1 + b2x2 + b3x3 + b4x4 + b5x5 + \ldots + bnxn$

Table 2. Kalimantan orangutan population 2014-2019 at study area

Year	Lamandau Wildlife Reserve (individual)					Sebangau National Park (individual)			Tanjung Puting National Park (individual)			
	Hulu	Buluh	Teringin	Mangkung	Total	Mangkok	Baun Bango	Total	Camp Leakey	Baung	Tanjung Rengas	Total
2014	34	192	21	23	270	103	109	212	174	213	29	416
2015	34	27	17	23	101	108	109	217	174	107	29	310
2016	34	98	28	23	183	108	109	217	213	111	15	339
2017	21	364	20	57	462	108	142	250	288	114	8	410
2018	25	91	31	119	266	112	142	254	329	202	14	545
2019	26	31	32	71	160	107	151	258	420	91	6	517

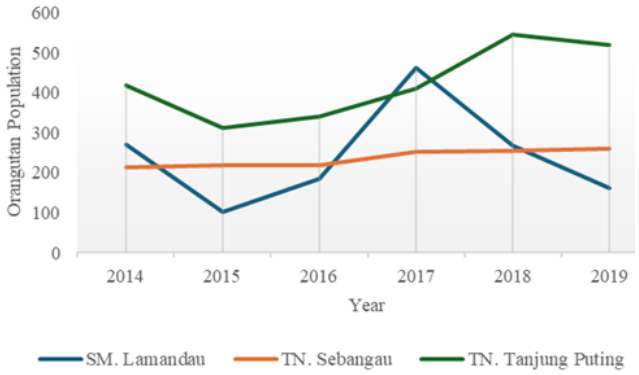

Figure 2. Chart of the orangutan population

Data on orangutan populations in each conservation area unit were collected through field surveys using the line transect method conducted by the relevant representative at the research site from 2014 to 2019. Kalimantan orangutan population data sharing from data representative is obtained using the same method between each representative, namely, to determine the density of orangutans in an area, it can be determined by nests counting using the line transect method (van Schaik et al. 1995). Research by Rahman (2008) stated that the use of the nest count method showed reliable results and was good for estimating orangutan population density. Nest counting is the basis for determining orangutan population density because nests are evidence of the existence of orangutans in nature. The nest is very important for orangutans, because it has the function of shelter, resting, giving birth, and sometimes eating activities are carried out in the nest (Sosilawaty et al. 2020).

The Lamandau Wildlife Reserve, originally a permanent production forest, was transformed into a wildlife reserve in 1998. In 2014, the reserve was home to 270 orangutans, with the population fluctuating over the years. The lowest count was in 2015, with 101 individuals. However, the highest was in 2017, with 462 individuals, which marks a success in conservation efforts and the potential for further growth. However, there was a decline of 196 individuals to 266 in 2018 and 160 in 2019.

Sebangau National Park was previously a Production Forest and Convertible Production Forest area. In 2004, it was designated a national park based on the decree of the Minister of Forestry because it is one of the habitats of the Kalimantan orangutan, which makes this National Park the largest orangutan population in Kalimantan middle. This research focused on two of the eight resorts in Sebangau National Park, Mangkok Resort and Baun Bango Resort, which had the lowest population in 2014 at 212 individuals and stayed mostly the same in 2015 (212 to 217 orangutans). In six years, the number of orangutans increased by 46 individuals to 258 in 2019, the highest orangutan population since 2014.

Tanjung Puting National Park, before being designated as a national park in 1984, was a conservation area consisting of nature reserves and wildlife sanctuaries. This study focused on three resorts out of nine: Camp Leakey, Baung Resort, and Tanjung Rengas Resort. The year with the lowest population was 2015, with 310 individuals. There was a significant increase in the total orangutan population in Tanjung Puting National Park from 2015 to 2018 and a decline to 517 individuals in 2019. A summary of how the Kalimantan orangutan population has change is shown in Figure 2.

Figure 2 shows that the change of the Kalimantan orangutan population in the three specific areas fluctuates up and down from year to year. Lamandau Wildlife Reserve experienced a decrease in population. In contrast, Sebangau National Park experienced a population increase, and Tanjung Puting National Park experienced a decline in population in 2019 after having experienced a fluctuating increase in the previous year. The decline in orangutan numbers in recent years is also due to the fire factor, which occurred in Central Kalimantan in the vulnerable years of 2014, 2015, 2018, and 2019. This is consistent with van Eijk et al.'s (2009) findings that Kalimantan orangutans are increasingly threatened by forest fires, even in protected areas. Forestry Department (2007) stated that several threats faced by Kalimantan orangutans is caused by anthropogenic factors which cause orangutans to lose their habitat by illegal logging, land fires, hunting and trade. Aside from antropogenic factors, population decline can also caused by natural factors such as disease, fights between orangutans, and natural predators in a food-chain ecosystem can cause populations to decline. This is in line with IUCN (2023), which states that one of the causes of orangutan decline, apart from converting forests to large plantations, is forest fires, also caused by natural factors such as predators.

Habitat degradation can trigger individuals migration from burned to unaffected areas, causing population increases in certain years (Mang 2017). The increase in the number of orangutans in certain places occurs because, generally, orangutans explore or move to find food and mates. Orangutan movements are influenced by the availability of food and nest trees, Ancrenaz (2006) stated that the distribution of orangutan nests generally fluctuates according to the availability of suitable nesting sites, proximity to food sources, and disturbance. This is what makes the number of orangutan populations in a place fluctuate, because it is adjusted to the suitability of orangutans in the area. When fruit is abundant in the forest, orangutans tend to be able to choose the food they like best to eat, but when it is not the season, orangutans eat whatever they find or switch to poor quality food sources such as leaves, shoots and bark (Meijard et al. 2001; Knott 1998; Vogel et al. 2015) while continuing to explore the forest. Orangutans are semi-solitary animals that do not form permanent groups like other species of apes and monkeys, they will only associate with other individuals if there are food trees that are bearing fruit and when they are about to mate which lasts approximately 2-3 weeks or when caring for their baby (Wastoni 2010). In moving from a place affected by fire to a safer place or in looking for food or to fulfill their biological needs, orangutans will explore to compete for their home range and food sources. This can then cause an increase or decrease in the number of orangutan populations at a particular site, because basically selecting a suitable habitat is an action carried out by wild animals to obtain a series of conditions that are favorable for their successful reproduction and survival (Bolen and Robinson 1995).

The increase in population, apart from migration, also occurs in natural reproduction, female orangutans will give birth at the age of 7-10 years with a gestation period of between 8-9 months, the number of babies born to a female is usually only one baby with subsequent birth intervals reaching 7-8 years (Winarno and Sugeng 2018). Natural breeding in each location and reintroduction efforts by orangutan conservation organizations in collaboration with related agencies can also increase the population. One of these is OF-UK (Orangutan Foundation - United Kingdom) in collaboration with the Central Kalimantan Natural Resources Conservation Office, which has successfully reintroduced orangutans to Lamandau Wildlife Reserve, the Lamandau Wildlife Reserve has been one of the orangutan release sites since 1999 (Nawangsari 2016) and also Lamandau Wildlife Reserve is one of the habitats for Kalimantan orangutans since it was designated as a wildlife reserve. According to Nawangsari (2016), in Lamandau Wildlife Reserve, the level of habitat suitability of Lamandau as a release habitat was 86.25%, so it can be said that Lamandau Wildlife Reserve has high habitat suitability for Kalimantan orangutans. The same thing applies to Sebangau National Park and Tanjung Puting National Park, which is the area with the largest orangutan population (Atmoko et al. 2017). Releasing or reintroduced orangutans into their natural habitat is one of the conservation efforts that can be carried out to restore the form of a species that was once part of that area (Beck et al. 2007). On average, orangutans released into the wild are juvenile orangutans who have gone through the forest school process and are deemed capable of surviving in nature, because they already know the food trees and their nests. This release activity will automatically increase the population in nature, especially at certain sites. Naturally, when orangutans are in their habitat, they will breed, and the population will automatically increase.

Rate of land cover change in Central Kalimantan conservation areas

Land cover changes were analyzed using post-classification comparative analysis by comparing the changes in the t_1 image classification results with the t_2 image classification results. This analysis was conducted at each research location in the same year range, 2014-2019. The classification of each location shows different types of land cover; the Lamandau Wildlife Reserve has five types of land cover: secondary swamp forest, shrub swamps, bushes, agriculture, and open land (Table 3).

Since 2014, the secondary swamp forest has been decreasing every year. In six years, there was a decrease of 21.79 km^2, but since 2018, it's been increasing. The decrease in swamp area was 21.9 km^2, the decrease in shrub area was 2.9 km^2, and the same was true for plantation land cover. Open land cover increased by 46.64 km^2, the largest increase in land cover. The loss and change of land cover in Lamandau Wildlife Reserve at the highest threat level is caused by land fires. This aligns with Santoso (2010), where land fires occur because of land clearing for plantations around the area using a slash-and-burn system and illegal logging. The positive increase in some land cover is due to the rehabilitation activities that have been carried out, as well as to succession, which can restore the forest cover that has been cleared due to fires and illegal logging.

Sebangau National Park is a conservation area; a very dense peat swamp forest with a depth of 3 to 26 meters is the Sebangau National Park (Page et al. 1999). Sebangau National Park has the same land cover types as Lamandau Wildlife Reserve, namely secondary swamp forest, swamp including swamp shrubs, shrubs, agricultural land, and open areas; the results of the annual area classification are in Table 4.

Table 3. Land cover in Lamandau Wildlife Reserve, Central Kalimantan, Indonesia in 2014-2019

Year	Wide (km^2)				
	SSF	Sw	Sh	Agr	OL
2014	373.63	211.15	20.09	0.45	38.11
2015	367.64	206.82	25.86	0.45	42.66
2016	334.04	203.95	14.09	0.45	90.98
2017	332.69	233.06	14.17	0.45	63.07
2018	336.41	209.31	20.12	0.48	77.08
2019	351.84	189.24	17.19	0.42	84.75

Note: SSF: Secondary Swamp Forest, Sw: Swamp, Sh: Shrubs, Agr: Agricultural, OL: Open Land

Table 4. Land cover in Sebangau National Park, Central Kalimantan, Indonesia in 2014-2019

Year	Wide (km^2)				
	SSF	Sw	Sh	Agr	OL
2014	1,647.87	164.79	8.35	0.00	36.09
2015	1,652.11	177.07	3.85	0.00	24.07
2016	1,613.77	164.01	4.41	4.12	70.79
2017	1,599.90	161.43	5.85	19.99	69.94
2018	1,572.67	208.13	4.90	18.62	52.78
2019	1,609.89	211.46	3.12	19.03	13.61

Note: SSF: Secondary Swamp Forest, Sw: Swamp, Sh: Shrubs, Agr: Agricultural, OL: Open Land

Table 5. Land cover in Tanjung Puting National Park, Central Kalimantan, Indonesia in 2014-2019

Year	Wide (km^2)							
	M	SSF	Sw	Shr	Agc	Mng	OL	WB
2014	13.77	580.89	583.55	46.86	1.23	0.38	75.57	3.26
2015	11.45	645.93	571.55	41.93	1.49	0.45	30.56	2.15
2016	12.29	461.96	513.07	24.39	1.59	0.45	289.60	2.22
2017	11.19	475.45	587.56	22.24	4.64	0.45	201.80	1.90
2018	11.80	491.92	630.71	11.09	5.92	0.44	151.24	2.40
2019	12.38	478.94	522.30	8.94	4.87	0.44	274.87	2.77

Note: M: Mangrove, SSF: Secondary Swamp Forest, Sw: Swamp, Sh: Shrubs, Agr: Agricultural, Mng: Mining, OL: Open Land, WB: Water Body

Table 6. Results of multiple linear regression analysis of orangutan population size on land cover change

Equations	Sig.	r (partial)	R *Square*
$Y = -0.090 + 0.080\ X_M + 0.492\ X_{SSF} + 0.192X_{Sw} - 0.274\ X_{Agr} + 0.378\ X_{Sh} + 0.298\ X_{Mng} - 0.237\ X_{Ol} + 0.112\ X_{WB}$	$X_M = 0.456$	0.723	0.917
	$X_{SSF} = 0.009$	-0.207	
	$X_{Sw} = 0.433$	0.704	
	$X_{Agr} = 0.178$	-0.20	
	$X_{Sh} = 0.027$	0.186	
	$X_{Mng} = 0.056$	0.717	
	$X_{Ol} = 0.021$	0.610	
	$X_{WB} = 0.445$	0.735	

Note: M: Mangrove, SSF: Secondary Swamp Forest, Sw: Swamp, Sh: Shrubs, Agr: Agricultural, Mng: Mining, OL: Open Land, WB: Water Body

Within six years, there was a decrease in secondary swamp forest cover and an increase in swamp cover of 46.66 km^2 in 2019. There was a decrease of 5.23 km^2 of shrubs, and in 2016, there was agricultural land cover in Sebangau National Park, and experienced a significant increase from 4.12 km^2 to 19.03 km^2 in 2019. While open land fluctuates up and down, there has been a decrease of 22.48 km^2.

Tanjung Puting National Park has eight land cover classifications: mangrove, secondary swamp forest, swamp including swamp shrubs, agricultural, mining, open land, and water body (Table 5).

In six years, Tanjung Puting experienced a decrease in mangrove forest cover by 1.39 km^2 and a decrease in secondary swamp forest by 101.95 km^2. There was a decrease in swamp land cover by 61.25 km^2 and an increase in agricultural land cover by 3.64 km^2. The shrub area has decreased significantly in the last six years, from 46.86 km^2 in 2014 to 8.94 km^2. Mining land cover is relatively small but has increased by 0.06 km^2. The area of open land experienced a significant increase of 199.3 km^2, while the water area decreased by 0.49 km^2.

The relationship between Kalimantan orangutan (*Pongo pygmaeus*) population size and land cover change in Central Kalimantan

Moreover, using multiple linear regression analysis, the orangutan population size (Y) was tested with different land cover types (X). The land cover types tested included mangrove (X_M), secondary swamp forest (X_{SSF}), swamp (X_{Sw}), agricultural (X_{Agr}), shrubs (X_{Sh}), mining (X_{Mng}), open land (X_{Ol}), waterbody (X_{WB}). Based on the results of the multiple linear regression analysis in Table 6, the coefficient of determination (R Square) obtained is 0.917, which means that all the land cover type factors (X) tested contribute 91.7% to the size of the orangutan population, while other independent variables outside this study explain the remaining 8.3% the remaining 8.3%. Five of the eight land cover type factors (X) tested had significance values higher than the error rate (> 0.05), so they did not have a significant effect on the dependent variable, in this case, orangutan population size. These variables are Mangrove (X_M), Swamp (X_{Sm}), Shrubs (X_{Sh}), Mining (X_{Mng}), Waterbody (X_{WB}). Meanwhile, the water body has the highest r (partial) value at 0.735, indicating that this variable has the greatest partial influence on orangutan population size. Multiple linear regression results and their significance are shown in Table 6.

Three of the eight land cover type variables tested (X) were strongly correlated with the Kalimantan orangutan population size, because they have a significance value that is lower than the error level (<0.05), so they have a significant effect on the dependent variable or, in this case, the size of the orangutan—population (Y). Secondary swamp forest (X_{SSF}) has a positive (+) regression coefficient of 0.492. The orangutan population will increase as the area of secondary swamp forest increases. This study's secondary swamp forests include freshwater and peat swamp forests. It is found in certain areas where Kalimantan orangutan population data is available.

Kalimantan's peat swamp forests are home to the highest density of orangutans; van Schaik et al. (1995) stated that this is related to the high variety of orangutan food plant species in this forest type. This condition occurs in forest areas where the soil is alluvial, including swamp forest areas or rivers with wide valleys (Meijard et al. 2001).

The regression coefficient of the shrubs variable (X_{Sh}) is 0.378. The orangutan population will increase the more extensive the shrub cover type. The food needs of orangutans are met not only by fruit but also by young leaves, tree bark, and tubers, including ants and termites, some of which are found in the shrub cover. This is in line with the statement of Prayogo et al. (2014) that areas in the shrub class, which consists of shrubs, young secondary forests, and old secondary forests, have abundant food sources, especially in the form of fruits and leaves or tubers of plants from the palm group, in this case, the higher photosynthetic process also influenced in this type of land cover compared to secondary forests or climaxing primary forests.

As shown in Table 6, the open land variable (X_{Ol}) has a regression coefficient value of (-) 2.037, indicating that the larger the area of open land cover, the smaller the size of the orangutan population. Open land is an area with almost no vegetation and usually consists of trees with small diameters, so orangutan presence is almost non-existent in these areas. Orangutan densities are low in cleared or severely degraded forest areas (Rijksen and Meijaard 1997) because orangutans are very sensitive to forest changes. This is in line with Santika et al. (2017) who stated that the lowest survival rate for orangutans occurs in fragmented forest areas or close to areas that have recently been converted into agricultural forests or to open land. Therefore, open land is a threat to orangutans because there are no food sources in the area.

The period from 2014 to 2019 in three specific areas has decreased in the Lamandau Wildlife Reverse, the fluctuating population in Tanjung Puting National Park, and an increase in the Sebangau National Park. The life of orangutans is very dependent on habitat conditions that support their survival, one of which is the availability of sufficient food. The availability of food is one of the factors that really determines the use of space and the existence of orangutans. Based on Muin (2007), the level of suitability of orangutan habitat is assessed based on two main biotic components, namely the availability of nest trees and food trees in their habitat which ensure the survival of orangutans in a habitat. The results of the analysis of land cover development in 2014-2019, Lamandau and Tanjung Puting experienced the largest increase in the open land area of 46.63 km^2 and 199.3 km^2, respectively. While Sebangau, at 46.67 km^2, has the largest increase in swamp-type area. Prayogo et al. (2014) in his research stated that, habitats that have high suitability for orangutans are areas that have good land cover and generally have lots of trees as a source of food and nests for orangutans. Changes in land cover can alter the provision of ecosystem services such as food, water and a habitat for wildlife.

Monitoring the orangutan population and identifying land cover in the same year is necessary to determine the relationship between the two. This can maximize conservation efforts in locations whose physical conditions are suitable for orangutans. Secondary swamp forests, bushes, and open land are the types of land cover most closely related to the population of Kalimantan orangutan at the study site.

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