The relationship between Bornean orangutans' (*Pongo pygmaeus*) population and land cover change in West Kalimantan, Indonesia

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Abstract. *Parida I, Santosa Y, Jaya INS. 2024. The relationship between Bornean orangutans' (*Pongo pygmaeus*) population and land cover change in West Kalimantan, Indonesia. Biodiversitas 25: 1831-1837.* Orangutans (*Pongo pygmaeus* Linnaeus 1760) are critically endangered species under IUCN Red List and classified in Appendix 1 of CITES. Their population is declining, which is largely caused by habitat loss. This study aims to investigate the population dynamics of the Bornean orangutans and changes in land cover in West Kalimantan and to analyze the relationship between the orangutan population and land cover change. Bornean orangutan population data from 2014 to 2019 at four locations (i.e. Belaban, Bukit Semujan Semangit Menyukung Melingkung, Embaloh Sibau watershed and Sungai Putri) were obtained from Bukit Baka Bukit Raya National Park, Betung Kerihun National Park, Danau Sentarum National Park, and West Kalimantan Natural Resources Conservation Agency, and land cover data were obtained from the Directorate General of Forestry and Environmental Planning of the Ministry of Environment and Forestry. The data obtained were analyzed using descriptive statistics, land cover analysis, and multiple linear regression analysis to test the relationship between orangutan population and eight variables, namely forest cover, shrubs (secondary regrowth), agriculture cover, open land, water body, road density, river density and settlement density. The results showed that orangutan population in the Bukit Semujan Semangit Menyukung Melingkung and Sungai Putri locations tended to increase. On the other hand, orangutan population in the Belaban and Embaloh Sibau watersheds tended to fluctuate. The land cover in the Belaban, Bukit Semujan Semangit Menyukung Melingkung and Sungai Putri tended to fluctuate, while that in Embaloh Sibau was steady. Bornean orangutan populations have a strong relationship with the extent of forest cover and shrubs. The findings of this study suggest that conserving the remaining forest and shrubs altogether with population monitoring, inventory of feed availability, and forest area patrol are imperative to protect and conserve orangutan population.

Keywords: Bornean orangutan, land cover, multiple linear regression analysis, population, relationship analysis

INTRODUCTION

Orangutans (genus *Pongo*) are the only great apes outside Africa and are the largest arboreal mammal on the Earth. This primate is only found in two islands, Sumatra and Borneo, and is shared by only two countries, Indonesia and Malaysia. In Indonesia, orangutans are protected under Law No. 5 of 1990 concerning the Conservation of Living Natural Resources and Ecosystems and the Minister of Environment and Forestry Regulation No. P. 106 of 2018 concerning Protected Plant and Animal Species. Globally, orangutans are listed in Appendix I of CITES, where this species is prohibited from commercial trade because it is highly vulnerable to extinction (Ancrenaz et al. 2023). Orangutans are also listed as Critically Endangered (CR) in the IUCN Red List of Threatened Species (Ancrenaz et al. 2023). This status was due to the tendency of population decline caused by various factors. Ecologically, orangutans have a role as seed dispersers that maintain forest species diversity (Ashbury et al. 2015).

Habitat destruction in the form of a decrease in area, quality, and fragmentation causes a reduction or loss of habitat-carrying capacity, resulting in the decline of orangutan populations. Several studies and reports state that the Bornean orangutan population continues to decline. Voigt et al. (2018) estimated that habitat loss from 1999 to 2015 had impacted 100,000 Bornean orangutans. Across Borneo, the orangutan population was estimated at 156,000 individuals between 1960 and 1970 (Meijaard et al. 2012). By the end of 1990, the population declined, leaving to only 25,000 orangutan individuals both on the islands of Borneo and Sumatra (Delgado and van Schaik 2000). In Sarawak and West Kalimantan, Abram et al. (2015) estimated that less than 10,000 orangutan individuals remain. Meijaard et al. (2011) mentioned from April 2008 to September 2009 alone, there were around 750 to 1,800 individuals of orangutan death.

Several factors threaten the existence of Bornean orangutans, including habitat loss due to conversion to agriculture and plantations, habitat fragmentation, illegal hunting and trade, forest fires and human-wildlife conflicts (Soehartono et al. 2007; Husson et al. 2009; Meijaard et al. 2011; Abram et al. 2015; Ancrenaz et al. 2023). Among such threats, changes in forest cover for various purposes are likely to have the highest impacts, resulting in the decline of the Bornean orangutan population. Kalimantan

(Indonesian Borneo) has the second-largest natural forest cover in the country, with 26.6 million hectares. Nonetheless, the natural forest cover in this region suffered deforestation and forest degradation. For example, during 2009-2013, West Kalimantan Province lost about 426,000 hectares of natural forest cover. Some portion of deforestation in Indonesia from 2009 to 2013 occurred in conservation areas, amounting to 0.23 million hectares (Purba et al. 2014).

Geographic information systems and remote sensing are effective and efficient methods for land cover monitoring. Using both tools makes it possible to assess land cover change through the image interpretation process. In the context of research on orangutans, there is an opportunity to employ both tools to investigate the relationship between land cover and orangutans' population. There are various population studies on orangutans in Borneo, including by Yuliani et al. (2023), which estimated the orangutan individuals within and around Lake Sentarum National Park and by Utami-Atmoko et al. (2017) for all orangutan populations on the islands of Sumatra and Kalimantan. Quantitative research on the changes in orangutan populations in relation to land cover change, especially in West Kalimantan Province, has never been conducted.

Therefore, the objectives of this study were (i) to identify the dynamics of Bornean orangutan population in four locations in West Kalimantan Province, Indonesia (i.e. the Belaban, Embaloh Sibau watershed, Bukit Semujan Semangit Menyukung Melingkung, and Sungai Putri monitoring sites) from 2014 to 2019, (ii) to assess the land cover change in the area and (iii) to analyze the relationship between Bornean orangutan population dynamics and land cover change. We expected the results of this study to be useful in providing information on the dynamics or development of the Bornean orangutan population, land cover dynamics, and land cover variables associated with orangutan populations. So that it can be taken into consideration in the management of orangutan populations and their habitats, especially for management authorities in Bornean orangutan (*Pongo pygmaeus* Linnaeus 1760) conservation.

MATERIALS AND METHODS

Study period and area

The study was conducted from August to December 2023 at four locations in West Kalimantan Province, Indonesia, namely: (A) the Belaban monitoring site of Bukit Baka Bukit Raya National Park (BBBRNP), Melawi District; (B) Embaloh Sibau watershed monitoring site of Betung Kerihun National Park (BKNP), Kapuas Hulu District; (C) Bukit Semujan Semangit Menyukung Melingkung monitoring site of Danau Sentarum National Park (DSNP), Kapuas Hulu District; and (D) Sungai Putri monitoring site of the West Kalimantan Natural Resources Conservation Agency (BKSDA), Ketapang District (Figure 1).
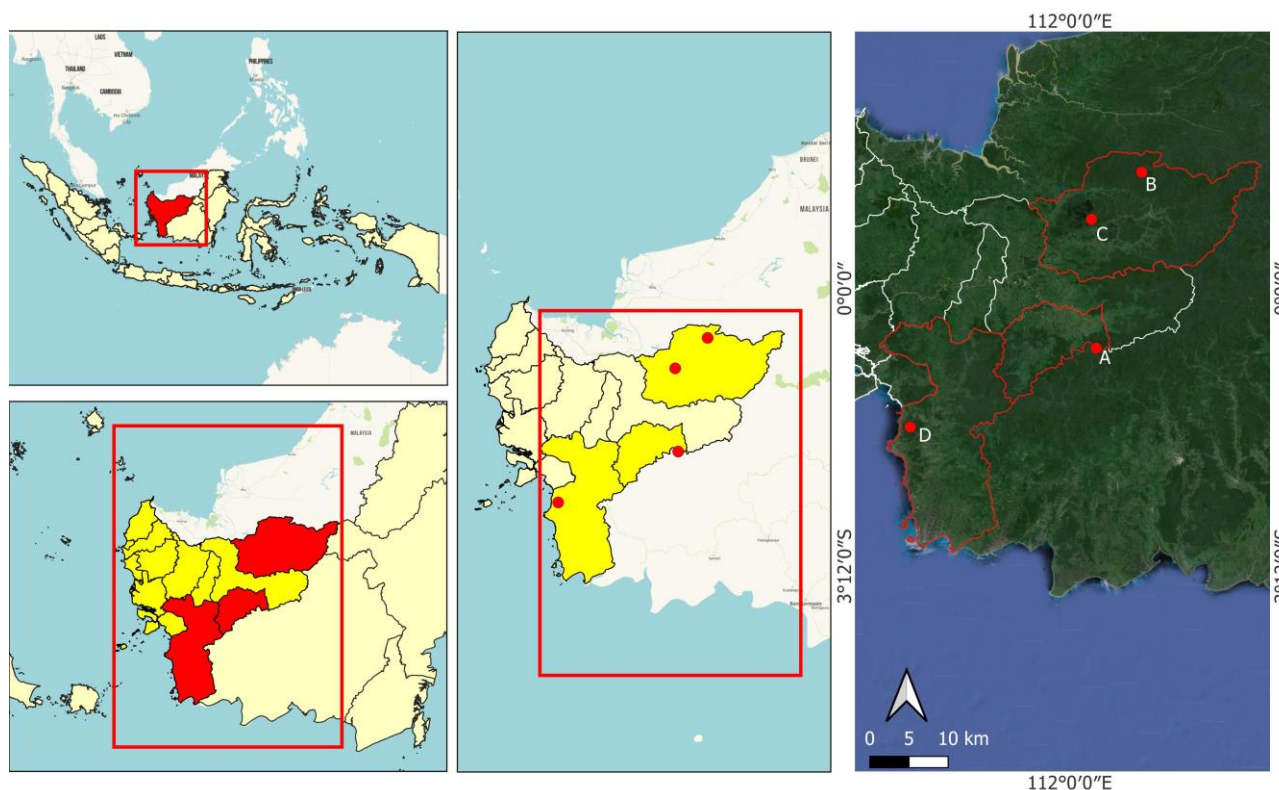

Figure 1. Map of four research locations in West Kalimantan Province: A. Belaban, Melawi District and B. Embaloh Sibau watershed, Kapuas Hulu District C. Bukit Semujan Semangit Menyukung Melingkung, Kapuas Hulu District; and D. Sungai Putri monitoring site, Ketapang District, West Kalimantan Province, Indonesia

Data collection

The research used primary and supporting data. The primary data consisted of Bornean orangutan population data from 2014 to 2019, land cover data from 2014 to 2019, Landsat 8 images, and research site boundary data. Supporting data consisted of road network maps, river network maps, and settlement maps. The data on the orangutan population was obtained from the results of population monitoring, which were collected directly by the management agency at the Belaban monitoring site in the BBBRNP, the Bukit Semujan Semangit Menyukung Melingkung monitoring site in the DSNP, the Embaloh watershed monitoring site in the BKNP, and the Sungai Putri West Kalimantan monitoring site. The method used to collect orangutan population data was through counting nests within the monitoring transect (line transect). Data on orangutan nests were analyzed for nest density, orangutan density and estimated number of orangutan individuals (population). The population data used in this study was limited from 2014 to 2019. The population data was adapted to the availability of data at the four research locations collected by the managing agency. Based on the results obtained from the data providers, population data was available from 2014 to 2019. On the other hand, no population monitoring was conducted in 2020 due to the COVID-19 disease outbreak, so population data is not yet available. The land cover data was downloaded through the Google Earth Engine site, Ina-Geoportal. The types of data and methods used in this study are presented in Table 1.

Data analysis

Population size data were analyzed using descriptive statistics to observe changes in orangutan population. The data on population dynamics was presented in line diagrams.

Interpretation of land cover was conducted using the 2014-2019 land cover data. Land cover data was verified using Landsat imagery by verifying cover data that did not match the actual field conditions. The interpretation was made visually based on recognizing spatial object characteristics using seven interpretation keys, including hue or color, shape, size, texture, pattern, shadow, and site (Rahman et al. 2022). Next, post-classification comparison spatial data analysis was carried out; this analysis was used to detect land cover changes. The post-classification comparison process was conducted using two classification result maps as input to determine land cover changes that occurred during 2014-2019. The data of each land cover class change are presented as a graph.

Multiple linear regression analysis was used to observe if there is an influence of one or more X variables on the Y variable. The X variable is the extent of identified land cover types, and the Y is the total Bornean orangutan population. The general equation of multiple linear regression can be seen in equation (i).

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 \ldots\ldots\ldots (i)$$

Where :

Y : Population size of Bornean orangutans
a : Regression constant
$b_1, b_2, \ldots, b_8$: Regression coefficient
X_1 : Area of forest cover
X_2 : Area of shrub cover
X_3 : Area of agricultural cover
X_4 : Area of open land
X_5 : Area of water body
X_6 : Road density
X_7 : River density
X_8 : Settlement density

The T-test was conducted to see if variable X has a partial or individual influence on variable Y. If the significance value is <0.05, there is a partisan influence of variable X on variable Y. The F-test was carried out to see if variable X has a simultaneous or joint influence on variable Y. If the significance value is <0.05, there is a mutual influence of variable X on variable Y.

Table 1. Types of data and research methods used in this study

Objective	Variable type	Data collection method	Data analysis method
Identify the dynamics of Bornean orangutan population during 2014-2019	Population size data from 2014-2019	Data sharing (BBBRNP, BKNP, DSNP, and West Kalimantan Natural Resources Conservation Agency)	Descriptive statistical analysis
Identify land cover change during 2014-2019	Land cover data 2014-2019 Landsat 8 images recorded in 2014-2019 Research area boundary map Road network map, river network map, and settlement map	Directorate General of Forestry and Environmental Planning https://code.earthengine.google.com/ https://tanahair.indonesia.go.id/	Qualitative classification (visual interpretation) Post classification comparison
Analyze the relationship between Bornean orangutan population size and land cover change during 2014-2019	Population size data from 2014-2019 Land cover data interpreted from 2014 to 2019		Multiple linear regression analysis

RESULTS AND DISCUSSION

The dynamics of Bornean orangutan population

The dynamics of the total orangutan population at the four research locations from 2014 to 2019 are presented in Figure 2. Figure 2 shows that at the Belaban monitoring site, the Bornean orangutan population from 2014 to 2019 tended to fluctuate. The population increased by 2 individuals in 2015, 5 individuals in 2017 and 4 individuals in 2018, while the other years experienced a decline. At the Bukit Semujan Semangit Menyukung Melingkung monitoring site, the Bornean orangutan population tended to increase from 2014 to 2019. The population increase occurred from 2015 to 2018 with the highest recorded in 2018 with 47 individuals. During the period of 2014 to 2019, the population increased by 65 individuals. At the Sungai Putri monitoring site, the Bornean orangutan population increased from 2014 to 2018 before declining in 2019. Overall, the population increased by 467 individuals, with the highest occurring in 2018 with 190 individuals. At the Embaloh watershed monitoring site, the Bornean orangutan population tended to fluctuate from 2014 to 2019. Population increased in 2015 by 39 individuals, in 2017 by 3 individuals, and in 2019 recorded the highest by 153 individuals, while the other years experienced a decline.

An increase in orangutan population can occur due to the birth of new individuals, as reported by Anugrah (2023), in which one individual orangutan was born in the Bukit Baka Bukit Raya National Park area. In addition, orangutan migration from other areas can also increase the existing population. Population migration from an area can be influenced by food availability. Research by Kanamori et al. (2016) states that orangutans can temporarily move to surrounding areas to search for fruits. In addition, male orangutans will explore new habitats when they reach adulthood. Research by Mörchen et al. (2023) explains that orangutans can eventually settle down and become residents or remain nomadic and move around the region. Furthermore, reintroducing populations into areas also helps to increase population numbers. In Indonesia, such programs are increasingly developed to enhance wild populations and rescue unfortunate orangutan individuals (Maskulino et al. 2021).

On the other hand, population decline can be caused by various factors, including natural mortality of individuals, disease, age, and human-caused disturbances such as habitat loss and destruction, hunting, fire, and human-wildlife conflict. Any disturbance to the habitat occupied by orangutans will make them move to other undisturbed locations so that the population in the area is reduced (Prasetyo et al. 2021). Research by Jainuddin (2023) states that unsuitable habitats affect population decline, especially for species that rely on forests as a place to live, feed, and breed. Habitat disturbances affect the existence of forest vegetation diversity, especially large trees which might affect mass fertilization patterns and wildlife reproductive cycles, threatening the survival of animals (Fawzi et al. 2020b).

According to Santika et al. (2017), the decline in orangutan population in West Kalimantan province was caused by habitat loss, human-orangutan conflict, anthropogenic pressure, and habitat fragmentation. Research by Ridadiyanah and Subekti (2021) also explained that logging caused a drastic decrease in vegetation, direct mortality, decreased birth rates, diet changes, abandonment, and infant primate mortality. Other factors, such as forest fires, also contribute to population decline that will directly kill orangutans. In addition, forest fires can destroy and fragment habitat (Ridadiyanah and Subekti 2021).
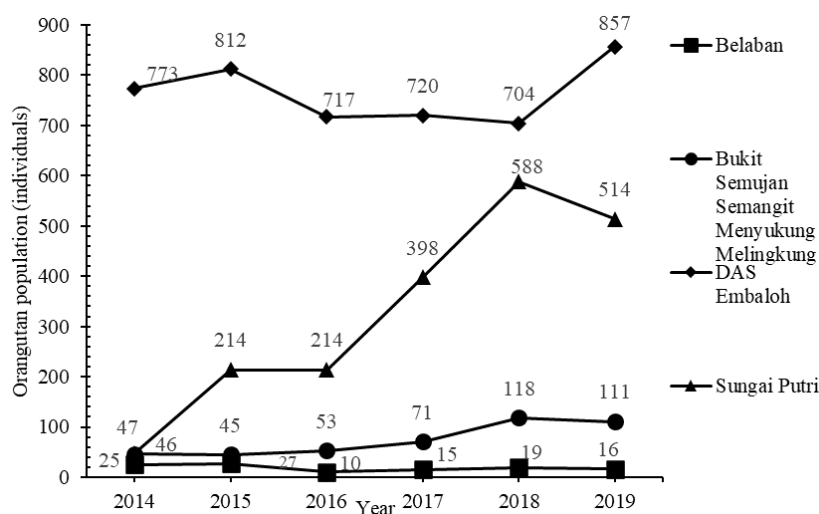

Figure 2. The dynamics of Bornean orangutan population from 2014 to 2019 at four monitoring sites in West Kalimantan, Indonesia

The dynamics of land cover change

The Belaban monitoring site had an area of 271.64 km^2 and consisted of five classes: forest, shrubs, agriculture, open land, and water bodies. These classes fluctuated in the area from 2014 to 2019 (Figure 3). Forests occupied most of the area from 2014 to 2019, followed by agriculture, water bodies, shrubs, and open land. From 2014 to 2019, the forest cover and water bodies increased, but shrubs, open land, and agriculture decreased. The forest class had the largest increase, with a total of 0.36 km^2 in 2019. On the other hand, the open land class had the largest decrease between 2014 and 2019 at 0.14 km^2.

Five land cover classes were obtained at the Bukit Semujan Semangit Menyukung Melingkung monitoring site: forest, shrubs, agriculture, open land, and water bodies, with a total area of 399.54 km^2. These classes increased and decreased in area from 2014 to 2019. The land cover change at the Bukit Semujan Semangit Menyukung Melingkung site tended to fluctuate in all types of cover (Figure 4). Forests occupied most of the area from 2014 to 2019, followed by water bodies, shrubs, open land, and agriculture. From 2014 to 2019, forest cover, shrubs, and water bodies decreased while agriculture and open land increased. The open land class had the largest increase, with 6.03 km^2 in 2019. On the other hand, the shrub class had the largest decrease with 2.4 km^2, followed by forest with 2.13 km^2 from the beginning of 2014.

There was only one land cover class obtained at the Embaloh Sibau watershed monitoring site: forest with total area of 2,219.59 km^2. The forest class did not change in area from 2014 to 2019. The land cover in the Embaloh Sibau watershed site tended to be stable or constant (Figure 5).

Five land cover classes were obtained at the Sungai Putri monitoring site: forest, shrubs, agriculture, open land,

and water bodies, with a total area of 914.295 km^2. Land cover change in this area tended to fluctuate in all types of cover (Figure 6). Forests occupied most of the area from 2014 to 2019, followed by shrubs, open land, agriculture, and water bodies. From 2014 to 2019, forest cover decreased, but shrubs, agriculture, open land, and water bodies increased. The shrubs class had the largest increase, with 53.86 km^2 in 2019. On the other hand, the forest class decreased, by 91.11 km^2.
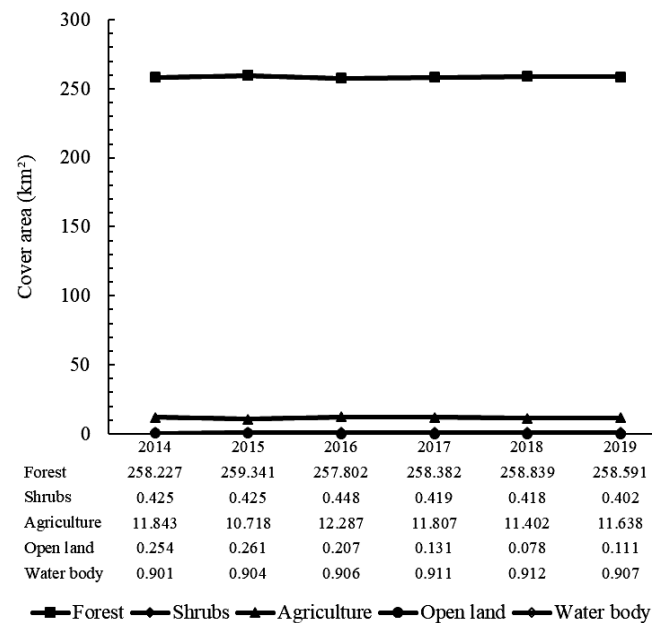

	2014	2015	2016	2017	2018	2019
Forest	258.227	259.341	257.802	258.382	258.839	258.591
Shrubs	0.425	0.425	0.448	0.419	0.418	0.402
Agriculture	11.843	10.718	12.287	11.807	11.402	11.638
Open land	0.254	0.261	0.207	0.131	0.078	0.111
Water body	0.901	0.904	0.906	0.911	0.912	0.907

Figure 3. The dynamics of land cover change at the Belaban monitoring site from 2014 to 2019

	2014	2015	2016	2017	2018	2019
Forest	214.526	212.822	212.842	212.231	211.467	212.400
Shrubs	35.605	38.079	36.808	39.160	34.308	33.202
Agriculture	2.572	2.572	2.656	2.656	2.572	2.656
Open land	2.072	3.961	5.739	6.623	2.461	8.097
Water body	144.766	142.107	141.496	138.870	148.732	143.185

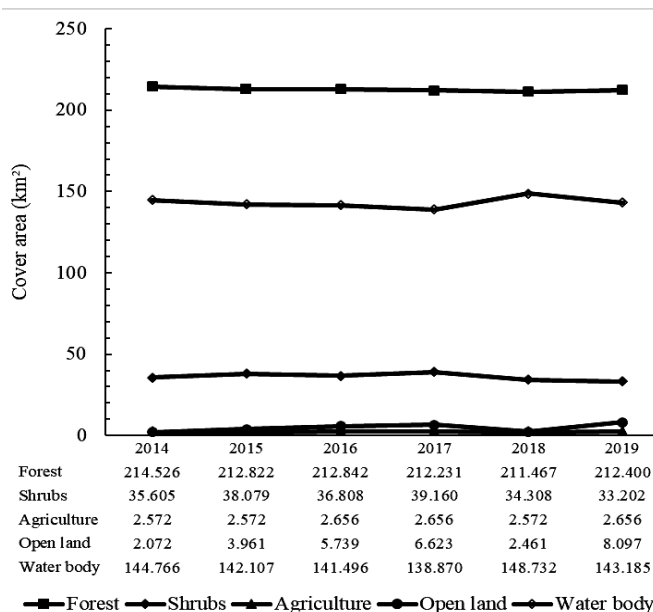**Figure 4.** The dynamics of land cover change at the Bukit Semujan Semangit Menyukung Melingkung site from 2014 to 2019

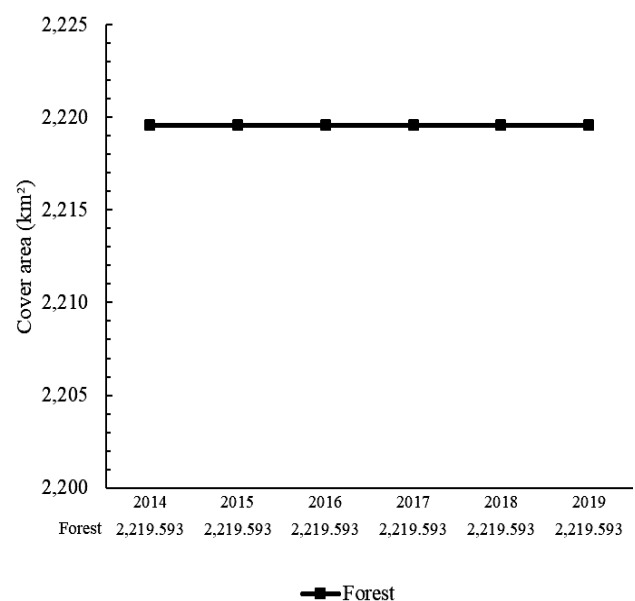|	2014	2015	2016	2017	2018	2019
Forest	2,219.593	2,219.593	2,219.593	2,219.593	2,219.593	2,219.593

Figure 5. The dynamics of land cover change at the Embaloh Sibau watershed monitoring site from 2014 to 2019

Some of the factors that caused the decrease in forest cover included land conversion to agriculture, illegal logging and fires. Research by Fawzi et al. (2020a) stated that around 41% of species, including plants, have disappeared from damaged tropical forests. The increasing human population that relies on forests as a source of livelihood reduces the quantity and quality of forests (Ridadiyanah and Subekti 2021). Forest encroachment by communities for agricultural and plantation land has reduced secondary forest cover by 953.96 hectares (Harianto et al. 2022). Illegal logging causes a decrease in the number of important plant species, particularly trees (Hardus et al. 2012). In addition, fires also contribute to the decrease in forest cover. The long dry season in West Kalimantan due to El Nino in 2015 has caused forest fires that reduced primary forest cover by 1,914 hectares (Fawzi et al. 2020b).

Meanwhile, the increase in forest cover is caused by habitat conservation, protection and restoration, so forest cover did not change much. Restoration and rehabilitation programs along with protection from illegal logging activities contribute to regeneration degraded or deforested land into secondary forests (Fawzi et al. 2020b).

Relationship between orangutan population size and land cover change

The result of multiple linear regression analysis of orangutan population size with land cover change is shown in Table 2. Multiple linear regression analysis resulted in a coefficient of determination (R^2) of 0.864, indicating that the contribution of the independent variable X (land cover) to Y (orangutan population) was 86.4%, while other factors affect the remaining 13.6%. The significance value of the F test is 0.000, which is smaller than 0.05, suggesting that the independent variables, including forests, shrubs, open land, water bodies, road density, river density and settlement density, have a simultaneous influence on the dependent variable of orangutan population size. Partially, of the eight variables tested, only two variables, namely forest (X1) and shrubs (X2), have a significance value <0.05, thus partially influencing the size of the orangutan population. The variable X3 (agricultural cover) is not in the equation because when testing the classical assumptions X3 caused multicollinearity symptoms and after X3 was removed, the classical assumptions were met and then continued with multiple linear regression analysis; therefore X3 does not appear in the equation.

Table 2 shows that the variable of forest (X1) has a regression coefficient of 0.014, meaning that the increase in forest cover results in an increase in population size by 0.014. Increasing forest cover area will likely provide more food sources and shelter (nests) and increase habitat-carrying capacity. Hardus et al. (2012) found that orangutan density increased with higher quality and quantity of food sources. In addition, Kanamori et al. (2016) revealed that population density increased sharply at the peak of fertilization.

The variable of shrubs (X2) has a regression coefficient of 0.701, meaning that for every increase in X2, the population size increases by 0.701. Orangutans are frugivorous primates with fruits as their primary food. However, when it is not a fruiting season, orangutans will look for other food sources such as flowers, leaves, bark, tubers, and insects (termites). Shrub land cover is thought to help provide additional food for orangutans during the non-fruiting season. Based on Fawzi et al. (2020a), orangutan food during the non-fruiting season is 37% bark, 25% leaves, 21% fruit, 10% tree essence, and 7% insects. Fauzi et al. (2017) also mentioned those foods orangutans consume tubers of rattan trees (*Calamus* spp.) or from other palm tree species such as *Licuala* spp. and *nibung* (*Oncosperma* sp).

Table 2. Results of multiple linear regression analysis of orangutan population size with land cover change

Regression equation	Coefficient of determination	F-test	T-test
Y = 1.515+0.014X₁+ 0.701X₂- 0.450X₄ -0.082X₅+9.063X₆+ 0.650X₇+457.205X₈	0.864	0.000	X1=0.000 X2=0.000 X4=0.052 X5=0.103 X6=0.813 X7=0.760 X8=0.100

Notes: Y: orangutan population size, X1: forest, X2: shrubs, X4: open land, X5: water body, X6: road density, X7: river density, X8: settlement density
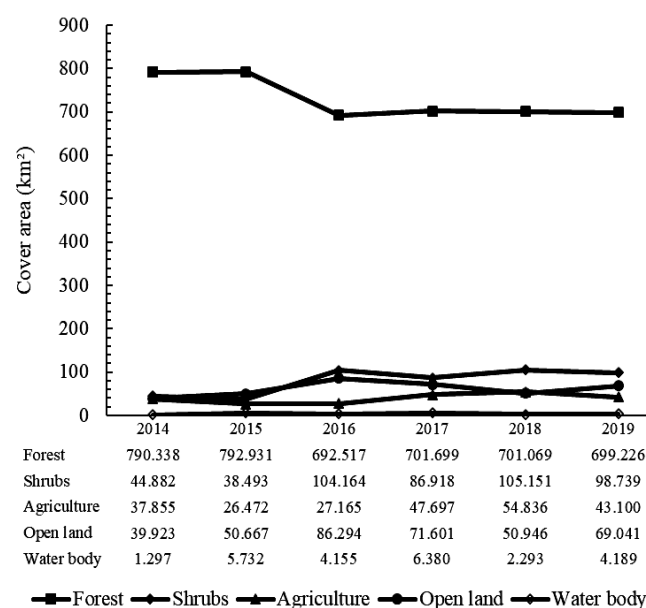

	2014	2015	2016	2017	2018	2019
Forest	790.338	792.931	692.517	701.699	701.069	699.226
Shrubs	44.882	38.493	104.164	86.918	105.151	98.739
Agriculture	37.855	26.472	27.165	47.697	54.836	43.100
Open land	39.923	50.667	86.294	71.601	50.946	69.041
Water body	1.297	5.732	4.155	6.380	2.293	4.189

Figure 6. The dynamics of land cover change at the Sungai Putri monitoring site from 2014 to 2019

In conclusion, in the period of 2014 to 2019, the orangutan population at the Sungai Putri and the Bukit Semujan Semangit Menyukung Melingkung tended to increase, while at the Belaban and Embaloh Sibau watersheds tended to fluctuate. The land cover at the Belaban, Bukit Semujan Semangit Menyukung Melingkung, and Sungai Putri monitoring locations tended to fluctuate, while that in the Embaloh Sibau tended to be steady. The regression analysis results show that forest and bush cover types influence the Bornean orangutan population. Population monitoring, inventory of food availability, and patrols to secure forest areas as sustainable orangutan habitats are essential to protecting and conserving orangutan populations.

ACKNOWLEDGEMENTS

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