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The estimation of mammal species loss and gain from shrubs to oil palm plantations in South Sumatera

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Abstract. *Several previous studies stated that land cover changes to oil palm plantations caused the loss of wildlife species, one of which was mammals. Therefore, data on the magnitude of this type of loss is needed. This study estimates the amount of loss and gain of mammal species due to the development of oil palm plantations. Data were taken by direct observation (strip transect method) in parallel at the oil palm plantation of PT Rambang Agro Jaya, South Sumatra. This research was conducted on the land cover before (shrubs) and after the development of oil palm plantations. The study shows that the change from shrubs to oil palm plantations decreases the evenness index but increases the species richness index. There is no change in the number of mammal species. The similarity index of shrubs and oil palm plantations is 0.56. The development of oil palm plantations also causes the loss and gain of mammal species with the same percentage of 67%. The presence of mammals in oil palm plantations is thought to be due to feed availability.*

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INTRODUCTION

The oil palm plantation is one industry that has large export value in Indonesia. The export value of oil palm plantations increased in 2020 from $20.22 billion to $22.97 billion (GAPKI, 2021). The increase in economic value in the oil palm industry is also in line with its area in Indonesia. It led to negative accusations, especially regarding wildlife diversity, turning forests into monoculture plantations (Setiawan *et al.*, 2016; Utami *et al.*, 2017). According to Barthel *et al.* (2018), the European Commission has accused that oil palm plantations caused a decline in habitat quality and biodiversity.

Ecologically, the land cover change in oil palm plantations impacted wildlife diversity and caused species loss (Colchester *et al.*, 2011; Muin, 2013; Utami *et al.*, 2017; Kwatrina *et al.*, 2019). Meijide *et al.* (2018) stated that the conversion of tropical forests to oil palm plantations also affects the microclimate condition and the loss of biodiversity. The conversion of secondary forests to oil palm plantations impacted on loss and gain of several communities such as bird, mammal, herpetofauna, butterfly, and soil macroinvertebrate (Erniwati and Santosa, 2019; Ginoga *et al.*, 2019; Santosa and Rejeki, 2019; Yeo *et al.*, 2020). Similar to secondary forests, the land cover change from shrubs to oil palm plantation can affect species diversity of tropical

vegetation and wildlife species such as herpetofauna and mammal (Nugroho and Santosa, 2018; Hilwan and Santosa, 2019; Rahmadiyanti and Santosa, 2019; Al-Faritsi and Santosa, 2021).

Mammals are one of the wildlife groups that can be affected by the land cover change to oil palm plantations (Santosa and Rejeki, 2019). This taxon can be affected if there is a significant environmental change (Morueta-Holme *et al.*, 2010). Previous studies stated that mammal species were lost due to the land cover change to oil palm plantations, but on the other side, it is possible to gain new mammal species (Kwatrina *et al.*, 2018; Nugroho and Santosa, 2018). As an ecological component, mammals are very important for soil fertility, seed dispersal, biological pest control, and predators in the food chain (Suyanto *et al.*, 2009; Corlett and Primack, 2011; Pratiwi, 2014).

The changes in land cover to oil palm plantations are thought to affect the mammal composition. It caused biodiversity loss or biodiversity gain in mammals. The study about species loss and gain is important to provide scientific evidence, and it can be added as the latest data and also complement the existing studies, especially regarding the land cover change from shrub to oil palm plantation. One of the benefits of this study is it can be used as basic consideration of sustainable oil palm management. This study aims to estimate the impact of the land cover change from shrubs to oil palm plantation on mammal species richness, evenness, and composition and estimate the amount of loss and gain of mammal species due to oil palm plantation development.

METHOD

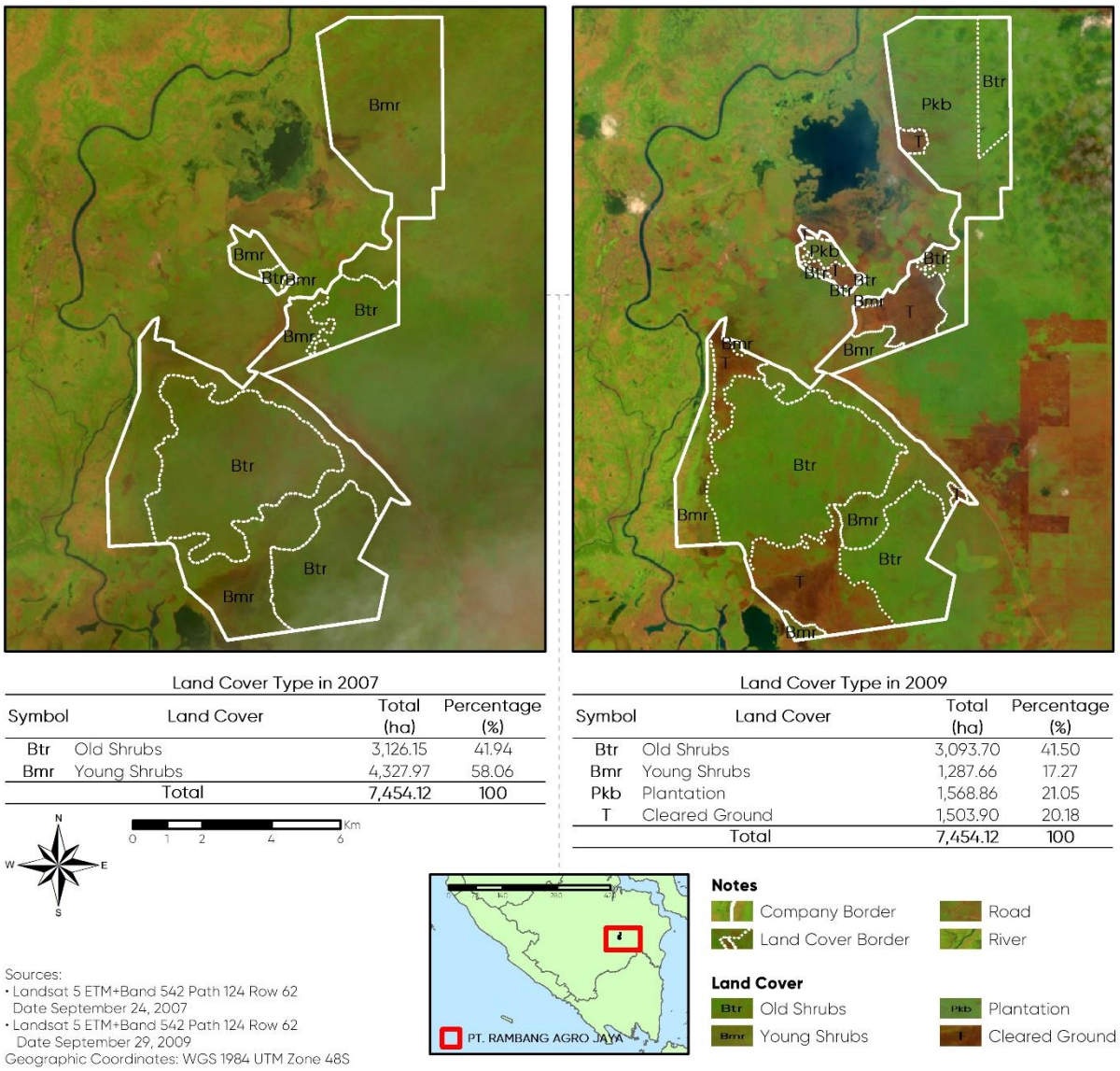
Time and Study Area

This study was conducted before oil palm plantation land cover and after oil palm plantation. We identified satellite imagery through visual classification to find land cover before oil palm plantation. The satellite imagery used is Landsat 5 TM Collection 2 Level-2 Path 124 Row 62 using 543 bands. This imagery is available at https://earthexplorer.usgs.gov/. Identification of land cover was used as coverage image for September 24, 2007, and September 29, 2009. The time of image coverage was based on the business license issued for the oil palm plantation of PT Rambang Agro Jaya. The results of the visual classification method are shown in Figure 1.

Based on Figure 1, the land cover before the oil palm plantation was dominated by shrubs. This study assumed that the nearest shrubs are considered as before the oil palm plantation cover. Meanwhile, the land cover type after oil palm plantation was divided into young-aged oil palm (year of plant 2013), middle-aged oil palm (year of plant 2011), and old-aged oil palm (year of plant 2009) belonging the oil palm plantation of PT Rambang Agro Jaya (RAJ), Ogan Komering Ilir Regency, South Sumatera. This study was conducted in July−August 2021.

Data Collection

Mammal data collection used direct observation through the strip transect method and was carried out in parallel (simultaneously). The length of the strip used for observation is 1 km with a 50 m length of width. The observation strip was made of two lines in opposite directions and a 100 m distance. This method can observe mammals in oil palm plantations (Marshall *et al.*, 2008; Yudea and Santosa, 2020). The time of observation is in the morning (06.00-08.00), in the afternoon (16.00-18.00), and the evening (19.00-21.00) with three repetitions each time. The selection of observation time is based on the average active time of mammals (Ashby, 1972; Hayward and Slotow, 2009; Zhang *et al.*, 2017). The data collected were encounter time, species name, number of individuals, activity, substrate, GPS point, and photos of mammal species. Observations on undergrowth species, water sources, temperature, and humidity were also carried out in this study to support mammal data.



Land Cover Type in 2007

Symbol	Land Cover	Total (ha)	Percentage (%)
Btr	Old Shrubs	3,126.15	41.94
Bmr	Young Shrubs	4,327.97	58.06
Total		7,454.12	100

Land Cover Type in 2009

Symbol	Land Cover	Total (ha)	Percentage (%)
Btr	Old Shrubs	3,093.70	41.50
Bmr	Young Shrubs	1,287.66	17.27
Pkb	Plantation	1,568.86	21.05
T	Cleared Ground	1,503.90	20.18
Total		7,454.12	100

Sources:
- Landsat 5 ETM+Band 542 Path 124 Row 62 Date September 24, 2007
- Landsat 5 ETM+Band 542 Path 124 Row 62 Date September 29, 2009

Geographic Coordinates: WGS 1984 UTM Zone 48S

Figure 1 Land cover type in 2007 and 2009 at oil palm plantation of PT Rambang Agro Jaya

Data Analysis

Estimation of loss and gain in this study was carried out by looking at the mammal species in the land cover before and after the development of oil palm plantations. In connection with this, it is necessary first to determine the diversity of mammal species. The diversity calculation in this study uses the simplest measure of biodiversity, namely Margalef species richness index (D_{mg}). Species richness is known to be one of the best substitutes for other more complex diversity measures and has a positive relationship with other measures (Krebs, 1989; Rahman, 2021). In addition, this study uses a species evenness index (E) to compare the evenness of each species in a community and Jaccard similarity index (S_j) that shows the similarity composition (Krebs, 1989). Jaccard Index will compare before oil palm plantation cover and after oil palm plantation. It is also a basis for showing how similar communities exist in ecology (Krebs, 1989).

Meanwhile, to estimate the amount of mammal species loss and gain, analysis was used is making a list of the types of mammals found in each land cover and counting the species number in the land cover before and after oil palm plantation (Nugroho and Santosa, 2018; Erniwati and Santosa, 2019). The species found in this study are also categorized based on feeding guild. The data source to determine the feeding guild is taken from Wilman *et al.* (2014). There are four groups of feeding guilds, namely Herbivore (feeding on ≥50% of

plant material), Carnivore (feeding on ≥50% of vertebrates), Insectivore (feeding on ≥50% of invertebrates), and Omnivore (feeding on ≥50% on both plant and animal material) (Rovero *et al.*, 2020). The formula used in this study is shown in Table 1.

Table 1 Data analysis and formula used

Objective	Analysis	Formula	Note
Estimate the impact of oil palm plantation on mammal species richness, evenness, and composition	Margalef species richness index	$D_{mg} = \frac{(S-1)}{\ln (N)}$	D_{mg} = Margalef species richness index S = Number of species N = Total of all species individual
	Evenness species index	$E = \frac{H'}{\ln S}$	E = Evenness species index (0 – 10) H' = Shannon-Wiener diversity index S = Number of species
	Jaccard index (S_j)	$S_j = \frac{a}{a+b+c}$	S_j = Jaccard index a = Number of species in combined sample unit (A and B) b = Number of species in the sample unit B but not in sample unit A c = Number of species in the sample unit A but not in sample unit B
Estimate the amount of loss and gain of mammal species	Biodiversity loss	$Loss = \frac{\sum_{i=1}^{n} S_{ik1}}{\sum_{i=1}^{n} S_{ik2}} \times 100\%$	S_{ik1} = Species in the sample unit k (before oil palm plantation) that are not found in the sample unit after oil palm plantation or both S_{ik2} = Species in the sample unit k (before oil palm plantation) n = The total species found at the sample location
	Biodiversity gain	$Gain = \frac{\sum_{i=1}^{n} S_{ij}}{\sum_{i=1}^{n} S_{ik}} \times 100\%$	S_{ij} = The species in the sample unit j (after oil palm plantation) and not in the sample unit k (before oil palm plantation) or both S_{ik} = Species in the sample unit k (before oil palm plantation) n = The total species found at the sample location

RESULT AND DISCUSSION

The Impact of Oil Palm Plantation on Species Richness, Evenness, and Composition of Mammals

The development of oil palm plantations in the study area shows no composition changes in the number of species between shrubs and oil palm plantations. The number of species found in shrubs cover is three species, consisting of 23 individuals and three different families. The three species are Asian small-clawed otter (*Aonyx cinereus*), common long-tailed macaque (*Macaca fascicularis*), and plantain squirrel (*Callosciurus notatus*). Meanwhile, after the development of oil palm plantation, three mammal species are found, consisting of 13 individuals from 3 different families. The species are leopard cat (*Prionailurus bengalensis*), plantain squirrel (*Callosciurus notatus*), and wild boar (*Sus scrofa*). A list of mammal species found before oil palm plantation and oil palm plantation is shown in Table 2.

Table 2 Species of mammals and number of individuals found in land cover before and oil palm plantation

No	Species Name	Scientific Name	Family	Location Found	
				Before Oil Palm Plantation (Shrubs)	Oil Palm Plantation
1	Asian Small-clawed Otter	*Aonyx cinereus*	Mustelidae	10	0
2	Common Long-tailed Macaque	*Macaca fascicularis*	Cercopithecidae	7	0
3	Leopard Cat	*Prionailurus bengalensis*	Felidae	0	1
4	Plantain Squirrel	*Callosciurus notatus*	Sciuridae	6	1
5	Wild Boar	*Sus scrofa*	Suidae	0	11
Number of individuals				23	13
Number of species				3	3

There was a change in the total number of mammals individual from shrubs to oil palm plantations. This statement follows several previous studies, where the changes in land cover from shrubs to oil palm plantations caused the number of mammals individual changes (Kwatrina *et al.*, 2018; Nugroho and Santosa, 2018; Santosa and Rejeki, 2019). The availability of feed is thought to be one factor that influences the existence of mammals on oil palm plantations. This statement could be proven when we observed the study area. We found one individual wild boar (*Sus scrofa*) was eating oil palm fruit. This species has many types of feed, including crops, mushrooms, seaweed, mesofauna, and soil macro-fauna (Barrios-Garcia and Ballari, 2012; Anggrita *et al.*, 2017).

Figure 2 shows compare species number, species richness index, and evenness index of mammal species from shrubs to oil palm plantations at PT RAJ. The species richness index shows an increase from 0.64 to 0.78. This increase is influenced by the total number of individuals found and the number of species in the community. Species richness is based on binary data (presence-absence) and used to measure the actual number of species present (Tuomisto, 2010). Enquist *et al.* (2002) show that an increase in the species richness value will affect if there is an increase in the taxonomic level (including family, genus, or species). This study shows that the same number of species, but lower total individuals, will lower the richness index value. As known, the number of mammals individual before oil palm plantation was 23 individuals, and after oil palm plantation was 13 individuals.

This study shows a decrease in the evenness index of mammal species after oil palm plantation from 0.98 to 0.49. The evenness value shows the dominance of each species in a community (Santosa *et al.*, 2008). The high value of the evenness index before oil palm plantation indicates a low number of mammal species dominated in these land cover types. Wild boar (*S. scrofa*), with 11 individuals, dominated the oil palm plantation and affected the lower evenness index. The domination of this species is regarding feed availability in oil palm plantations such as oil palm fruit, and they are usually found in groups, where one group can reach 11 individuals (Harich and Treydte, 2016; Yudea and Santosa, 2020).

The value of the similarity index of mammals before oil palm plantation and after oil palm plantation was in the value of 0.50 to 0.60 (Figure 3). Based on each type of land cover (young-aged oil palm, middle-aged oil palm, and old-age oil palm), young and middle-aged oil palm have the same similarity index. Meanwhile, for old-aged oil palm plantations, the value is 0.60. It shows that the change from shrubs to oil palm plantations with different age conditions can cause differences in the composition of mammals. In all oil palm covers, the similarity index between shrubs and oil palm plantations is 0.56. The change in mammal species composition can be caused by the mammal's characteristics that tend to be sensitive to environmental changes and disturbances (Morueta-Holme *et al.*, 2010; Rubidge *et al.*, 2011; Pardo *et al.*, 2018).

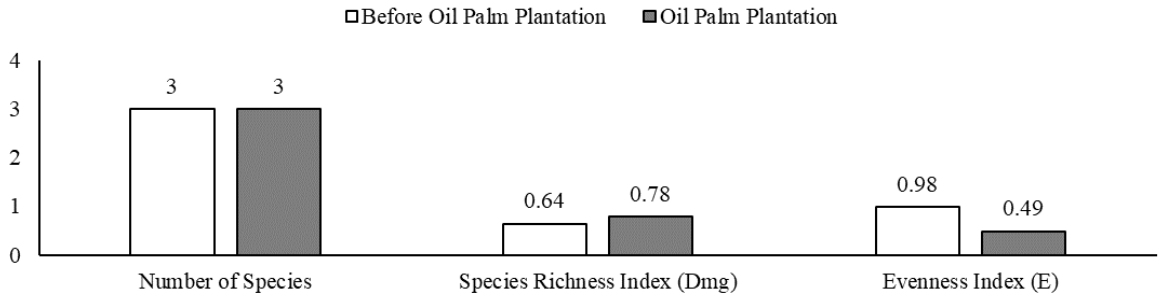


Figure 2 Comparison of the species number, species richness index, and evenness index of mammal species between before and after oil palm plantation

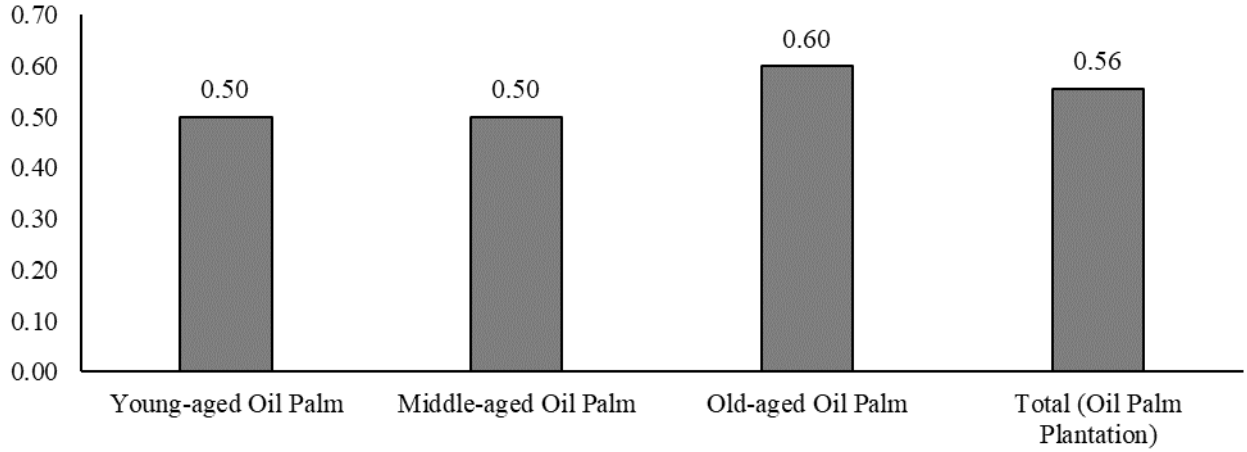


Figure 3 Comparison of Jaccard species similarity index between the before (shrubs) and after oil palm plantations

The result of this study is in line with previous studies that land cover change in oil palm plantations can affect the structure and composition of mammal species (Kwatrina *et al.*, 2018; Pardo *et al.*, 2018a; Knowlton *et al.*, 2019; Mohd-Azlan *et al.*, 2019; Santosa and Rejeki 2019). This study shows that the development of oil palm plantations from shrubs decreased the number of individuals and mammal species' evenness. Besides that, the oil palm plantation impacted to increase mammal species richness. These changes can be caused by the feed availability and the sensitivity of mammals due to environmental change as previously explained. Another factor can be caused by conditions that provide a suitable habitat for foraging, living, or breeding. These conditions could support the existence of mammals in the ecosystem (Gray *et al.*, 2007; Gray and Phan, 2011; Rovero *et al.*, 2014).

The Estimation of Loss and Gain of Mammal Species

Changes in land cover from shrubs to oil palm plantations caused loss and gain of mammal species in PT RAJ. The percentage of loss in the study area is 67%, and species gain is 67% (Figure 4). This value indicates that the percentage of mammal species loss and gain is the same. New suitable habitats can cause the gain of mammal species and provide needs for mammals, such as the undergrowth plants used for shelter or as a source of food in oil palm plantations (Payán and Boron, 2019). In the oil palm plantation, the undergrowth are dominated by *Fimbristylis ovata* (Cyperaceae) and *Psychotoria* sp. (Lauraceae). Pardo *et al.* (2018b) stated that the density of undergrowth is positively correlated with mammal's presence. Oil palm plantation should maintain their existence by clearing it around the oil palm plant than clearing it all on the land surface.

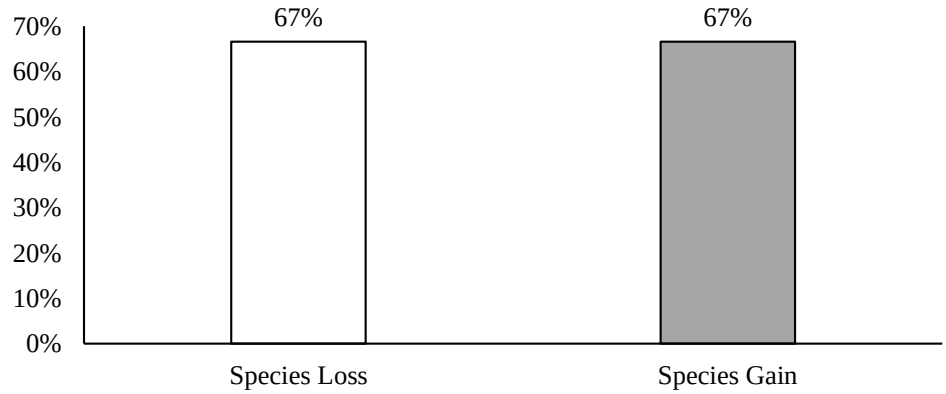


Figure 4 Percentage of loss and gain of mammal species

Table 3 shows mammal species that survive, loss, and gain. Loss species are found in the baseline (shrubs) but cannot be found in oil palm plantation cover. The gain species are mammals not found in the baseline (shrubs) but only in oil palm plantation cover. Meanwhile, survived species can be found in both land cover types (shrubs and oil palm plantations). This study shows one mammal species that survived before and after oil palm plantation cover, namely plantain squirrel (*Callosciurus notatus*). The species loss is two species, namely Asian small-clawed otter (*Aonyx cinereus*) and common long-tailed macaque (*Macaca fascicularis*). Meanwhile, there are two species gained after oil palm plantation: wild boar (*Sus scrofa*) and leopard cat (*Prionailurus bengalensis*). The survive, loss, and gain species of mammal indicates that it's taxon can be affected by the land cover change. The feed availability and suitable habitat for foraging, living, or breeding are several factors that affect the presence of mammals in a habitat (Rovero *et al.*, 2014).

Plantain squirrel (*C. notatus*) is a species that survives before and after oil palm plantations. The survival of this species in both land cover types indicates that this species can adapt to habitat changes. Noor *et al.* (2019) study states that *C. notatus* is an adaptive species in various habitat types. In addition, several studies have shown that this type of squirrel can dominate a habitat because of its adaptive level, wide distribution, large population, and tolerance level that can make it survive changes in habitat (Ruppert *et al.*, 2015; Kwatrina *et al.*, 2018). One of the lost species at PT RAJ is common long-tailed macaque (*M. fascicularis*). The loss of this species could be caused by the loss of canopy diversity that the species usually uses. The wide and protected canopy are usually used to sleep, playground, and shelter from predators (Ziyus *et al.*, 2019; Nasution *et al.*, 2021). Meanwhile, the oil palm plantation in PT RAJ has a similar canopy height and more open area under the canopy.

Mammals species gained in this study can usually be found in oil palm plantation areas (Fujinuma and Harrison, 2012; Jennings *et al.*, 2015; Nugroho and Santosa, 2018; Santosa and Rejeki, 2019). The availability of palm fruit is a source of feed for wild boar (*S. scrofa*) because this species usually looks for food at night and will return to its shelter during the day (Sun *et al.*, 2007). The existence of the leopard cat (*P. bengalensis*) in oil palm plantations is thought to be due to the availability of the undergrowth. Silmi *et al.* (2021) stated that the species frequently use the undergrowth and palm frond to shelter themselves and their kittens. Several species of the undergrowth at PT RAJ are *Fimbristylis ovata*, *Psychotria* sp., *Stenochlaena palustris*, *Syzygium zeylanicum*, and *Dianella ensifolia*.

Based on the classification of the feeding guild, there are four groups in this study, namely herbivore (H), carnivore (C), insectivore (I), and omnivore (O). This study shows insectivore and omnivore lost after the land cover changed from shrubs to oil palm plantations. The species gained are classified as herbivore and carnivore, while the survived species belong to herbivore (Table 3). The number of similarity index also indicates the change in mammal structure. The loss of omnivore and insectivore due to oil palm plantations has disrupted the completeness of the food chain. This is caused by the loss of the role of these species in the

ecosystem. The type of insectivore that is lost will affect the presence of insects in the oil palm plantation area. Insects in oil palm plantations can become pests and parasites for plants (Rizali *et al.*, 2019; Sulaiman and Talip, 2021).

Table 3 The survive, loss, and gain of mammal species

No	Survive Species	Loss Species	Gain Species
1	*Callosciurus notatus* (H)	*Aonyx cinereus* (I)	*Sus scrofa* (H)
2		*Macaca fascicularis* (O)	*Prionailurus bengalensis* (C)

The loss of insectivore species in this study allows its role to be replaced by the presence of wild boars (*S. scrofa*) and leopard cat (*P. bengalensis*). Although they are not insectivores, previous studies have shown that they can prey on various insects (Gentle *et al.*, 2015; Hisano and Newman, 2020). However, the mammal species' loss in an ecosystem cannot be measured from one aspect (feed) alone because other aspects also disappear due to the development of oil palm plantations. For example, the loss of large mammals could significantly lead to a loss of the cycling of nutrients in nature (Abraham *et al.*, 2021). Further research is needed to assess the relationship between land cover change in oil palm plantations and the roles of lost or gained wildlife species.

CONCLUSION

The impact of the land cover change from shrubs to oil palm plantations is decreases the evenness index of mammal at PT RAJ. Besides that, there is an increase in mammal species richness index. The development of oil palm plantations causes the loss and gain of mammal species. The similarity index of shrubs and oil palm plantation is 0.56. The number shows a change in mammal composition because the land cover changes from shrubs to oil palm plantation. The percentage of species lost and gained were 67% and 67%. The mammal species lost are Asian small-clawed otter (*Aonyx cinereus*) and common long-tailed macaque (*Macaca fascicularis*). In contrast, the mammal species gained are wild boar (*Sus scrofa*) and leopard cat (*Prionailurus bengalensis*). The lost and gained species (including the change of composition structure) cannot be ignored dan it is important to be noted because it affects the ecosystem, such as the food chain and nutrient cycle.

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