How land fires impact mammal diversity after several years: A study in Waimusi Agroindah Oil Palm Plantation, South Sumatra

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Abstract. Forest and land fire are one of the global disaster that raging every year. Most of the time, fire from concession and oil palm plantation area are accused to be the main factor that caused degradation of natural habitat and the biodiversity, including mammals. Mammals have important roles in sustaining a balanced ecosystem. However, the study of the impacts and mammals response to forest and land fires is yet to be fathomed. To provide more understanding in the impacts of fire on mammals a study was conducted at Waimusi Agroindah Oil Palm Plantation, South Sumatera, in two different periods, which are two years and four years after the fire to identify and comparing the diversity of mammal species. The data was collected with strip transect method, parallel in post-burned area and in unburned area with total four repetitions in each areas. The estimation of the impact was obtained by calculating the loss and gain of mammals from the unburned area and post-burned area, the level of species richness, evenness, also the similarity. Result shows that two years after fire, the habitat are already recovering, the number of species, species richness and evenness index was increased 2, 0.19, and 0.1. There was one species lost and two species gained. In the time of four years after the fire, opposite was resulted, all the parameters were decreased, species number decreased one species, richness and evenness number each decreased 0.42 and 0.32 and there was one species lost, but no species gained. This study indicates that land fire impacted mammal diversity, not only caused a degradation, but also an increase on the diversity.

1. Introduction
Forest and land fires are one of the global disaster and has been a global biggest concern. In Indonesia almost every year fires are raging. Massive forest and fires in Indonesia occurred between the year 1981/1982, 1997/1998, 2007, 2013, and 2015 [1]. In 2015, it is estimated that 2,089,911 hectares of Indonesian areas have experienced fires both in forest and land areas [2]. Those land areas including oil palm plantation. According to Indonesia statistic (BPS) 2015, total exports of crude palm oil (CPO) by Indonesia in 2015 is 26,467,6 ton. World output of CPO rise to 76.9 Mn T in Oct/Sept 2018/19. Consumption is forecast to increase by 7.9 Mn T in 2018/19 (76.8 Mn T) [3] and predicted to continuously increase. This contributed to the increase of Indonesian foreign exchange, providing employment for 41% of Indonesia's population, and rural development [4]. Beside those advantages, oil palm plantation is also a habitat for diverse wildlife, including the diversity of mammals [5]. Most of the time, concession and oil palm plantation area are accused to be the main factor that start the massive forest and land fires in Indonesia. In agriculture, land clearing often used fires due its easy and cheap
way, there are also land conflict, land claiming and lack incentive to conduct land preparation without burning that are also the causes of fires [6]. Reference [7] revealed that the development of large-scale oil palm plantations was one of the factors that triggered forest and land fires in Indonesia. The development of oil palm plantations is blamed for causing deforestation and fires, where climate change, deforestation rates and peatland subsidence are causing fires in the coming years [8]. The impacts of fire commonly assessed to cause disadvantages. Then reference [8] states that fires increased air pollutants, caused health decrease and respiratory disturbances, economic losses, decreased biodiversity, and even death. Kinnaird and O’Brien 1998 also stated that land fires caused biodiversity decline due to loss of native habitat. Negative impacts on mammals include loss of natural habitat, reduced abundance of food, moving to safer places, and even death [9]. Meanwhile reference [10] categorize the impact of fires on wildlife in three categories, first is causing death, movement of animals, decreasing habitat value, second causing hunger and third modifying species. Mammals have an important roles in sustaining a balanced ecosystem, it has roles in controlling pests, seed dispersers, predators and pollinators for plants [11], [12], [13]. However the study of the impacts and mammals response to forest and land fires is limited and yet to be fathomed. To provide more understanding in the impacts of fire on mammals this study was conducted, by identifying and comparing the diversity, lost and gain of mammal species in post-burned plantation area (after 2 and 4 years of fire) with those area that did not burn and knowing the species loss and gain.

2. Method
Impacts of land fire on mammal diversity were determined by comparing the biodiversity found on post burn area, with those found on the unburned area. We used assumption for the valuation in unburned area where the number of species were assumed to be remain the same, as we combined the total number of species that found from 2017 and 2019, and for the number of individual species we took the highest number from between those years.

2.1. Site description
Fieldwork was conducted in Waimusi Agroindah Oil Palm Plantation, within its 11 and 12 block, in Sepucuk Hamlet, Pulau Geronggang Village, Pedamaran Timur District, Ogan Komering Ilir Regency, South Sumatra Province. Some part of the land was on fire on August 2015, the research was conducted in 2 periods, first in February – March 2017 and the second in February – March 2019. The data was collected from two different land covers, which are unburned area and post burned area. The research location map is presented in Figure 1.
2.2. Data collection

2.2.1 Strip Transect Method
Strip transect method counts presume a complete census of all the species within the track with fixed strip width [14]. Right and left width of each observation track is 50 m and the length of the track is 1 km. Observations were done with a constant speed of approximately 10 m / min. Observations were taken in the morning (06.00-09.00), evening (15.00-18.00) and night (19.00-21.00). Repetition is done 3 times on each path (3 times for morning observations, 3 times for afternoon and 3 times for night). Illustration of observation paths as in Figure 2.

![Figure 2. Illustration of strip transect method](image)

2.2.2 Trapping
The trapping method was applied for small mammals. Ten traps were used and the distance between the trap was at least 25 m. Installation of traps carried out in each observation tracks. The bait given in the trap is grilled coconut and salted fish.

2.2.3 Animal’s traces
It is everything left by the wildlife that marks its presence in a particular habitat. The traces can be footprints, feeding signs, and scratch marks. Traces left by mammals can help to find out the presence of mammal species in a place even if the mammal is not found directly.

2.3. Data analysis

2.3.1 Richness index
Species richness index functions to find out the species richness of each species in each community that is found. Mammal species richness can be calculated using Margalef index [14]. The equation is as follows:

\[ D_{mg} = \frac{S}{\ln(N)} \]  

(1)

2.3.2 Evenness number
Evenness index is used to determine the evenness between each species in a location. The formula used to calculate the type evenness index is [15]:

\[ E = \frac{H'}{\ln S} \]  

(2)

\[ H' = \sum p_i \ln p_i \]  

(3)

\[ p_i = \frac{n_i}{N} \]  

(4)
2.3.3 Similarity index
Species similarity index is used to determine the similarity of mammal species found in different habitats. The equation of community similarity index is as follows [15]:

\[ Si = \frac{2C}{A+B} \] (5)

3. Result and discussion
On August 24 to September 13, 2015, fires were raging in Sepucuk oil palm plantation region, total area that has been scorched is around 580 ha (measurement results of SOMA, BPKH Wil Palembang, 2015). In addition, according to reference [16], land fires that occurred at PT Waimusi Agroindah were included in class E fires, based on the large area of the fires. Two and four years after this fire, sampling observation on the habitat and mammals diversity in the plantation area were conducted.

3.1. Vegetation
From Table 1 below, we can see that post-burned areas has the highest density and vegetation diversity rather than the unburned area. Undergrowth species that has the highest relative density index in unburned area are Scleria sumatrensis, Eleocharis dulcis and Melastoma malabathricum. Both post-burned area, in 2017 and 2019 has Eleocharis dulcis as the species that has the highest density. Fires impact the soil properties including soil chemical properties. Those chemical properties of soils that affected by fire tend to increase the soil pH due to alkaline ash deposits. An increase in pH will increase the level of availability and proportion of nitrogen nitrates that are more easily washed out [17]. This causes the undergrowth such as grass, fern and plants from the family Poaceae is type of plant that is easy to grow, they can grow with lots of accompaniment with the help of high light intensity.

| Land Cover           | Density (ind/ha) | Number of Species |
|----------------------|------------------|-------------------|
| Unburned area        | 851              | 12                |
| Post-burned area 2017| 985              | 16                |
| Post-burned area 2019| 1485             | 32                |

Vegetation density is commonly increase after a fire, post-fire condition restores habitat where indirectly effect the succession [18]. It can even cause new undergrowth, new resources that caused heterogeneities in landscape [19]. Vegetation that dies from fire will slowly recover after fire [20]. Vegetation have an important role in a habitat and its function as a place to hide animals from the predators. Low plant density and a clear ground floor with less undergrowth will make it difficult for animals to make it a cover, on the other side when the vegetation density is high, it will be easier to make it a shelter.

3.2. Impact on mammal diversity
Overall results from the observations show that there are six mammal species in Waimusi Agroindah oil palm plantation area. Three species of them are found all locations, the unburned area, post burned 2017 and 2019. Those species are Presbytis cristata, Macaca fascicularis, and Rattus tiomanicus. In each locations, Macaca fascicularis was found to be the most dominant species and had the highest number of individuals among others. Based on several studies about this species, it is said that indeed this species are one of the most widespread primates, they are a generalist species, a high opportunistic omnivores, so they can use various habitat type [21], [22]. They even exploit areas that disturbed by human settlement and agriculture [22-24]. They occur in a variety of natural habitats including primary, secondary, freshwater swamp, mangrove forests, and also along the habitat edge that surrounded by urbanized areas, most of their groups include both natural forest and urbanized areas as their home range [25], [26].
Table 2. List of mammals species diversity and individual number that found in each land covers

| No | Species                  | Unburn | Post-burned 2017 | Post-burned 2019 |
|----|--------------------------|--------|------------------|------------------|
| 1  | *Presbytis cristata*     | 1      | 2                | 1                |
| 2  | *Macaca fascicularis*    | 12     | 14               | 25               |
| 3  | *Callosciurus notatus*    | -      | 1                | -                |
| 4  | *Rattus tiomanicus*      | 5      | 6                | 2                |
| 5  | *Prionailurus bengalensis* | 1    | -                | -                |
| 6  | *Sus scrofa*             | -      | 4                | -                |
|    | Total of Individual Number | 19    | 27               | 28               |
|    | Total of Species Number  | 4      | 5                | 3                |

From Table 1 above, it shows that the highest number of species was found in the post-burned area in 2017, showing that there was an increase in the number of species after a fire. This result indicates that within two years the habitat has recovered and feasible for the wildlife habitat, even better than before burning. Cited by [27], [28] that seven months after a stand-replacing fire, the wildlife, in this case is moose, had moved into the post-burned area, attracted by increased forage and a low-density resident of that species population, making this area preferred. Some of the species that found on the post-burned area are species generalist, they are capable of using a variety of habitat conditions [29], including those produced by a range of burn severities [30]. Small mammals tend to have high reproductive rates, as the post-burned area has greater diversity and density of vegetation, it can provide food and shelter for them, so their populations can recover rapidly.

As can be seen in figure 3, the richness and evenness number work in line with the species number. In 2017, the richness number increased 18.63% (from 1.02 to 1.21) and in 2019 decreased 50.41% (from 1.21 to 0.6). The value graphic is also in line with the evenness number. It is increased 14.5% (from 0.69 to 0.79) in 2017 and as the result there was no domination of a species, (no individual number is massively increased). Where in 2019, the value was decreased 31.88% (from 0.69 to 0.57) and as the number of species was decreased, there was a domination of a species (it has high individual number), which is *Macaca fascicularis* (Table 2).

![Figure 3. Comparison of mammal diversity values](image-url)

The results of the increase on mammal diversity values in 2017 is supported by others research. Reference [31] found that fire could give positive impact on small mammal diversity, as species diversity is higher in areas where fire is a periodic disturbance. Also in reference [32] the research encountered a higher diversity in burned habitats than that found in any habitats in their study. It has been cited that a habitat after fire can provide good conditions for mammals [33], [34]. However, in 2019 instead of having a greater mammal diversity as expected, turns out there was a decrease of species diversity. While doing the observation, the habitat still looks the same, but this time human interfere is much more
happen, the plantation activity is being implemented, where when 2 years after fire, no plantation activity in that area was carried out. From the vegetation analysis on Table 1, we can see that the habitat condition post-burned in 2019 even has a greater diversity and density than the unburned area, and increase from the post-burned in 2017. This shows that the vegetation condition does not the factor that caused the decrease of mammal diversity.

3.3. Lost and gained of mammal species

Figure 4 shows that the similarity index between unburned and post-burned area from 2017 to 2019 is increased. The high number of similarity index indicates that many species exist in both locations that being compare. Stated that the more likely the habitat or it has the same condition/ or recover as how it was, the more it will has species similarity [35]. In this case, the decrease of species number from 2017 to 2019 help the similarity index increase.

![Comparison of mammals species similarity index](image)

**Figure 4.** Comparison of mammals species similarity index

The similarity index can also indicate a species lost or gained, the lack of its full presentation value shows that there are species differences in each locations or periods. Shown by table 3 below, the species that lost and gained in each periods.

| Species Loss      | Post-burned 2015 | Post-burned 2019 |
|-------------------|------------------|------------------|
| Prionailurus bengalensis | Prionailurus bengalensis | - |

| Species Gain      |
|-------------------|
| Callosciurus notatus |
| Sus scrofa |

On the post-burned land in 2017, there was an increase in one species, which is *Callosciurus notatus*. Based on the response of mammals to fires, recovered habitats support several types of mammals to return to areas of land that have been affected by fires in search of food sources. Some food sources such as insects are found in many areas that have been burned. The most interesting thing happens in insect ecology where insects from the subgenus Melanophila, for example, use their infrared radiation sensors to find burning trees as a place where they mate and lay eggs [36]. The existence of this phenomenon can attract the attention of insect-eating mammals that will settle in the area, and in this case is *Callosciurus notatus*, as known that the diet of this species includes fruit pulp, flowers, leafy shoots, seeds, and insects. Other reference cited that area that has moderate to high severity burned patches that contain open canopies, dominated by herbaceous plants and shrubs might be a preferable habitat for ground dwelling squirrels [37]. As for *Sus scrofa* the habitat post-burned area is more likely support to find the forage as the unburned area condition is easily covered with water. Meanwhile, the absence of *Prionailurus bengalensis* on post-burned area can be caused by interruption of anglers activities. Anglers start activities in the afternoon after work in the garden until the evening, so that it
can cause the bird away from the post-burned area, considering that they went out to hunt in the evening and night.

4. Conclusion
Land fires not only caused a negative impacts on mammals by causing death and species lost, in fact after two years the post-burned area recover and became a better habitat, resulted in the increase of mammal diversity, where there are two species gained and one lost. However, the condition after four years of fires, there is only a species lost, that happen through an intervention of human disturbance factor. In this research, land fires evidently did not cause a serious species composition change, where there are presence of species that are able to survive in the post-burned area.

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