A case study on the impacts of oil palm plantation on butterflies: differences in plantation scale and management implications

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Abstract. Changes in land use to oil palm plantations have an impact on the biodiversity of tropical butterflies known to have species with a wide ecological range. We research to determine the impact of oil palm plantations on the diversity of butterfly species on two different plantation scales (large scale and small scale of plantation). The results showed that both of the oil palm plantations equally affected the increase in the number and level of species diversity of butterflies as many as 100 - 366% on large-scale oil palm plantations and by 0 - 466% on small-scale oil palm plantation. The development of oil palm plantations also has an impact on changes in species composition which is reflected in the level of similarity in species which is quite low, namely 0 - 0.22 in large oil palm plantations and 0.12 - 0.20 in small-scale plantations. The percentage of species loss in both types of plantations is the same, namely 60%, but there is greater species gain on small-scale oil palm plantations (60 - 400%) than large-scale (166 - 366%). Plantation management that creates habitat heterogeneity can increase the level of butterfly biodiversity on both plantations.

1. Introduction
One of the most pressing global topics now is achieving food security as well as biodiversity conservation. Tropical countries are the regions with the highest potential for conflict, where low food security and high biodiversity occur simultaneously [1]. Based on the conflict risk index, Indonesia was recorded as the seventh highest-ranking country with oil palm (Elaeis guineensis) as a strategic commodity.

The main factor as a cause of the high conflict between overlapping agricultural expansion and biodiversity hotspots is land use change. As the largest palm oil exporter in the world, Indonesia has plantations covering an area of 14.03 million hectares in 2018 [2] which has the potential to change the type of origin land cover. Oil palm plantations in Indonesia are developed on a large scale and small scale. Large Scale Plantation (LSP) usually have an area of more than 25 ha and have several age classes of plants, and are managed by the state, national private, or foreign private. Small-scale plantations/smallholder plantation (SP) generally have an area of less than 25 ha, only have one age class of plants, and are managed by communities or community groups. Both types of plantations have the potential to have an impact on biodiversity loss.
Butterflies are one of the biodiversity commonly found in oil palm plantations and have the potential as an environmental bio-indicator [3]. Butterflies also have a role as pollinators, host of parasites, and the prey for predators [4], [5]. Its species richness was also affected by environmental factors; climatology and topography, vegetation structure, and human disturbance [6]. Several studies have shown that butterfly species can survive in oil palm plantation habitats with various age groups of plants, and belong to several feeding guilds [7], [8]. Other studies suggest that butterfly species are sensitive to the effect of converting primary forest to plantations [9]. However, the study on this insect was still limited, one of less ‘charismatic’ group but global dominance among all of the animal communities [10].

The difference in the type of the original land cover and the scale of the plantation affected the impact of land clearing on biodiversity. The oil palm plantations in Indonesia do not fully originate from the conversion of primary forests [11] so that the variety of land cover can have a different impact. This study attempts to look at the impact of large and small oil palm plantations on butterfly species diversity and management implications for species conservation.

2. Methods

The research conducted in July until August 2018 at the oil palm plantation of PT. BPK, which is located in West Kalimantan Province, Indonesia. The study area has six types of a land cover consisting land cover origin before the existence of oil palm plantations (secondary forest) and two types of oil palm plantation (large scale plantation and smallholder plantation). Large Scale Plantation consists of four types of land cover on large-scale oil palm plantations (the old oil palm, mature oil palm, and young oil palm, high conservation value area/HCV), as well as Smallholder Plantation, consists of two smallholdings area.

Young oil palm (YOP) planted in 2015. This area surrounded by oil palm plantations with 2015, 2013, and 2010. The conditions of canopy cover tend to be open with undergrowth dominated by ferns. Mature oil palm (MOP) planted in 2009 and the canopy cover conditions tend to be dense. Old oil palm (OOP) planted in 2001, the canopy cover is quite dense, and the plantation floor covered with ferns. Smallholder plantation one planted in 2000. Apart from oil palm, there are also other types of vegetation such as bananas and cassava. This area borders on community-owned gardens and rubber gardens. Smallholder plantation two planted in 2017 and adjacent to secondary forest and HCV area. This area does not have canopy cover because the age of oil palm is still very young. The plantation floors covered with ferns, and there are water sources/canals around the area. Secondary forest area is located outside the PT BPK area, have water sources in the form of small canals, and bordered by shrubs and oil palm plantation.

Butterfly data collection conducted by using a combination of Line Transect method and Time Search method. A one-kilometer transect was used as an observation track, and record the type and number of mammals species found. Observations carried out simultaneously on all of the habitat type and repeated three times to maximize recording. Measurement of environmental parameters (temperature) also performed in the morning and afternoon in every type of habitat observed.

Figure 1. Map of research location in West Kalimantan Province, Indonesia
The data analyzed by quantifying the diversity of species in each type of habitat in oil palm plantations using Margalef Index (DMg), Shannon-Wiener index (H’), Evenness index. The similarity among land cover types calculated using Sorensen similarity index (SI). The composition of species compared between large-scale plantation and smallholder plantation based on the list of species loss, species gains, and species persistence. Loss species is species found before plantation development but not found in the following conditions. Gain species are species that found in the area after plantation development but not found in the previous conditions. Persistence of species is a species found in both conditions before and after plantation development. Data analyzed to estimate the value of species loss and acquisition due to oil palm plantations, namely differences in species gain and species loss. A comparison was made on the number of species, species diversity, and species composition.

3. Results and Discussion
3.1. Comparison of Butterflies Species Diversity
The number and diversity of butterfly species found in large oil palm plantations and smallholder plantations are higher than the original land (secondary forest). The increase in the number and level of species diversity of butterflies in each habitat type indicated by species diversity index, as many as 100 - 366% on large-scale oil palm plantations and by 0 - 466% on small-scale oil palm plantation. A similar trend is also occurring in the total value and diversity of species in the two types of plantations. Index of species diversity in secondary forest as an original land cover type before the development of plantation, large-scale plantation, and smallholder plantation displayed in figure 2.

![Graph showing species diversity comparison](image)

Remarks: SF = secondary forest, YOP = Young oil palm, MOP = Mature oil palm, OOP = Old oil palm, HCV = High conservation value, LSP = Large scale plantation, SP = Smallholder plantation, DMg = Margalef species richness index, H' = Shannon-Wiener species diversity index, E = Evenness index

**Figure 2.** Comparison of species diversity level in secondary forest, large-scale plantation, and smallholder plantation in PT. BPK West Kalimantan

Totally, 27 butterfly species comprising five families recorded. The families were Hesperiidae, Nymphalidae, Papilionidae, dan Pieridae. Three species were recorded at origin land use (secondary forest), while 6 - 11 species and 3 - 14 species were recorded at large scale plantation, and smallholder plantation, respectively (see table 1). Nymphalidae is the most common butterflies found in all of the habitat types. This trend was similar to the result found in several studies who found Nymphalidae as the biggest group among other butterflies groups [8], [12]. This group known as a diverse habitat range and broad food variety [13].
Table 1. Butterflies species composition at origin land use type and oil palm plantations in PT. BPK West Kalimantan

| No. | Species              | Family         | Secondary Forest | Large Scale Plantation | Smallholder Plantation |
|-----|----------------------|----------------|------------------|------------------------|------------------------|
| 1   | Pelopidas agna       | Hesperiidae    |                  | YOP 2 MOP 3            | OOP 1 HCV 1 SP1 1 SP2 1 |
| 2   | Telicota augias      | Hesperiidae    |                  | YOP 3 MOP 3            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 3   | Acraea violae        | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 4   | Amathusia phidippus  | Nymphalidae    |                  | YOP 38 MOP 6 HCV 1 SP1 1 SP2 1 |
| 5   | Cethosia hypsea      | Nymphalidae    |                  | YOP 2 MOP 2 HCV 1 SP1 1 SP2 1 |
| 6   | Elymnias cumaeae     | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 4 HCV 1 SP1 1 SP2 1 |
| 7   | Elymnias vicetas     | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 1 HCV 1 SP1 1 SP2 1 |
| 8   | Elymnias hypermenstra| Nymphalidae    |                  | YOP 1 MOP 1            | OOP 1 HCV 1 SP1 1 SP2 1 |
| 9   | Hypolimnas bolina    | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 1 HCV 1 SP1 1 SP2 1 |
| 10  | Hypolimnas bolina jachynta | Nymphalidae |                  | YOP 1 MOP 2 HCV 1 SP1 1 SP2 1 |
| 11  | Junonia atlites      | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 12  | Junonia orithya      | Nymphalidae    |                  | YOP 8 MOP 8 HCV 3 SP1 1 SP2 1 |
| 13  | Medusa ciphera       | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 14  | Neptis hylas         | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 15  | Orsotriaena medus    | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 16  | Pandita sinope       | Nymphalidae    |                  | YOP 3 MOP 3 HCV 1 SP1 1 SP2 1 |
| 17  | Vindula dejone       | Nymphalidae    |                  | YOP 1 MOP 1            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 18  | Ypthima pandocus     | Nymphalidae    |                  | YOP 5 MOP 5 HCV 1 SP1 1 SP2 1 |
| 19  | Graphium agamemnon   | Papilionidae    |                  | YOP 1 MOP 1            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 20  | Papilio demoleus     | Papilionidae    |                  | YOP 1 MOP 1            | OOP 2 HCV 1 SP1 1 SP2 1 |
| 21  | Appias olferna       | Pieridae       |                  | YOP 2 MOP 2 HCV 1 SP1 1 SP2 1 |
| 22  | Catopsilia phyranthe | Pieridae       |                  | YOP 1 MOP 1            | OOP 3 HCV 1 SP1 1 SP2 1 |
| 23  | Catopsilia scylla    | Pieridae       |                  | YOP 3 MOP 3 HCV 1 SP1 1 SP2 1 |
| 24  | Delias hyparate      | Pieridae       |                  | YOP 1 MOP 1            | OOP 1 HCV 1 SP1 1 SP2 1 |
| 25  | Eurema hecabe        | Pieridae       |                  | YOP 1 MOP 1            | OOP 3 HCV 1 SP1 1 SP2 1 |
| 26  | Eurema sari          | Pieridae       |                  | YOP 1 MOP 1            | OOP 3 HCV 1 SP1 1 SP2 1 |
| 27  | Leptosia nina        | Pieridae       |                  | YOP 1 MOP 1            | OOP 1 HCV 1 SP1 1 SP2 1 |

| Total of species number (S) | 3 | 11 | 9 | 6 | 6 | 14 | 3 |
| Total of individual number (N) | 4 | 25 | 64 | 6 | 20 | 30 | 3 |

We found that butterflies species in oil palm plantation have low similarity with those in secondary forest, indicated by low similarity index range only 0 - 0.22 for large-scale plantation and 0.21 – 0.20 for smallholder (table 2). The higher similarity of species composition is seen in the young age class and the middle age class located on large-scale plantations with smallholder plantations 1. Each is 0.7 and 0.6. This high level of similarity caused by the condition of a better plant canopy to create protection for butterflies in both areas. On the contrary, the low similarity of LSP with SP2 influenced by the age of plants in SP2 (one year), so that differences in vegetation cover on the garden floor can affect species composition. It confirmed by other research [3] that mention the number of species is influenced by the cover of the tree canopy and the intensity of sunlight.

Table 2. Index of similarity of each land cover type at large scale plantation, smallholder plantation, and secondary forest in PT. BPK West Kalimantan

| Land cover | SF | YOP | MOP | OOP | HCV | SP1 | SP2 |
|------------|----|-----|-----|-----|-----|-----|-----|
| SF         | 1.00 | 0.00 | 0.22 | 0.22 | 0.22 | 0.20 | 0.12 |
| YOP        | 1.00 | 0.60 | 0.13 | 0.44 | 0.70 | 0.12 |   |
| MOP        | 1.00 | 0.40 | 0.67 | 0.60 | 0.12 |   |   |
| OOP        | 1.00 | 0.22 | 0.30 | 0.12 |   |   |   |
| HCV        | 1.00 | 0.30 | 0.35 |   |   |   |   |
| SP1        | 1.00 | 0.35 |   |   |   |   |   |
| SP2        | 1.00 |   |   |   |   |   |   |

Changes in species composition are reflected in species loss, species gain, and species persistence. The percentage of species loss in both types of plantations is the same, namely 60%, but there is greater species gain on small-scale oil palm plantations (60 - 400%) than large-scale (166 -
366%). Table 3 and Table 4 show LSP and SP lose only two species. This amount far less than the species gain which amounts to 20 species in LSP and 12 species in SP. 8 species can be found in LSP and SP. The only species of persistence in both types of gardens is *Amathusia phidippus* or Palm King that commonly found in coconut trees. This species not classified as threatened under the IUCN Red Data List, but some research results refer to Palm King as a rare and endangered species on the Indian Peninsula [14].

**Table 3.** The exchange of species composition in a large-scale plantation in PT BPK West Kalimantan

| Species loss | Species gain | Species persistence |
|--------------|--------------|---------------------|
| *Cethosia hypsea* | *Pelopidas agna* | *Amathusia phidippus* |
| *Delias hyparate* | *Telicota augias* | |
| | *Acraea violae* | |
| | *Elymnias cumae* | |
| | *Elymnias hicetas* | |
| | *Elymnias hypermnestra* | |
| | *Hypolimnas bolina* | |
| | *Hypolimnas bolina jachynta* | |
| | *Junonia aitiltes* | |
| | *Junonia orithya* | |
| | *Medusa ciptera* | |
| | *Pandita sinoe* | |
| | *Graphium agamemnon* | |
| | *Papilio demoleus* | |
| | *Appias olferna* | |
| | *Catopsilia phyranthe* | |
| | *Catopsilia Scylla* | |
| | *Eurema hecabe* | |
| | *Eurema sari* | |
| | *Leptosia nina* | |

**Table 4.** The exchange of species composition in smallholder plantation in PT BPK West Kalimantan

| Species loss | Species gain | Species persistence |
|--------------|--------------|---------------------|
| *Cethosia hypsea* | *Acraea violae* | *Amathusia phidippus* |
| *Delias hyparate* | *Elymnias hypermnestra* | |
| | *Hypolimnas bolina* | |
| | *Junonia aitiltes* | |
| | *Junonia orithya* | |
| | *Neptis hylias* | |
| | *Orsotriaena medus* | |
| | *Vindula dejone* | |
| | *Ypthima pandocus* | |
| | *Appias olferna* | |
| | *Eurema sari* | |
| | *Leptosia nina* | |

3.2. Discussion

3.2.1. Response of butterfly to oil palm plantation with different scale

We found that LSP and SP together showed a positive impact on increasing the number and diversity of species compared to conditions before the development of oil palm plantations (secondary forests). This study shows that no difference impact in plantation scale on butterfly species diversity. Other studies have already shown that oil palm plantation could affect butterfly diversity found in farmland [8], [9], [15]. The species obtained are generally generalist species in the family group Nymphalidae. Nymphalidae is the largest butterfly group and has a wide range of habitat types.

Species of the Papilionidae, *Graphium agamemnon* and *Papilio demoleus* groups were only found in LSP in the old age group (19 years). Both of them known as swallowtail butterfly. Indonesia has 121 species of swallowtails, over 20 per cent of the world total [16]. *Graphium agamemnon* is one of the charismatic species while *Papilio demoleus* is one of widest spread members of the family Papilionidae and have the quick expansion of its range. Habitat alteration is one of threats swallowtail
butterfly. This result reveals that the presence of this species in old oil palm age class may indicate that oil palm plantation could be part of its habitat.

Species diversity influenced by physical factors. One physical factor that influences the diversity of butterfly species is temperature [12]. The temperature may affect the ecology and life history of butterflies [17] and furthermore could affect its species richness. In term of temperature, the optimum temperature for the butterfly to actively search for food is between 23-30 °C [18]. The temperature at large scale plantation range from 24 until 29.5 °C, from 23 – 26 °C at smallholder plantation, and 27 °C at the secondary forest. The age variation of plants in LSP causes a greater temperature range than SP. The presence of young, medium, old, and HCV class plants provide more variation than only one plant age class in SP or natural forest vegetation in SF.

### Table 5. Temperature (°C) at origin land use type and oil palm plantations in PT. BPK West Kalimantan

| Time       | LSP     | SP     | SF     |
|------------|---------|--------|--------|
|            | YOP  | MOP  | OOP  | HCV  | 1   | 2   |        |
| Morning    | 26   | 24   | 26   | 29.5 | 26  | 23  | 27    |
| Afternoon  | 26   | 24   | 25   | 28.5 | 23.5| 24.5| 27    |

3.2.2. Management implication in the context of wildlife conservation

Conversion of land cover from secondary forest to oil palm plantation can change the level of diversity and composition of species inhabiting an area. Even though the expansion of tropical forests by man will inevitably disturb swallowtail populations, but the extent of the impact depends on the level of disturbance, the extent of the biotope and its ability to recover, and the willingness of people to allow it to do so [16]. One of the challenges in butterfly conservation is creating habitat heterogeneity in monoculture oil palm plantations. Heterogeneity can provide habitat components needed by butterflies so that they can recover ecologically.

Efforts made on LSP and SP can be different because of differences in land size, level of diversity of plant age, and management by humans. The main components of butterflies are water and feed plants and host plants, so the management carried out should support an increase in the number and quality of the components [19]. Characteristics of LSPs that have canals in the garden area are supporting physical factors for butterflies. Large oil palm plantations can managed by maintaining the various age classes by setting the new planting period and site locations while enhancing the quality of forest patch in the High Conservation Value (HCV) area. For smallholder plantation, the land sharing approach could be a strategy in enhancing the diversity and the richness of vegetation. Combine the oil palm with host trees and food crop diversity are another alternative to maintain the ecological environment for butterflies.

4. Conclusion

The development of oil palm plantation has a positive and negative impact on butterfly diversity. The positive impact is gaining species, while the negative impact is loss of species. Both of Large-scale Plantation and Smallholder plantation indicate no differences impact in plantation scale on butterfly species diversity. The species diversity increasing after the development of oil palm plantation derived from the secondary forest area on both of plantation type. The species dominated by Nymphalidae species. Habitat heterogeneity is a key point in management implication for the species diversity conservation.

Acknowledgments

Our sincere thanks go to the chiefs and staffs of PT. BPK in West Kalimantan for supports and facilities that provided during field activities, BPDPKS for financial support, and all of the teams for dedication and cooperation during data collections.

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