The loss, gain, and diversity of butterfly species due to the development of PT PKWE oil palm plantation, West Kalimantan Province

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Abstract. An increase in oil palm plantation area of ± 9.3 million hectares within 20 years (1997 – 2006) raises concerns of the international communities on the loss of diversity, including butterflies. Butterflies have multiple ecological functions, including as pollinator and ecosystem balancer, hence research about the impact of oil palm plantation development on the loss, gain, and diversity is important to conduct. The research was conducted in March 2018 in PKWE Plantation, West Kalimantan Province, by using Pollard transect method and trap in seven land covers. The land covers consist of two original land covers before made into oil palm plantation, in the form of shrubs and secondary forest, and five land covers after made into oil palm plantation, in the form of old, medium, young oil palm plantation, High Conservation Value (NKT) area, and yard. The total butterfly species found amounted to 49 species, 315 individuals, four families: Papilionidae (8 species), Pieridae (8 species), Nymphalidae (31 species), and Lycanidae (2 species). The highest number of species and diversity were discovered in the High Conservation Value (HCV) area (S=26; Dmg=6.24), while the lowest ones were located in a yard area (S=11; Dmg=2.09). Based on conservation status, there were a butterfly species which is protected namely Troides helena. Regarding the loss and gain of butterfly species, oil palm plantation development had caused a much lower loss than gain. With the loss of five species and gain of 27 species compared to the original land cover in the form of secondary forest, and the loss of three species and gain of 26 species compared to the original land cover in the form of shrubs.

1. Introduction
Oil palm plantation area in Indonesia grew significantly by ± 9.3 million ha, from 2.911.296 ha in 1997 to 12.307.677 ha in 2017 [1]. Oil palm plantation as a source of alternative energy provides a positive contribution to the national economy and as people’s livelihood [2]. However, several experts often accuse the conversion of forest area into oil palm plantation as one of the main factors causing the occurrence of deforestation and the loss of biodiversity in various tropical countries [2], [3], [4], [5], [6], [7]. Reference [5] emphasized that the conversion of primary or secondary forest into oil palm plantation have an impact that can damage species diversity including butterfly. Reference [8] stated that primary and secondary forest converted into oil palm plantation lowered the butterfly species richness by around 79-83%.
Butterflies need a suitable habitat for their life. They can live in various habitats ranging from primary forest, secondary forest, agricultural area, plantation, to house yard, with an altitude of 0 - 2 000 meters above sea level. Sources of water, sunlight, temperature, and humidity have important roles in supporting the life of butterflies [9], [10]. The optimum temperature for butterfly is 28 – 35° C [11], while the humidity favored by them is less than 85% [9]. Butterflies utilize plants as their place of life, which are food plant and host plant. Butterflies categorized as herbivore who eat plants. Their food when they are still larvae is part of the plant (vegetation) and their food after becoming an adult is flower nectar [9].

Butterflies are part of biodiversity which must be conserved from extinction and species diversity decline. Butterflies have important values, such as the value of ecology (pollinator), endemism, conservation, education, culture, aesthetics, and economy [12]. Butterfly, as a pollinator, helps in maintaining biodiversity and ecosystem balance. Researches concerning butterfly species diversity in oil palm plantation had been conducted several times, but most of them were conducted in Sumatera area like the study carried out by reference [13] in West Sumatera, in Bengkulu [14], in Riau [15], [16], while in Kalimantan, there have not been many researches conducted. Research regarding the impact of oil palm plantation on the loss, gain, and diversity of butterfly species also has not been undertaken much. Thus this research is important to carry out.

This research aims to identify butterfly species diversity, compare the loss and gain of butterfly species in original land cover before made into oil palm plantation, land cover after converted into oil palm plantation and study the conservation status of the butterflies found. The results of this research can be utilized as a reference and consideration in formulating and developing policies on land management in oil palm industry by keep maintaining wildlife conservation, especially butterflies.

2. Materials and methods

2.1. Location and time

This research was conducted in PT PKWE, West Kalimantan Province, in seven land covers. The two land covers were original land cover before made into oil palm plantation, namely protection forest (HL) and shrubs (SB). The other five land covers were land cover after made into oil palm plantation, namely oldest oil palm plantation (ST) established in 2006, medium oil palm plantation (SS) established in 2011, young oil palm plantation (SM) established in 2016, High Conservation Value (NKT) area, and yard (PKR). Figure 1 presents the research location map. This research was performed in March 2018.
2.2. Tools and materials
The tools and materials used included Landsat imagery, tally sheet, stationery, GPS Garmin 62s, camera, area map for data collection, butterfly hand net, butterfly trap, tape measure, rope, book of field guide and butterfly species identification titled Identification guide for butterflies of West Java (Schulze), Practical Guide to The Butterflies of Bogor Botanic Garden [17], and The Illustrated Encyclopedia of the Butterfly World [18]. The tools and materials for butterfly preservation were syringe, alcohol, Styrofoam, papilot paper, straight pin, adhesive tape, and camphor.

2.3. Data collection method
The data were collected using strip transect method [19]. The length of the transect line was made 1 km long and 150 m wide, and one repetition was carried out in the adjacent line so that the total length of the line became 2 km. The data collection repetition was undertaken three times (3 observation days) simultaneously in all types of land cover in the morning at 09.00-11.00 WIB according to the active time of the butterfly. The observation was performed at a constant speed by using butterfly hand net to catch the butterflies directly. Butterfly trap was also utilized which was installed at the height of ± 1m as many as six traps in each observation line.

2.4. Data analysis
The data was analyzed in a quantitative and descriptive qualitative manner, encompassing the number of species, species richness index, species similarity index, species loss and gain ratio, and butterfly conservation status.

Number of Species (S)
The number of species is the number of all types of butterfly found in PKWE plantation.

Species Richness Index (Dmg)
Species richness index serves to show the number of species in a certain type of habitat using Margalef’s index [20], with the formula as follows:

\[ Dmg = \frac{(S - 1)}{\ln N} \]

Information:
- Dmg : Species richness index
- S : Number of species
- N : Total number of individuals of all types

Sorensen’s Species/Community Similarity Index
To find out the impact of oil palm plantation on the composition, the number of loss and gain of butterfly species, Sorensen’s species/community similarity index was applied [20] as follows:

\[ IS = \frac{2c}{a + b} \]

Information:
- a: Number of species found in community a
- b: Number of species found in community b
- c: Number of species found in community a and b

Conservation Status
Butterfly conservation status covers extinction status, trade arrangements, and butterfly species protection according to the International Union for Conservation of Nature (IUCN) Red List, Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), and Government Regulation (PP) No. 7 Year 1999 concerning Plant and Animal Species Preservation.
3. Results and discussion

3.1. General condition of the research location

Protection Forest (HL)
Protection forest is a government-owned land, which was adjacent to the oldest oil palm plantation, community-owned field, and several community’s residences. This area had a river flow with a closed riparian. It had the characteristics of hilly and a relatively open canopy cover in the hilly area, an area that was still in the form of shrubs, and an area bordering the community fields. The average temperature in this area was 29° C with an average humidity of 83%. The lowest temperature recorded was 28° C and the highest was 32° C with the lowest humidity of 70% and the highest of 91%.

Shrubs (SB)
Shrubs had a relatively open canopy with the floor covered by high and dense shrubs. This area was adjacent to the youngest oil palm plantation and access road. Water often flooded several locations especially during rainy season due to the uneven topography. There was a road building activity next to this area. The average temperature in this area was 27° C with an average humidity of 91%. The lowest temperature recorded was 25° C and the highest was 9° C with the lowest humidity of 74% and the highest of 91%.

The Oldest Oil Palm Plantation (ST)
The oldest oil palm plantation was adjacent to the collision road (CR) which motor vehicles usually passed. The northern part of this area bordered the buffer area before entering the protected forest area. The canopy cover condition was relatively dense with the plantation floor was overgrown with understories. In every two planting points, there was a trench in the form of water flow or waste storage place. The average temperature in this area was 29° C with an average humidity of 86%. The lowest temperature recorded was 26° C while the highest was 29° C with the lowest humidity of 59% and the highest of 91%.

Medium Oil Palm (SS)
Medium oil palm plantation area had a dense canopy cover with the plantation floor was overgrown with a wide range of understory species. This area bordered the access road and NKT area. Several locations in this area were often flooded especially after rain. The average temperature in this area was 29° C with an average humidity of 83%. The lowest temperature recorded was 27° C while the highest was 30° C with the lowest humidity of 77% and the highest of 91%.

The Youngest Oil Palm Plantation (SM)
The youngest oil palm plantation area directly bordered shrubs area. The canopy cover in this area was exceptionally open due to the young oil palm with a height of around 2-3 m. This area was often flooded with water from the trench and boundary canal between blocks. The average temperature in this area was 29° C with an average humidity of 83%. The lowest temperature recorded was 28° C while the highest was 32° C with the lowest humidity of 77% and the highest of 91%.

High Conservation Value Area (NKT)
NKT area was in the form of riparian area, which extends along the river. This area was adjacent to the medium oil palm plantation, had a relatively dense canopy cover in the area of tree vegetation, and was open in river course. The average temperature in this area was 28° C with an average humidity of 83%. The lowest temperature recorded was 26° C while the highest was 30° C with the lowest humidity of 76% and the highest of 91%.

Yard Area (PKR)
Yard area is a community residence area. This area is an open area in which people often plant various types of flowering plants, such as Ixora flower (Ixora coccinea), rosy periwinkle (Catharanthus roseus), and pucuk merah (Syzygium oleana). This area was an area with the highest level of human disturbance as there are house and school buildings. The average temperature in this area was 29° C with an average
humidity of 83%. The lowest temperature recorded was 28° C while the highest was 32° C with the lowest humidity of 77% and the highest of 91%.

Overall, there found 49 families among 120 species of understories in PKWE plantation. The family that had the highest number of species and density value was Poaceae family with 16 species. Figure 2 portrays the variation of understory species diversity in various types of land covers.

3.2. Butterfly species diversity in various types of land cover

Butterfly species found in PT PKWE oil palm plantation varied in each type of land cover as presented in the following table 1:

| No. | Species            | Family     | SM  | SS  | ST  | NKT | SB  | HS  | PKR | Total Individuals |
|-----|--------------------|------------|-----|-----|-----|-----|-----|-----|-----|-------------------|
| 1.  | Neptis hylas      | Nymphalidae| 7   | 2   | 1   | 3   | 14  | 5   | 1   | 33                |
| 2.  | Euploea mulciber  | Nymphalidae| 0   | 12  | 0   | 2   | 2   | 4   | 0   | 20                |
| 3.  | Junonia atlites   | Nymphalidae| 5   | 3   | 5   | 1   | 3   | 1   | 1   | 19                |
| 4.  | Orsotriaena medus | Nymphalidae| 12  | 0   | 0   | 0   | 0   | 6   | 0   | 18                |
| 5.  | Eurema hecabe     | Pieridae   | 2   | 2   | 2   | 5   | 3   | 2   | 1   | 17                |
| 6.  | Parthenos sylvia  | Nymphalidae| 13  | 0   | 0   | 1   | 0   | 2   | 0   | 16                |
| 7.  | Catopsilia pyranthe| Pieridae  | 5   | 9   | 0   | 0   | 0   | 0   | 0   | 14                |
| 8.  | Mycalesis horsfieldi| Nymphalidae| 3   | 5   | 0   | 1   | 1   | 4   | 0   | 14                |
| 9.  | Mycalesis anapita | Nymphalidae| 7   | 0   | 1   | 4   | 0   | 0   | 0   | 12                |
| 10. | Eurema sari      | Pieridae   | 2   | 1   | 2   | 0   | 1   | 2   | 3   | 11                |
| 11. | Others (39 species)|           | 17  | 16  | 14  | 26  | 19  | 21  | 6   | 49                |

This research found 49 butterfly species from 315 individuals and four families, namely Papilionidae (7 species), Pieridae (8 species), Nymphalidae (31 species) which is family with the highest number of species, and Lycanidae (2 species) which is family with the lowest number of species. There was no Hesperidae family in this research. NKT area had the highest number of species as many as 26 species, while yard area had the lowest number of species (6 species). The high number of butterfly species in NKT was directly proportional to its species richness value. NKT area has the highest species richness value (Dmg=6.24). Figure 3 shows a comparison between the number of species and species
richness in each type of land cover. These results are different with the previous researches conducted by reference [15] that stated that the highest diversity was in the youngest oil palm plantation and reference [16] that revealed that the highest diversity was in the secondary forest area. Environmental condition in each research location is different in the aspect of vegetation, geology, and ecology, is the cause of these differences.

![Comparison between the number of species (S) and species richness (Dmg) in various types of land cover](image)

**Figure 3.** Comparison between the number of species (S) and species richness (Dmg) in various types of land cover.

The high level of butterfly species diversity and richness in NKT area caused by the habitat condition, which can support the life of butterflies. In NKT area there are trees and understories which some of them are butterfly feed plants, namely *Piper sp.* as caterpillar feed, *Dillenia suffruticosa* (Griff.) Martelli and *Macaranga triloba* (Thunb.) Müll.Arg. as butterfly feed, and *Bellucia pentamera* Naudin as caterpillar and butterfly feed. Reference [21] stated that butterfly larvae love young betel leaves (*Piper sp.*). The other conditions are the relatively dense canopy cover in forest area and open around the river, abundant water source comes from the river and the moist soil which supports the life of butterflies in that area. This is supported by the research carried out by reference [22] which showed that riparian habitat had high potential as the habitat of butterflies, owing to the availability of water source, open vegetation, and high sunlight intensity. Likewise, reference [23] mentioned that the characteristics of optimal habitat for butterflies are sufficient to light factor, clean or unpolluted air and water as the material required for the humidity of the environment where butterflies live.

The lowest number of butterfly species was found in the yard area, namely two species, as well as the lowest species richness value (Dmg = 2.09), compared to the other types of land cover. These results are different with the result of previous research conducted by reference [15] that declared that the yard area adjacent to the oldest oil palm plantation caused the high number of butterfly species as there were flowering plants grown in people’s yard and the yard borders the secondary forest. That condition is different with the condition in the yard area of PKWE plantation that although there were flowering plants, some of them were not in flowering condition, and there was no water source around the yard. Besides, the high level of human disturbance also caused a low level of butterfly diversity in the yard. That condition caused butterflies to prefer oil palm plantation area, NKT area, and protection forest, which were more favorable for their life. Reference [24] stated that the change of habitat and lack of food generated the occurrence of butterfly migration to the area far from human disturbance.

### 3.3. Butterfly species similarity in various types of land cover

In general, the analysis of butterfly community similarity in various types of land cover in PKWE plantation generated a low species similarity. The highest species similarity value existed in the oldest oil palm plantation and shrubs area with the value of 0.55. The high value, compared to the other land covers, was because there were nine similar species found in both locations. Those similar butterfly species were *Eurema sari*, *Leptosia nina*, *Eurema hecabe*, *Neptis hylas*, *Junonia atlites*, *Amathusia phidippus*, *Hypolinmas bolina*, *Parantica agloides*, and *Parantica aspasia*. The species similarity
between both locations was influenced by the characteristics of habitat in each location. According to reference [25], the high value of the similarity coefficient caused the species found to be similar, or the composition is almost similar in both different location. This showed that the higher the species similarity value, the higher the similarity of habitat characteristics, vice versa. Both shrubs and old oil palm plantation area had much water. In the oldest oil palm plantation, there were two types of trench, which were lengthwise in each two planting points as water flow and waste storage place. Meanwhile, in shrubs area, the puddle existed because of an uneven topography. The following table 2 presents the community similarity values:

| Types of land cover | Youngest oil palm | Medium oil palm | Oldest oil palm | NKT | Shrubs | Secondary forest | Yard |
|---------------------|-------------------|-----------------|-----------------|-----|--------|------------------|------|
| Youngest oil palm   | 0.48              | 0.39            | 0.51            | 0.50| 0.42   | 0.43             |      |
| Medium oil palm     |                   | 0.33            | 0.38            | 0.51| 0.38   | 0.45             |      |
| Oldest oil palm     |                   |                 | 0.40            | 0.55| 0.46   | 0.40             |      |
| NKT                 |                   |                 |                 | 0.49| 0.47   | **0.19**         |      |
| Shrubs              |                   |                 |                 |     | 0.45   | 0.40             |      |
| Protection forest   |                   |                 |                 |     |        |                  |      |

The lowest species similarity value existed in yard area and NKT area with the same number of species, which was three species (IS=0.19), namely *Eurema hecabe*, *Neptis hylas*, and *Junonia atlites*. The species similarity value was low because both areas had distinct habitat characteristics. Yard area is an open area with buildings, rocky roads, and open water source are rarely found, low amount of understories but there are several flowering plants. NKT area is a riparian forest, closed in forest part and open area around the river flow has many understories, stakes, and trees. NKT was an area with the highest number of butterfly species, namely 26 species, while the yard is an area with the lowest number of butterfly species, namely 6 species so that the difference of number of species between the two locations reached 20 butterfly species. That supported the low level of species similarity in both types of land cover, in line with reference [26] that distinct habitat had a low species similarity.

The most dominating butterfly species in PKWE plantation was *Neptis hylas*, which amounted to 33 of the total 315 butterfly individuals found. This butterfly species can also be found in all types of land cover, which showed its high adaptation power with different land covers. *Neptis hylas* is one of the species that are members of Nymphalidae family, which is adaptable. Reference [27] stated that Nymphalidae is a butterfly family who had the highest number of species and is cosmopolitan, has a widespread family distribution in many areas in the world, has a great survival ability in multiple types of habitat as they are *polifag*. *Polifag* is a group of animal living and eating in various types of plants from various families [28]. The *polifag* nature causes these species do not rely on solely one feed plant so that it is more adaptive in many kinds of environmental conditions. According to reference [29], the host plants of Nymphalidae family were Annonaceae, Asteraceae, Moraceae, Rubiaceae dan Anacardiaceae. Also, reference [15] mentioned that the feed plants of Nymphalidae family butterflies are of Asteraceae, Melastomataceae, Solanaceae, and Poaceae family. The host plants of Nymphalidae family found in the location were *Ageratum conyzoides* (L.) L., *Mikania micrantha* Kunth, *Climedia hirta* (L.) D. Don, *Uncaria acida* (Hunter) Roxb., and *Paspalum conjugatum* P.J. Bergius.

Several types of butterfly existed in all types of land cover, but there were also species that existed only in one type of land cover. There were three butterfly species that exist in all types of land cover, namely *Eurema hecabe*, *Neptis hylas*, and *Junonia atlites*. The butterfly species that could be found only in young oil palm plantation was *Ideopsis vulgaris*, in medium oil palm plantation were *Graphium antiphates*, *Papilio polytes*, *Gandaca harina*, *Euoplea tulliolus*, and *Mycalesis perseus*, in old oil palm plantation was *Mycalesis janardana*, in NKT area were *Eurema alitha*, *Hypolimnas misippus*, *Cupha
erymanthis, and Faunis canens, in shrubs area were Moduza procris and Ideopsis gaura, and in secondary forest were Danaus melanippus and Junonia orithya. However, there were no certain species only found in yard area. The difference of butterfly species between types of land cover was due to the difference of habitat characteristics supporting the life of butterflies, both from the factor of geology, ecology, and larvae and adult butterfly feed plant distribution [10].

3.4. The percentage of loss and gain of butterfly species diversity due to oil palm plantation development

The change of land cover due to oil palm plantation development had an impact on the change of biodiversity [30]. The existing change can cause a loss or gain of new butterfly species in that area. The loss of butterfly species is a loss of butterfly species, which originally found in original land in the form of HS and SB before made into oil palm plantation (ST, SS, SM, areal NKT, and PKR). On the other hand, species gain is the finding of butterfly species in oil palm plantation, which is not found in original land. The percentages of loss and gain of butterfly species due to the change of secondary forest into oil palm plantation are portrayed in figure 2, while the percentages of loss and gain of butterfly species due to the change of shrubs land into presented in figure 4.

![Figure 2](image2.png)

Information: ST = Old oil palm, SS = Medium oil palm, SM = Young oil palm, NKT= High Conservation Value area, PKR = Yard, SK = After converted to oil palm plantation

**Figure 2.** The loss and gain of butterfly species in the original land of secondary forest

![Figure 3](image3.png)

Information: ST = Old oil palm, SS = Medium oil palm, SM = Young oil palm, NKT= High Conservation Value area, PKR = Yard, SK = After converted to oil palm plantation

**Figure 3.** The loss and gain of butterfly species in the original land of shrubs

Figure 4 and figure 5 show that the change of secondary forest and shrubs into oil palm plantation in four land covers, namely ST, SS, SM, and PKR caused a higher species loss than gain. It was different with NKT area, which had a lower species loss than gain. The highest loss happened in yard area, while the highest gain happened in NKT area. Overall, oil palm plantation development both in the original land of secondary forest and shrubs had caused a higher species gain than species loss.

3.5. Butterfly conservation status

Wildlife conservation status can be categorized based on three references, namely IUCN Red List, CITES, and Government Regulation (PP) No. 7 Year 1999 (table 3).
Table 3. Conservation status of butterflies found in research location

| No. | Species             | Family        | Conservation status | IUCN | CITES | PP NO. 7/1999 |
|-----|---------------------|---------------|---------------------|------|-------|---------------|
| 1   | Troides helena      | Papilionidae  | -                   | Appendix II | -     | Protected     |
| 2   | Eurema alitha       | Pieridae      | LC                  | -    | -     | -             |
| 3   | Mycalesis janardana | Nymphalidae   | LC                  | -    | -     | -             |
| 4   | Thaumantis noureddin| Nymphalidae   | LC                  | -    | -     | -             |
| 5   | Ideopsis vulgaris   | Nymphalidae   | LC                  | -    | -     | -             |
| 6   | Tanaecia pelea      | Nymphalidae   | LC                  | -    | -     | -             |

This research found one protected butterfly species, namely *Troides helena*, which was found in two types of land covers, namely NKT area and secondary forest area. This butterfly species protected in Indonesia since 1980, by the decree (SK) of Minister of Agriculture No. 576/Kpts/Um/8/1980 and No. 716/Kpts/Um/8/1980. This species also belongs to the list of species with the CITES status of Appendix II so that it is prohibited from being traded except that it is originated from the captive breeding [31]. The presence of *Troides helena* in NKT area and secondary forest area was because both areas were able to provide feed sources and suitable habitat. Other than *Troides helena*, there were five other butterfly species which had the conservation status of Least Concern (LC) based on the category of IUCN’s conservation status. Butterfly species, which had the LC status based on IUCN mean that they had been evaluated, but not categorized as threatened or nearly threatened, so that the status is low risk. In other words, they have no urgent conservation dependency.

4. Conclusion

NKT area is the land cover with the highest number of species and species richness with the value of S=26 and Dmg=6.24 respectively. The lowest number of species existed in the yard area with the lowest species richness value as well, which were S=6 and Dmg=2.09 respectively. NKT area was the habitat that was most favorable for butterfly species existence.

The highest community similarity was obtained between the oldest oil palm plantation area and shrubs area (IS=0.55), while the lowest community similarity was obtained between NKT area and yard area (IS=0.19). The most dominating butterfly species in the research location was Neptis hylas. *Troides helena* was a protected species found in this research.

The change of secondary forest into oil palm plantation resulted in butterfly species loss by 23.81% and butterfly species gain by 128.57%, while the change of shrubs land into oil palm plantation resulted in butterfly species loss by 15.79% and butterfly species gain by 136.84%.

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