Impact of oil palm plantation on species diversity of tropical vegetation

Iwan Hilwan¹ and Yanto Santosa²

¹ Department of Silviculture, Faculty of Forestry, Bogor Agricultural University
² Department of Conservation of Forest Resources and Ecotourism, Faculty of Forestry, Bogor Agricultural University

*E-mail: ihilwan@yahoo.co.id

Abstract. The area size of oil palm plantation in Indonesia increases significantly every year. The great expansion of oil palm plantation stimulates the emergence of negative accusation that oil palm plantation development caused deforestation, reduction of biodiversity, and environmental degradation. This research aimed to analyze the impact of oil palm plantation development on species diversity of tropical vegetation. This research was conducted on 5 types of land cover in BPME oil palm plantation (young growth oil palm, medium growth oil palm, and old growth oil palm, bush land, and coconut plantation) by single plot method. Research results show that, the change of bush land to oil palm plantation caused biodiversity loss as many as 7 species (38.89%), biodiversity gain as many as 44 species (244.44%) and 18 species being found both in bush land and oil palm plantation, while 3 species of epiphyte moss were found too. On the other hand, change from coconut plantation to become oil palm plantation caused biodiversity loss as many as 6 species (60%), biodiversity gain as many as 52 species (520%) and 10 species being found both in coconut plantation and oil palm plantation, while 3 species of epiphyte moss were also found.

1. Background

Indonesia has succeeded in becoming the largest oil palm producer in the world with significant contribution toward national economic development. According to Directorate General of Plantation, Ministry of Agriculture [1], such contribution was among others in the form of state foreign exchange earning as large as around Rp 287 trillion in the year 2017, employment opportunity for more than 5.5 million people in on-farm sector (plantation) and in other multiplier effects sector. Area size of oil palm plantation in Indonesia exhibited significant increase from year to year, and in the year 2017 has reached area size of 14.03 million hectare. Such high rate expansion of oil palm plantation, stimulate the emergence of negative accusation toward oil palm management, namely accusation of oil palm plantation as the cause of biodiversity reduction, deforestation and environmental degradation.

One of the negative accusation toward the development of oil palm plantation as the cause of biodiversity reduction, especially for vegetation, should be proven in the field through research. Therefore, the objectives of this research were: (1) making inventory of plant species diversity on land before being converted to oil palm plantation (which in this research was in the form of coconut plantation and bush) and on young growth oil palm plantation, moderate age oil palm plantation and old growth oil palm plantation, and (2) estimating the magnitude/ value of loss / gain of plant species diversity resulting from oil palm plantation development. The desired output of this research is data...
and information on the magnitude of loss/gain of species diversity due to oil palm plantation development.

Data and information obtained from this research will serve as one important source of information concerning the impact of oil palm plantation development on loss/gain of plant species diversity. These data will also serve as consideration for developing oil palm plantation which supports biodiversity conservation. Particularly for companies, data, especially those which are related with biodiversity, could enrich the collection of data which are needed for certification process by ISPO (Indonesian Sustainable Palm Oil) or RSPO (Roundtable on Sustainable Palm Oil). Besides that, the research results could also be used by the Indonesian government or private institutions to give clarification or explanation in responding to the negative accusation, and for designing the best efforts to handle the issue of biodiversity reduction.

2. Materials and methods
This research was conducted in the area of BPME plantation, regency of Indragiri Hilir, the province of Riau, at 5 kinds of land cover, namely: (1) young age oil palm plantation (4 years old), (2) moderate age oil palm plantation (6 years old), (3) old age oil palm plantation (9 years old), (4) bush land area, and (5) coconut plantation. Bush land and oil palm plantation were land cover type before conversion to oil palm plantation.

On the 5 land cover types, there were construction of single compartment measuring 40 m x 40 m for each land cover type. The area of 40 m x 40 m is optimal sample plot for measuring plant species diversity in low land tropical forest [2]. Afterwards, in every single compartment, there was construction of 20 subcompartments measuring 2m x 2m for analysis of undergrowth vegetation and shrubs. The collected data were in the form of plant species and their abundance.

In data analysis, several equations were used, namely:

a. Species Richness Index of Margalef:
\[ Dmg = \frac{(S-1)}{\ln N} \]
b. Species Diversity Index of Shannon-Wiener:
\[ H' = -\sum pi \ln pi \]
c. Species Similarity Index of Sorensen:
\[ IS = \frac{2C}{(A + B)} \]
d. Percentage of species biodiversity loss = \( \frac{\text{Number of lost species}}{\text{Number of similar species}} \) x 100 %
e. Percentage of Biodiversity Gain = \( \frac{\text{Number of Species Gain}}{\text{Number of similar species}} \) x 100 %

3. Results and discussion
3.1. Number of species and diversity
Table 1 shows that the number of species in the initial land cover was as many as 35 species comprising SRB (25 species) and CCP (16 species). In oil palm plantation land cover, there were found 64 plant species which could be detailed as follows: in young oil palm plantation (YPO) there were 23 species, in moderate age oil palm plantation (MPO) 46 species, and in old age oil palm plantation (OPO) 34 species. Therefore, number of plant species in land cover in the form of oil palm plantation was greater than those in initial land cover in the form of SRB and CCP. In terms of their habitus, undergrowth vegetation in the form of herbs and shrubs possessed a far greater number of species as compared with those of tree habitus. The number of plant species in the oil palm plantation, as many as 64 species was a little bit higher than that in study results of reference [3] in oil palm
plantation in Sumatera, namely as many as 56 species. On the other hand, reference [2], reported that undergrowth vegetation in Dharmasraya area, West Sumatera, comprised only 39 species.

Table 1. Number of plant species in each land cover type

| Land Cover       | Species Number | Species Number | Species Number | Species Number | Species Number | Number of Spec. |
|------------------|----------------|----------------|----------------|----------------|----------------|-----------------|
|                  | Herb           | Seedling       | Sapling        | Poles          | Tree           |                 |
| Previously       | 24             | 1              | 1              | 0              | 0              | 25              |
| CCP              | 11             | 2              | 3              | 0              | 1              | 16              |
| Total            |                |                |                |                |                | 35              |
| Oil Palm         |                |                |                |                |                |                 |
| Plantation       |                |                |                |                |                |                 |
| YPO              | 22             | 0              | 0              | 0              |                | 23              |
| MPO              | 45             | 1              | 2              | 0              |                | 46              |
| OPO              | 33             | 1              | 0              | 0              |                | 34              |
| Total            |                |                |                |                |                | 64              |

Notes: SRB = Shrub, CCP = Coconut Plantation, YPO = Young Growth Oil Palm, MPO = Medium Growth Oil Palm, OPO = Old Growth Oil Palm

Undergrowth species with the highest abundance was pakis harupat or *Nephrolepis biserrata* (jalak harupat) and *Asystasia gangetica*. Species *N. biserrata* was so abundant because this species was left to grow uncontrolled (not being eradicated) by the plantation manager. The purpose of this policy was for maintaining soil surface humidity in order to keep it to remain high. According to [4], the presence of *N. biserrata* as land cover crop reduce water deficit by 51.53% at the condition of maximum water deficit in oil palm plantation land. Besides that, another contribution of *N. biserrata* was as the contributor of nutrients as large as 15.7 tons of dry matter/ha/year or 7.7 tons C/ha/year. Species *A. gangetica*, which is like *N. biserrata*, is categorized as undergrowth vegetation which can grow under the shade of oil palm. [3] found the species *A. gangetica* to be very dominant, with highest IVI in 10 years old oil palm plantation in Muaro Jambi. This made the species *A. gangetica*, which was also categorized as oil palm weeds, to be very difficult to eradicate. Other species which was also categorized as having high population were *Peperomia pellucida*, *Digitaria adscendens*, and *Stenochlaena palustris* (pakis kelakai).

Table 1 also shows that the number of plant species varies greatly between land covers. This phenomenon also resulted in varying values of Shannon-Wiener Species Diversity Index (H') and Margalef Species Diversity Index (Dmg) (figure 1). The number of species will linearly affect the value of H' and Dmg. Area of MPO with highest S (46 species) also possessed the highest value of H’ and Dmg (Dmg = 5.78 and H’ = 2.31). On the other hand, in area of CCP with smallest S (18), the value of Dmg was also smallest (2.07). The low species richness in CCP was supposed possibly due to considerably high disturbance by human activities. In figure 1, it can be seen the number of species (S) and species richness (Dmg) at various land covers.
Notes: SRB = Shrub, CCP = Coconut Plantation, YPO = Young Growth Oil Palm, MPO = Medium Growth Oil Palm, OPO = Old Growth Oil Palm, S = Number of Species, Dmg = Richness Index of Margalef, H’ = Diversity Index of Shannon-Wiener

Figure 1. Number of species and level of plant species diversity at each type of land cover.

It can be seen, in figure 1, the increase of number of plant species (S), Shannon-Wiener Species Diversity Indexes (H’) and Margalef Species Diversity Index (Dmg) due to change from bush land and coconut plantation to oil palm plantation. In young oil palm plantation (YPO), such increase of plant species diversity had not occurred, but this diversity increased in medium age oil palm plantation (MPO) or old age oil palm plantation (OPO). Therefore, in terms of plant species diversity, conversion from bush land to oil palm plantation was very positive.

3.2. Community similarity
Levels of plant community similarity between land cover types were shown by Sorensen Similarity Index (IS). The IS measure similarity of species composition between 2 types of land cover being compared. Based on measurements, there were no 2 types of land cover which possessed similarity of species composition which composed them. This appears from IS values which are all less than 0.75. The largest value of IS, namely 0.60 occurred between moderate age oil palm plantation (MPO) and old age oil palm plantation (OPO). Complete values of IS can be seen in table 2.

| Land cover | YPO | MPO | OPO | CCP | SRB |
|------------|-----|-----|-----|-----|-----|
| YPO        | 1   | 0.38| 0.56| 0.17| 0.54|
| MPO        | 1   | 0.60| 0.20| 0.25|
| OPO        | 1   | 0.27| 0.42|
| CCP        |     |     | 0.33|
| SRB        |     |     |     | 1   |

Notes: SRB = Shrub, CCP = Coconut Plantation, YPO = Young Growth Oil Palm, MPO = Medium Growth Oil Palm, OPO = Old Growth Oil Palm.

3.3. Biodiversity loss and gain
In the change from bush land to oil palm plantation there was loss of plant species, while at the same time, there was gain of plant species, while also there were plant species which were found in both types of land cover being compared (table 3). In medium age oil palm plantation (MPO), number of plant species obtained (gain) was categorized as high, namely as many as 34 species or as large as
261.54 %, and the lowest was found in young age oil palm plantation (YPO) which was only 10 species or as large as 76.92%. On the whole, within the area of oil palm plantation (POP), there were 44 plant species being obtained or as large as 244.44%, with only 7 plant species being lost, or as large as 38.89%.

Table 3. Loss and gain of species biodiversity between bush land and oil palm plantation.

| SRB | YPO | MPO | OPO  | POP  | Loss | Gain | Similar | % Loss | % Gain |
|-----|-----|-----|------|------|------|------|---------|--------|--------|
| 25  | 23  | 25  | 12   | 10   | 13   | 92.31| 76.92   |        |        |
| 25  | 47  | 25  | 11   | 22   | 14   | 78.57| 157.14  |        |        |
| 59  | 7   | 36  | 18   | 34   | 13   | 92.31| 261.54  |        |        |

Notes: SRB = Shrub, YPO = Young Growth Oil Palm, MPO = Medium Growth Oil Palm, OPO = Old Growth Oil Palm, POP = Palm Oil Plantation

The change from coconut plantation to oil palm plantation also exhibited plant species loss, and gain in plant species, as well as plant species which were found in both types of land cover being compared (table 4). Number of plant species obtained (gain) was categorized as high in medium age oil palm plantation (MPO), namely as many as 38 species or 422.22%, while the lowest was found in young age oil palm plantation (YPO) namely as many as 15 species or as large as 187.50%. On the whole, within the area of oil palm plantation (POP), there were 52 plant species being obtained or as large as 520.00%, with only 6 plant species being lost or as large as 60%.

Number of obtained plant species (gain) due to change from coconut plantation to oil palm plantation (52 species) was greater than that of change from bush land to oil palm plantation (44 species).

Table 4. Loss and gain of species diversity between coconut plantation and oil palm plantation

| CCP | YPO | MPO | OPO | POP | Loss | Gain | Similar | % Loss | % Gain |
|-----|-----|-----|------|------|------|------|---------|--------|--------|
| 16  | 23  | 16  | 8    | 15   | 8    | 100.00| 187.50  |        |        |
| 16  | 47  | 16  | 7    | 38   | 9    | 77.78 | 422.22  |        |        |
| 16  | 36  | 16  | 6    | 52   | 10   | 60.00 | 520.00  |        |        |
| 62  | 18  | 25  | 12   | 22   | 14   | 78.57 | 157.14  |        |        |

Notes: CCP = Coconut Plantation, YPO = Young Growth Oil Palm, MPO = Medium Growth Oil Palm, OPO = Old Growth Oil Palm

4. Conclusion
Change of land cover from bush land and coconut plantation to oil palm plantation had a positive impact, namely increase in plant biodiversity. This was indicated by the following phenomena:

1. Number of plant species in oil palm plantation was 2.5 and 4 times greater than in bush land and that of coconut plantation respectively.
2. Change of land cover from bush land to oil palm plantation obtained a gain of 44 species of plants (244.44%) and loss of 7 species (38.89%).
3. Change of land cover from coconut plantation to oil palm plantation obtained a gain of 52 species of plants (520%) and loss of 6 species (60%).

References
[1] Direktur Jenderal Kementerian Pertanian. 2018. Industri Kelapa Sawit Berkontribusi Besar terhadap Ekonomi
[2] Kusuma S. 2007. Penentuan Bentuk dan Luas Plot Contoh Optimal Pengukuran Keanekaragaman Spesies Tumbuhan pada Hutan Hujan Dataran Rendah: Studi Kasus di TN Kutai. [Tesis] Sekolah Pascasarjana IPB
[3] Hutwan S, Novianti S, Adriani A. 2017. Analisis Indeks Kepekaan Ekologi terhadap Hijauan Pakan di Bawah Perkebunan Kelapa Sawit. Jurnal Ilmu-Ilmu Peternakan Vol. 20 No.1: 25-32. eISSN: 2528 0805 pISSN: 1410 7791

[4] Purwantari ND. 2016. Sumberdaya Genetik Tanaman Pakan Ternak Toleran Naungan. WARTAZOA Vol. 26 No.2 Th 20016 Hal. 051-056

[5] Rahmadayanti R, Nursyahra, Rizki. 2016. Komposisi Vegetasi Dasar pada Perkebunan Kelapa Sawir di Trimulya, Kecamatan Timpeh, Kabupaten Dhramasraya. STKIP PGRI Sumatera Barat

[6] Ariyanti M. 2016. Peranan Tanaman Penutup Tanah Nephrolepis biserrata pada Teknik Konservasi Tanah dan Air terhadap Neraca Air di Perkebunan Kelapa Sawit. [Thesis] Sekolah Pascasarjana IPB