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Diversity of butterflies (Lepidoptera) across rainforest transformation systems in Jambi, Sumatra, Indonesia

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Abstract. *Panjaitan R, Drescher J, Buchori D, Peggie D, Harahap IS, Scheu S, Hidayat P. 2020. Diversity of butterflies (Lepidoptera) across rainforest transformation systems in Jambi, Sumatra, Indonesia. Biodiversitas 21: 5119-5127.* The high rate of land conversion has put pressure on biodiversity, especially in the tropics. The lowlands of Sumatra, for example, are dominated by increasingly extensive areas of oil palm and rubber monoculture plantations, while rainforests are continuously vanishing. The status of many rainforest animal populations, including iconic insect groups such as butterflies, is largely unclear. With a rapid assessment approach, we studied butterflies along land-use gradients from lowland rainforest, via jungle rubber plantations (rubber agroforest system), to monocultures of rubber and oil palm in Jambi Province, Sumatra. Butterflies were caught in a nested replication design at eight research plots at each of the forest, jungle rubber, and rubber and oil palm locations. Butterfly abundance was the highest in the rainforest (204.3±82.1), slightly lower in the jungle rubber and oil palm areas (164.9±61 and 169.3±94.9, respectively), and the lowest in the rubber plantation (108.8±38.5). Similarly, butterfly species richness was the highest in the forest and jungle rubber areas (47.1±7.7 and 38.8±7.6, respectively), followed by the oil palm area (33.3±9.8), and the lowest in the rubber plantation (26.1±9.1). Likewise, Shannon-Wiener diversity was the highest in the rainforest, at an intermediate level in the jungle rubber, and lowest in the oil palm and rubber plantations. Butterfly community composition in the rainforest was very different from that in the other three land-use systems, in which it was similar. Overall, the study demonstrates that rainforest butterfly communities cannot be sustained in agricultural systems, highlighting the importance of rainforests for conserving the diversity of arthropods.

Keywords: Sumatra, butterflies, rainforest transformation, EFForTS project

INTRODUCTION

Large areas of rainforest in Indonesia have been and are still being converted to agricultural systems (Sodhi et al. 2010; Peggie 2014). This process is largely driven by population growth and increased demand for agricultural goods (Morris et al. 2014; Wheeler et al. 2013). In Sumatra, rainforests are mostly converted into monoculture plantations of rubber and oil palm (Drescher et al. 2016), resulting in a profound impact on biodiversity (Teuscher et al. 2016) due to the homogenization of ecosystem structures (Sodhi et al. 2010; Teuscher et al. 2016). Deforestation and forest degradation cause habitat loss, fragmentation, and species isolation (Wheeler et al. 2013). Therefore, comprehensive understanding is needed on how to design and manage landscapes that mitigate biodiversity loss while at the same time maintain the provision of agricultural goods (Gray et al. 2019).

Insects have become one of major biodiversity elements to use in research to understand the diversification of tropical forests that have high biodiversity (Azhar et al. 2011; Alexander and DeVries 2012). Among insects, butterflies are considered as charismatic fauna, making them the most intensively studied arthropod groups in the tropics. Their taxonomical information is relatively well described, in contrast to other insect groups that have a high proportion of unknown species. Butterflies are of significant importance as pollinators (Fukano et al. 2016), and serve as food for birds, bats, and other vertebrates, but their larvae are also recognized as agricultural pests. Due to their ease of visual identification, and the fact that host plants are often known, butterflies have been proposed as a model insect group for the rapid assessment of biodiversity (Kumar 2013; Koneri and Maabuat 2016). The presence of butterflies can also illustrate how butterfly communities and their environmental interactions can be used to assess the functioning of an ecosystem and conservation efforts (Fenner et al. 2018).

Previous studies have shown that land-use change in Southeast Asia is associated with changes in butterfly community composition (Mukherjee et al. 2015), with higher butterfly richness in rainforests than in plantations (Hantson and Baz 2013; Rusman 2015). However, detailed studies based on straightforward experimental design are lacking especially for butterfly research.

We studied the abundance, species richness, and community composition of butterflies across land-use gradients from lowland rainforest, via jungle rubber plantations (rubber agroforestry systems with extensively cultivated rubber and a high proportion of forest tree species), to monoculture plantations of rubber and oil palm in Jambi Province, Sumatra, Indonesia. Based on previous works in the region (Drescher et al. 2016; Grass et al. 2020), we expected butterfly abundance and species richness to be highest in the lowland rainforest, and lowest in the monoculture plantations of rubber and oil palm, with abundance and richness in the jungle rubber areas being at an intermediate level.

MATERIALS AND METHODS

Study area and period

The study was conducted in and around two rainforest reserves, the Bukit Duabelas National Park and Harapan Rainforest in Jambi Province, Sumatra, Indonesia (Figure 1), from July to October 2017. We counted and collected butterflies from four types of land-use: lowland secondary rainforest (henceforth referred to as forest), jungle rubber, and monoculture rubber plantation, and monoculture oil palm plantation. We used the nested, replicated core plot design established by the EFForTS project (Drescher et al. 2016), which consisted of eight 50x50 m plots in each of the four land-use systems. In total, we collected butterflies from 32 plots.

Procedures

Collection and observation of the butterflies were conducted by direct surveys using a scan sampling method. Butterflies were collected using sweep netting on three parallel transects per core plot, with two transects located on the outer borders of the core plots, and the third located through their center. Catching butterflies used insect nets in the plot for two days per plot. Observations were conducted in the morning (8:00-11:00 am) and afternoon (13:00-16:00 pm). All the butterflies were released after identification in the evening of the sampling day, with the exception of up to two individuals that were dried/mounted and five individuals that were preserved in 99% ethanol per species for the purpose of species identification and further analysis. Identification and preservation of the specimens were carried out at the Insect Biosystematic Laboratory, at the Department of Plant Protection and the Entomology Laboratory, Zoology Centre, Biology Research Center LIPI, Cibinong. Identification was based on the procedures of D'Abrera (1990) and Seki et al. (1991). A visual field guide of all the butterfly species encountered is available at https://www.uni-goettingen.de/de/handbooks+ and+guides /605977.html.

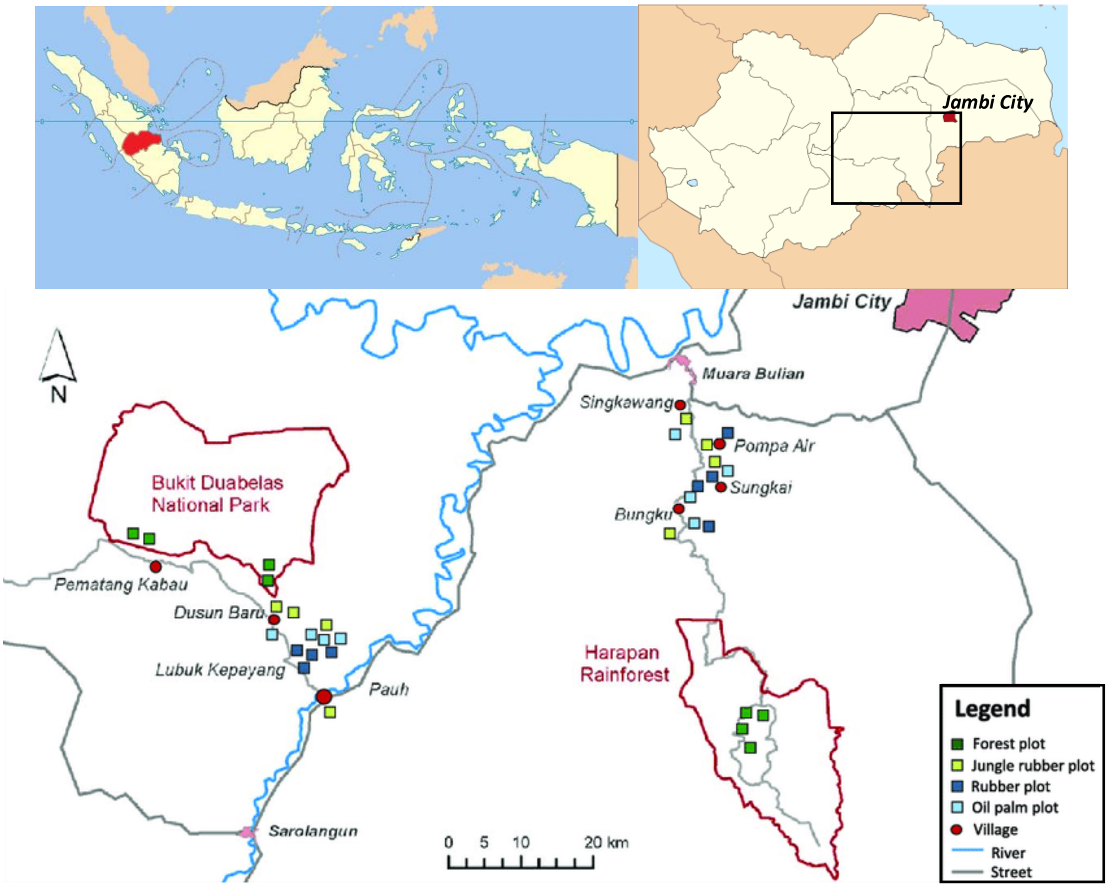

Figure 1. Map of research locations in the Bukit Duabelas National Park and Harapan Rainforest, Jambi, Indonesia (Drescher et al. 2016)

Data analysis

We first compared butterfly abundance in the four land-use systems using Waller-Duncan analysis. Butterfly diversity is expressed as the number of species, and additionally calculated as the Shannon-Wiener diversity index (H') and Simpson index (D). We tested for differences between species richness among the four land-use systems using Waller-Duncan analysis. Non-metric multidimensional scaling (NMDS) based on Bray Curtis distances was employed to visualize the community composition of butterflies in each land-use system. We then tested for statistical differences in community composition among the land-use systems by Analysis of Similarity (ANOSIM). All of the above were calculated using the vegan package in R 3.0.2 (Hothorn and Everitt 2009). A cumulative analysis of species overlap among the land-use systems was prepared as a Venn diagram, as can be seen at https://bioinfogp.cnb.csic.es/tools/venny/.

RESULTS AND DISCUSSION

Diversity of butterflies in the four land-use systems

A total of 5177 individuals consisting of 187 species from 19 sub-families and five families (Lycaenidae, Nymphalidae, Papilionidae, Pieridae, and Riodinidae) were recorded. The butterfly species found were the most from the Nymphalidae family compared to other families. Research conducted by other studies in Sumatra also found the Nymphalidae family to be the most dominant family (Estalita and Basukriadi 2012; Chahyadi and Bibas 2016). Butterfly species richness was the highest in the forest and jungle rubber locations (S_F = 47.1±7.7 and S_J = 38.8±7.6), followed by the oil palm plantations (S_O = 33.3±9.8), and lowest in the rubber plantations (S_R = 26.1±9.1). Species richness also varied significantly according to land-use (F = 8.54, P = 0.0003; Figure 2). Abundance was the highest in the rainforest (204.3±82.1), the lowest in the rubber plantations (169.3±94.9), and intermediate in the jungle rubber (164.9±6) and oil palm plantations (108.8±38.5) (F = 2.38, P = 0.0905; Figure 3). It declined in an almost linear way from rainforest, to jungle rubber, oil palm, and rubber plantations. Similarly, the Shannon-Wiener diversity (H') of butterfly species was the highest in the rainforests (4.1), slightly lower in the jungle rubber areas (3.9), and distinctly lower in the rubber (3.5) and oil palm plantations (3.4). The Simpson index followed a very similar pattern, but was equally high in the rainforest (0.97) and jungle rubber (0.96) areas.

The high diversity of butterflies in the rainforests is presumably related to their more heterogeneous structure, but also to the higher plant diversity compared to the other land-use systems (Rembold et al. 2017; Brown and Crone 2016). Harmonis and Saud (2017) also showed that butterfly diversity is higher in forests compared to degraded habitats. Generally, the presence of butterflies is highly correlated with the presence of host plants, which are used by the imago to lay eggs and on which caterpillars can then feed. Therefore, the transformation of plant communities will affect the biodiversity of butterflies (Nidup et al. 2014). Surprisingly, however, the decline in butterfly species with the transformation of rainforests into plantations was much less steep than that of plant species. At our study sites, the total number of plant species in the rainforests, and jungle rubber, oil palm, and rubber plantations were 963, 652, 219, and 230, respectively (Rembold et al. 2017); that is, compared to the rainforests there were only around 23% of the number of plant species in the oil palm and rubber plantations. This presumably reflects the fact that butterfly caterpillars often feed on a number of plant species, typically of the same genus or family of plants (Fukano et al. 2016). Furthermore, however, in particular, in the oil palm and rubber plantations, butterfly species richness may benefit from immigration from adjacent habitats. In fact, the landscape configurations that connect forest patches maintain more diverse butterfly communities than those with only monoculture plantations (Gilbert 2012).

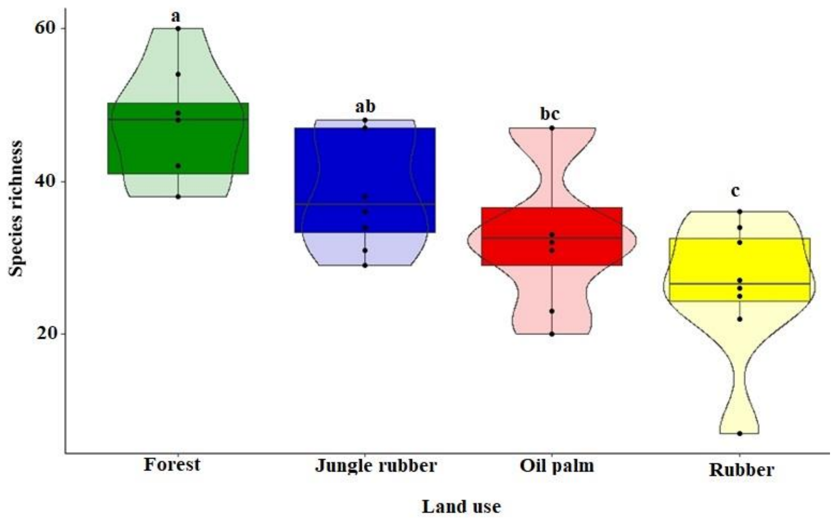

Figure 2. Species richness of butterflies in the four land-use systems studied, using the Waller-Duncan test with F: 8.54 and a P-value of 0.0003. Note: the difference in letters indicates a significant difference between land-uses; The box shape describes the values of Q1, Q2 (mean), and Q3; violin shape (middle box accompanied by dots) shows the distribution of data on each land-use

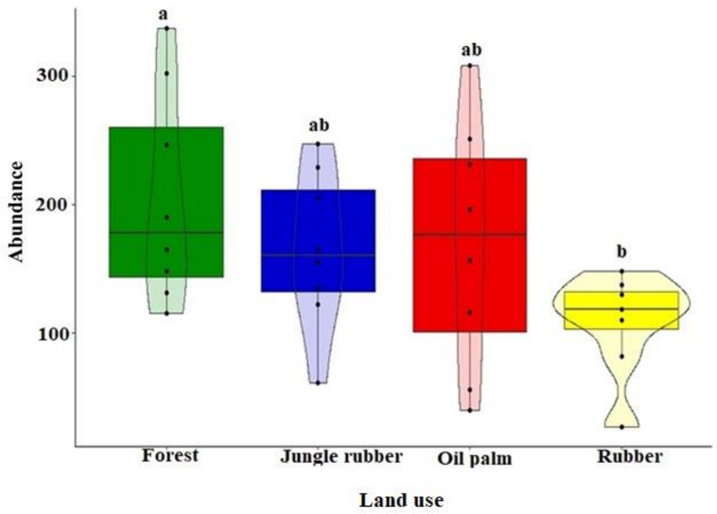

Figure 3. Abundance of butterflies in the rainforests, and jungle rubber, rubber, and oil palm plantations; means ± SD. Note: the difference in letters shows significant differences between land-uses. The box shape describes the values of Q1, Q2 (mean), and Q3; violin shape (middle box accompanied by dots) shows the distribution of data on each land-use

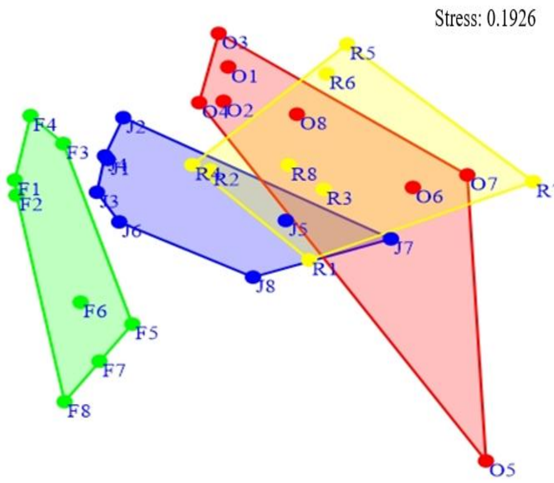

Figure 4. NMDS of butterfly community composition in the rainforest (F, green), jungle rubber (J, blue), rubber (R, yellow), and oil palm plantations (O, red), based on Bray Curtis distances

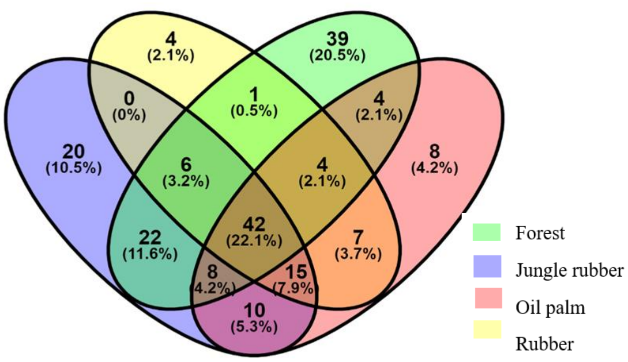

Figure 5. Similarity in butterfly species composition in the four types of land-use

NMDS separated the rainforest butterfly communities from those of each of the other land-use systems. Furthermore, jungle rubber communities were separated from those of the oil palm and rubber plantations, but the latter overlapped widely (Figure 4). It is likely that the differences reflect the differences in habitat structure and plant community composition in the four land-use systems and are related to food, i.e. host plants, but also to the abiotic variables related to canopy openness. In fact, microclimatic conditions in oil palm and rubber plantations differ markedly from those in rainforest and jungle rubber areas (Meijide et al. 2018). The similarity in butterfly species composition between land-uses is based on the Bray Curtis index (stress value: 0.1924; Anosim R_1: 0.66; R_2: 0.16), which is considered more relevant to illustrate the relationship with the characteristics of each land-use compared to simply the number of butterfly species. Diverse vegetation will enable butterflies to vary. The difference in the composition of vegetation in different land-uses is thought to be the cause of differences in the composition of butterflies found there. In oil palm and rubber plantations, vegetation is more homogeneous compared to that in forest and jungle rubber locations. Transforming forests into monoculture plantations has a negative impact on species diversity in all taxons (Grass et al. 2020). The forest transformation that has occurred in Sumatra has negatively affected species richness (Barnes et al. 2014), and it has been proven in this study that the diversity of butterflies was lower compared to that in the oil palm and rubber plantations.

The Venn diagrams illustrate that there were similarities among the land-use systems, but also there were unique species in each of these (Figure 5; Table 1).

Table 1. List of butterfly species found in four land-use systems in the studied area

Family/Subfamily/Species	Forest	Jungle rubber	Oil palm	Rubber
Lycaenidae				
Curetinae				
Curetis tagalica Felder, 1862	√	√	-	-
Curetis freda Eliot, 1959	√	-	-	-
Miletinae				
Allotinus substrigosus Moore, 1884	√	√	-	-
Allotinus unicolor Felder & Felder, 1865	√	√	-	-
Logania marmorata Moore, 1884	-	√	√	-
Miletus gaetulus de Niceville, 1894	√	√	√	√
Miletus gopara de Niceville, 1890	-	√	-	-
Spalgis epius (Westwood, 1851)	-	√	-	-
Polyommatinae				
Acytolepis puspa (Horsfield, 1828)	-	-	√	-
Anthene licaenina (Felder, 1868)	√	-	-	-
Caleta elna (Hewitson, 1876)	√	-	-	-
Discolampa ethion (Westwood, 1851)	-	-	-	√
Euchrysops cnejus (Fabricius, 1798)	-	-	√	-
Everes lacturnus (Godart, [1824])	√	-	√	-
Jamides alecto Felder, 1860	√	√	√	√
Jamides celeno (Cramer, 1775)	√	√	√	√
Jamides talinga Kheil, 1884	-	√	-	-
Jamides caeruleus Druce, 1873	-	√	√	-
Jamides philatus Snellen, 1878	-	-	√	-
Lycaenopsis haraldus (Fabricius, 1787)	√	-	-	-
Nacaduba kurava (Moore, 1857)	√	√	√	√
Nacaduba calauria (Felder, 1860)	-	√	-	-
Neopithecops zalmora (Butler, 1870)	-	√	-	-
Prosotas gracilis (Röber, 1886)	√	√	-	-
Zizula hylax (Fabricius, 1775)	-	-	√	√
Poritiinae				
Poritia sumatrae (Felder & Felder, 1865)	√	√	-	-
Theclinae				
Arhopala agesias Hewitson, 1862	√	√	-	√
Arhopala agesilaus Staudinger, 1889	√	√	-	-
Arhopala paraganesa (de Niceville, 1882)	√	√	-	-
Cheritra freja (Fabricius, 1793)	√	-	-	-
Dacalana vidura (Horsfield, 1828)	√	-	-	-
Deudorix epijarbas (Moore, 1858)	√	√	-	-
Drupadia niasica (Rober, 1886)	√	√	-	-
Drupadia ravindra (Horsfield, 1829)	√	√	√	√
Eliotia jalindra (Horsfield, 1829)	√	-	-	-
Eooxylides tharis (Geyer, 1837)	√	√	√	√
Flos fulgida (Hewitson, 1863)	-	√	-	-
Iraota rochana (Horsfield, 1829)	-	-	√	-
Loxura atymnus (Cramer, 1780)	√	-	-	-
Rapala dieneces (Hewitson, 1878)	√	√	√	-
Rapala domitia (Hewitson, 1863)	√	-	-	-
Rapala manea (Hewitson, 1863)	√	√	√	-
Rapala rhodopis de Nicéville, 1896	√	-	-	-
Sithon nedymond (Cramer, 1782)	-	√	√	√
Spindasis lohita (Horsfield, 1829)	-	√	-	-
Surendra vivarna (Hewitson, 1829)	√	-	-	√
Thamala marciana (Hewitson, 1863)	√	-	-	-
Nymphalidae				
Apaturinae				
Eulaceura osteria (Westwood, 1850)	√	√	-	√
Euripus nyctelius (Doubleday, 1845)	√	√	-	-
Biblidinae				
Laringa castelnaui (Felder, 1860)	-	√	-	-
Laringa horsfieldi (Boisduval, 1833)	√	-	-	-
Charaxinae				
Agatasa calydonia (Hewitson, 1855)	√	√	-	-
Charaxes bernardus (Fanricius, 1793)	√	√	√	√

Charaxes durnfordi Distant, 1884	√	-	-	-
Charaxes (Polyura) hebe (Butler, 1865)	√	-	√	√
Charaxes solon (Fabricius, 1793)	-	√	-	-
Prothoe franck (Godart, [1824])	√	√	-	-
Cyrestinae				
Chersonesia rahria (Moore, {1858])	√	√	-	-
Dichorragia nesimachus (Boisduval, 1836)	√	-	-	-
Danainae				
Danaus genutia (Cramer, [1779])	√	-	-	-
Danaus melanippus (Cramer, [1777])	-	√	√	√
Euploea algea (Godart, [1819])	√	-	-	-
Euploea crameri Lucas, 1853	-	√	√	√
Euploea mulciber (Cramer, [1777])	√	√	√	√
Euploea phaenareta (Schaller, 1785)	√	√	√	√
Euploea radamanthus (Fabricius, 1793)	√	-	-	-
Idea lynceus (Drury, 1773)	√	√	-	-
Ideopsis gaura (Horsfield, [1829])	√	√	√	-
Ideopsis juventa (Cramer, [1777])	√	√	√	√
Ideopsis vulgaris (Butler, 1874)	√	√	-	√
Parantica aspasia (Fabricius, 1787)	√	√	√	√
Parantica luzonensis (Felder & Felder, 1863)	√	-	-	-
Heliconiinae				
Acraea terpsicore (Linnaeus, 1758)	-	√	√	√
Cethosia hypsea Doubleday, 1847	√	√	√	√
Cirrochroa emalea (Guérin-Méneville, 1843)	√	√	-	-
Cupha erymanthis (Drury, 1773)	√	√	√	√
Cupha orissa Felder, 1860	√	-	-	-
Terinos terpander Hewitson, 1862	√	√	√	-
Vindula erota (Fabricius, 1793)	√	√	√	-
Limenitidinae				
Athyma kanwa (Moore, 1858)	√	√	√	√
Athyma bravura (Moore, 1858)	√	√	-	-
Athyma perius (Linnaeus, 1758)	√	-	√	√
Athyma reta (Moore, 1858)	√	-	-	-
Bassarona dunya (Doubleday, 1848)	√	-	-	-
Bassarona teuta (Doubleday, 1848)	√	-	-	-
Dophla evelina (Stoll, 1790)	√	√	-	√
Euthalia adonia (Cramer, 1782)	-	-	√	√
Euthalia agnis Vollenhoven, 1862	-	-	√	-
Euthalia alpheda Godart, 1823	√	√	√	√
Euthalia kanda Moore, 1859	-	-	-	√
Euthalia mahadeva Moore, 1859	-	√	√	√
Euthalia merta Moore, 1859	-	√	-	-
Euthalia monina (Fabricus, 1787)	-	√	√	√
Euthalia whiteheadi Grose-Smith, 1889	-	-	√	-
Lasippa tiga (Moore, 1858)	√	√	√	√
Lebadea martha (Fabricius, 1787)	√	√	-	-
Lexias pardalis Moore, 1878	√	√	√	√
Moduza procris (Cramer, 1777)	√	√	√	√
Neptis harita Moore, 1875	-	-	√	-
Neptis hylas (Linnaeus, 1758)	√	√	√	√
Neptis nata Moore, 1857	√	√	√	√
Pandita sinope Moore, 1858	√	-	√	√
Pantoporia aurelia Staudinger, 1886	√	-	-	-
Tanaecia coelebs Corbet, 1941	√	√	√	√
Tanaecia elone de Niceville, 1893	√	√	√	√
Tanaecia palguna (Moore, 1857)	√	√	√	√
Tanaecia pelea (Fabricius, 1787)	√	√	√	-
Morphinae				
Amathusia binghami Fruhstorfer, 1904	√	√	√	√
Amathusia perakana Honrath, 1888	√	√	√	√
Amathusia schoenbergi Honrath, 1888	√	-	-	-
Discophora necho Felder, 1866	-	√	-	-
Faunis canens Hübner, 1826	√	√	√	√
Faunis gracilis Butler, 1867	√	-	-	-
Faunis kirata de Nicéville, 1891	√	-	-	-
Thaumantis klugius Zinken-Somer, 1831	√	√	-	-

Thaumantis noureddin Westwood, 1851	-	√	-	-
Zeuxidia amethystus Butler, 1865	√	-	-	-
Zeuxidia doubledayi Westwood, 1851	√	-	-	-
Nymphalinae				
Ariadne ariadne (Linnaeus, 1763)	√	-	√	-
Doleschallia bisaltide (Cramer, 1779)	-	-	√	√
Hypolimnas bolina (Linnaeus, 1758)	-	√	√	√
Junonia almana (Linnaeus, 1758)	-	√	√	-
Junonia atlites (Linnaeus, 1763)	-	√	√	-
Junonia hedonia (Linnaeus, 1764)	-	-	√	√
Junonia orithya (Linnaeus, 1764)	-	√	√	√
Satyrinae				
Coelites epiminthia Westwood, 1850	√	√	-	-
Coelites euptychioides Felder, 1867	√	-	-	-
Elymnias hypermnestra (Linnaeus, 1763)	-	√	√	√
Elymnias nesaea (Linnaeus , 1758)	-	√	√	√
Elymnias panthera (Fabricius, 1787)	√	√	√	√
Elymnias penanga (Westwood, 1851)	√	-	-	-
Erites argentina Butler, 1868	√	√	-	-
Lethe mekara Moore, 1857	√	-	√	-
Melanitis leda (Linnaeus, 1758)	-	√	√	-
Melanitis phedima (Cramer, 1782)	-	√	√	√
Mycalesis anapita Moore, 1857	√	√	√	√
Mycalesis dohertyi Elwes, 1891	√	√	-	√
Mycalesis fusca Felder, 1860	√	√	√	√
Mycalesis horsfieldi Moore, 1880	-	√	√	-
Mycalesis janardana Moore, 1857	-	√	-	-
Mycalesis maianeas Hewitson, 1864	√	-	√	-
Mycalesis mineus (Linnaeus, 1758)	√	√	√	√
Mycalesis mnasicles Hewitson, 1864	√	-	-	-
Mycalesis marginata Moore, 1881	√	-	-	-
Mycalesis orseis Hewitson, 1864	-	√	√	√
Mycalesis oroatis Hewitson, 1864	-	√	√	-
Mycalesis perseus (Fabricius, 1775)	-	√	√	√
Neorina lowii (Doubleday, 1849)	√	-	-	-
Orsotriaena medus (Fabricius, 1775)	-	√	√	-
Ragadia crisilda de Nicéville, 1890	√	√	-	-
Ragadia makuta Fruhstorfer, 1911	-	√	-	-
Ypthima nebulosa Aoki &Uemura, 1892	√	-	-	-
Ypthima philomela (Linnaeus, 1763)	-	-	√	√
Ypthima horsfieldii Moore, 1884	√	√	√	√
Papilionidae				
Papilioninae				
Atrophaneura priapus (Boisduval, 1836)	-	√	-	-
Graphium agamemnon (Linnaeus, 1758)	√	√	√	√
Graphium (Pathysa) antiphates (Cramer, 1775)	-	√	√	-
Graphium eurypylus (Linnaeus, 1758)	-	√	-	-
Graphium ramaceus Westwood, 1872	-	-	-	√
Graphium sarpedon (Linnaeus, 1758)	√	√	√	-
Pachliopta antiphus (Fabricius, 1793)	√	-	√	√
Papilio demoleus Linnaeus, 1758	-	√	√	√
Papilio demolion Cramer, [1776]	√	√	√	√
Papilio helenus Linnaeus, 1758	-	√	-	-
Papilio iswaroides Fruhstorfer, 1898	√	√	-	-
Papilio memnon Linnaeus, 1758	√	√	√	√
Papilio nephelus Boisduval, 1836	√	√	√	√
Papilio polytes Linnaeus, 1758	√	√	√	√
Trogonoptera brookiana (Wallace, 1855)	√	-	-	-
Troides amphrysus (Cramer, [1779])	√	-	-	-
Pieridae				
Coliadinae				
Catopsilia pomona (Fabricius, 1775)	-	-	√	√
Catopsilia scylla (Linnaeus, 1763)	-	-	√	√
Eurema alitha (Felder & Felder, 1862)	√	√	√	-
Eurema hecabe (Linnaeus, 1758)	√	√	√	√
Eurema simulatrix Staudinger, 1891	√	√	√	√
Gandaca harina (Horsfield, 1829)	√	√	√	√

Pierinae				
Appias olferna (Swinhoe, 1890)	-	√	√	√
Appias pandione Geyer, 1832	√	-	-	-
Leptosia nina (Fabricius, 1793)	√	√	√	√
Riodinidae				
Nemeobiinae				
Abisara echerius (Stoll, 1790)	√	√	√	√
Abisara savitri (Felder & Felder, 1860)	√	-	-	-
Paralaxita orphana (Boisduval, 1836)	√	√	√	√
Taxila haquinus (Fabricius, 1793)	-	√	√	-
Zemeros emesoides Felder & Felder, 1860	√	√	-	√
Zemeros flegyas (Cramer, 1780)	-	-	-	√

Note: √: Present; -: Absent

In the rainforests, as many 39 species (20%) were only found in this land-use system; these are unique species and indeed live in heterogeneous forests. For example, *Trogonoptera brookiana* and *Troides amphrysus* are species that are only found in the forest. Both species are protected in Indonesia, based on government regulations on the protection of plants and animals in Indonesia No p20 of 2018 and are classified as "near threatened" by the IUCN Red List (IUCN 2020). The existence of species that can only be found in specific habitats is related to feed availability. The diversity of plants found in heterogeneous forests (Rembold et al. 2017) supports the high diversity of butterflies in that land-use system. Research conducted by Nyafwono et al. (2014) also concluded that some specialist species of butterflies are particularly attracted to heterogeneous forests because they are supported by host plant biomass and imago feed, so these butterflies can be used as indicators of forests. Butterfly species only found in the jungle rubber plantations included which 20 species. The function of land-use systems as a rubber plantation, also has species that are only found in the garden as many as four species. 42 species were found in the four land-uses (Figure 5; Table 1). The same butterfly species found across the four land-uses (42 species) is a species commonly found in settlements and has a wide distribution (D'Abrera 1990).

Differences in diversity and the abundance of butterflies in forests and plantations indicate that they are sensitive to changes in land-use (Gilbert 2012). In fact, butterflies are sensitive to changes in both abiotic environmental conditions (Hantson and Baz 2013; Molina-Martínez et al. 2016) and also plant community composition and other biotic factors (Nyafwono et al. 2014). One factor that makes butterflies as an indicator of environmental quality is that their presence is closely related to the plant species found in ecosystems (Hantson and Baz 2013). The higher the plant diversity found in ecosystems, the higher the corresponding diversity of butterflies (Hantson and Baz 2013), which may be due to the complexity of different land-uses (Hector et al. 2011; Molina-Martínez et al. 2016). Graça et al. (2017) found that the composition of butterflies in forests was different and higher compared to garden habitats in the tropics.

The conclusion from the results of this study is that different land-use results in differences in the wealth and abundance of butterflies. Forests are complex ecosystems and support a high diversity of butterflies compared to gardens. Butterflies are important as pollinators and environmental indicators, and play a role in the food chain, so it is important to maintain their presence in their habitat.

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