Agr. Nat. Resour. 56 (2022) 925–934

AGRICULTURE AND NATURAL RESOURCES

Journal homepage: http://anres.kasetsart.org

Research article

Comparison of butterfly communities between agroecosystems and dipterocarp forest in Khon Kaen province, Thailand

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Article Info

Article history:
Received 12 May 2022
Revised 12 July 2022
Accepted 31 July 2022
Available online 12 October 2022

Keywords:
Agroecosystem,
Butterfly,
Butterfly community,
Environmental factor,
Land conversion

Abstract

Importance of the work: Tropical forest areas in Southeast Asia have been extensively converted to other land uses. However, the impact of land conversion on butterfly diversity in this region has not been well studied.

Objectives: To assess the impacts of land conversion on butterfly community assemblages by comparing butterfly diversity in dipterocarp forest and two agroecosystems

Materials & Methods: Butterfly diversity was surveyed using belt transects and data on environmental factors that might be associated with butterfly distribution in the dipterocarp forest in Khok Phutaka, Khon Kaen province and in two adjacent agroecosystems (open areas and rubber tree plantations).

Results: In total, 685 individual butterflies of 56 butterfly species were collected. The butterfly species richness and the Shannon-Wiener species diversity index were highest in the open areas, whereas the number of butterflies collected was highest in the rubber plantations. The dissimilarity of butterfly species assemblages was greatest between the dipterocarp forest and the other habitat types. The constrained correspondence analysis (CCA) revealed that six environmental factors (elevation, air temperature, litter depth, tree density, tree diversity and degree of human disturbance) were associated with butterfly species distribution. Elevation-human disturbance and tree diversity-litter depth gradients were observed in the ordination diagram biplot from the CCA.

Main finding: Habitat conversion from dipterocarp forests to agroecosystems does not always lead to a decrease in butterfly diversity, but it does result in a change in butterfly community assemblages.

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https://doi.org/10.34044/j.anres.2022.56.5.07

Introduction

Southeast Asia is a global biodiversity hotspot with a high level of endemism. However, over the past 30 yr, tropical forest areas in this region have rapidly been converted for other land uses, such as agricultural or urban development (Food and Agriculture Organization of the United Nations, 2016). Now, the region is also one of the most biotically threatened on earth and agricultural intensification has resulted in the widespread loss of biodiversity (Hughes, 2017). Land conversion, species introductions and human disturbance can affect ecosystem structure and composition. In many cases, agricultural ecosystems (agroecosystems) have been created. Agroecosystems are a model for investigating the impacts of humans on wildlife and ecosystems because species compositions in agroecosystems have been altered from the original ecosystem both by human activities and natural processes (Perfecto and Vandermeer, 2015). Studying this model should enable the creation of suitable ecological planning for the conservation of biodiversity.

Butterflies are a group of pollinators that provide important ecosystem services, not only for natural plants, but also for crop plants (Steffan-Dewenter et al., 2005). Furthermore, they provide other essential ecosystem services, such as nutrient recycling in ecosystems (Munyuli, 2012) and food for animals and humans (Chaianunporn and Khoosakunrat, 2018). However, most butterfly larvae feed on living plants and some butterfly caterpillar species can be agricultural pests (Ryan et al., 2019). Several studies have shown that butterflies are good indicators of environmental changes and the impacts of anthropogenic activities because they are sensitive to ecosystem changes, especially land use changes (Koh and Sodhi, 2004; Schulze et al., 2004; Schneider and Fry, 2005; Rundlof and Smith, 2006; Koh, 2007; Öckinger et al., 2009; Jonason et al., 2010; Meehan et al., 2013; Jew et al., 2015; Chaianunporn and Chaianunporn, 2019).

The dipterocarp forest in Khok Phutaka in Khon Kaen province, Thailand, is representative of dipterocarp forests in northeastern Thailand (Kesonbua and Chantaranothai, 2011). It was part of the Phu Khieo-Nam Nao Forest Complex. However, areas surrounding the forest have been converted to agricultural landscapes and the dipterocarp forest remains only on a small hill named Khok Phutaka. At present, although it is not directly connected, one side of the forest is close to Phu Wiang National Park. In 1995, the Khok Phutaka area became a protected area under the Plant Genetic Conservation Project under the Royal Initiative of Her Royal Highness Princess Maha Chakri Sirindhorn (Kesonbua and Chantaranothai, 2011). The structure of the Khok Phutaka area provides a comparison of butterfly communities in the dipterocarp forest with those in agroecosystems surrounding the forest. For further understanding of the effects of land use change on butterfly communities, butterflies in the dipterocarp forest, open areas along sugarcane plantations or rice fields and rubber plantations were surveyed and the species compositions in different land use areas were compared. The environmental factors in dipterocarp forests and agricultural environments were also examined to determine which factors might be associated with butterfly distribution. The results reflect the effects of converting dipterocarp forest to agricultural areas on butterfly communities and highlight the importance of land management for conserving butterfly diversity.

Materials and Methods

Study site

Khok Phutaka (16.642827N, 102.292327E; Fig. 1) is located in Wiang Kao district, Khon Kaen province, Thailand. The area of dipterocarp forest in Khok Phutaka is approximately 113 ha. The forest has been isolated from the Phu Wiang National Park

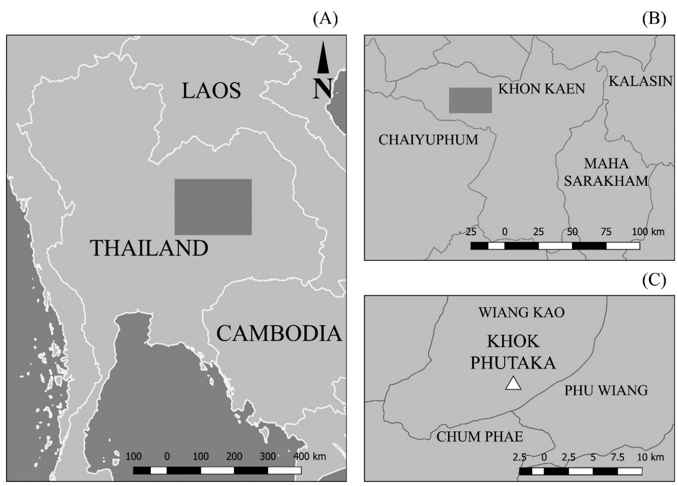

Fig. 1 Map of study location. (A) map of Thailand, where dark gray square indicates area represented in Fig. 1B; (B) Khon Kaen and nearby provinces, where dark gray square indicates area represented in Fig. 1C; (C) map showing locations of Khok Phutaka in Wiang Kao district, where dark gray lines represent district boundaries, with Phu Wiang and Chum Phae districts surrounding Khok Phutaka

by roads and agricultural areas (the shortest distance between Khok Phutaka and Phu Wiang National Park is about 300 m) for more than 30 yr (Kesonbua and Chantaranothai, 2011). The forest has been used for many purposes, including forest trails for flora and fauna studies, biodiversity research and seedling production for forest restoration. The land surrounding the dipterocarp forest has been intensively used by local people for agricultural purposes, such as rubber plantations, sugarcane plantations, rice fields, passion fruit plantations, vegetable farms and mixed farms (pers. obs.).

In this study, the following three habitat types were selected for comparing butterfly communities in Khok Phutaka (Fig. 2):

1. Dipterocarp forest (F) Butterflies on forest trails in the dipterocarp forest in the Khok Phutaka area were surveyed (Fig. 2B). The forest consisted of at least 47 tree species from 29 families and at least 108 ground flora species from 38 families. The dominant species were tree species in the family Dipterocarpaceae, such as *Dipterocarpus obtusifolius*, *Dipterocarpus tuberculatus* and *Shorea siamensis*. The dominant ground flora species were *Vietnamosasa pusilla* (Poaceae), *Trigonostemon reidioides* (Euphorbiaceae), *Indigofera* spp. (Fabaceae), *Droogmansia godefroyana* (Fabaceae), *Decaschistia parviflora* (Malvaceae) and *Hibiscus glandifolius* (Malvaceae) (Kesonbua and Chantaranothai, 2011). Some invasive plant species were also in the forest, such as *Praxelis clematidea* (Asteraceae).

2. Open areas (O) Transects for butterfly surveys were established in open grassland areas (three transects, Fig. 2D), dirt roads along sugarcane plantations (two transects, Fig. 2C) and dirt roads along sugarcane plantations and rice fields (two transects). All transects were located close to Khok Phutaka (the furthest transect was about 500 m). The total area of grassland was 3.84 ha and the total area of sugarcane plantations and rice fields was about 23 ha. Some economically important tree species were planted sporadically in these areas, such as teak *Tectona grandis* (Lamiaceae), resin trees *Dipterocarpus alatus* (Dipterocarpaceae), *Eucalyptus* spp. (Myrtaceae), doub palm trees *Borassus flabellifer* (Arecaceae) and coconut trees *Cocos nucifera* (Arecaceae). In some areas, natural trees from dipterocarp forests were sparsely distributed, such as *Flacourtia indica* (Salicaceae), *Senna garrettiana* (Fabaceae) and *Dipterocarpus obtusifolius* (Dipterocarpaceae). In all open areas, there were ground flora species, such as *Brachiaria mutica* (Poaceae), *Penisetum polystachyon* (Poaceae), *Chromolaena odorata* (Asteraceae), *Passiflora foetida* (Passifloraceae), *Asystasia gangetica* (Acanthaceae) and *Praxelis clematidea* (Asteraceae).

3. Rubber plantations (P) Transect surveys were carried out in two rubber plantations (Figs. 2A and 2E). The two areas of rubber plantations were 5.12 ha and 12.25 ha, respectively, with only the rubber tree *Hevea brasiliensis* (Euphorbiaceae) planted. These trees were older than 10 yr and had already been tapped for latex. The diversity of ground cover plants in rubber plantations was high; however, weed removal was carried out twice a year. Some species of ground cover plants with nectar were found in this habitat type, such as *Chromolaena odorata* (Asteraceae), *Praxelis clematidea* (Asteraceae), *Tridax procumbens* (Asteraceae) and *Ziziphus oenoplia* (Rhamnaceae).

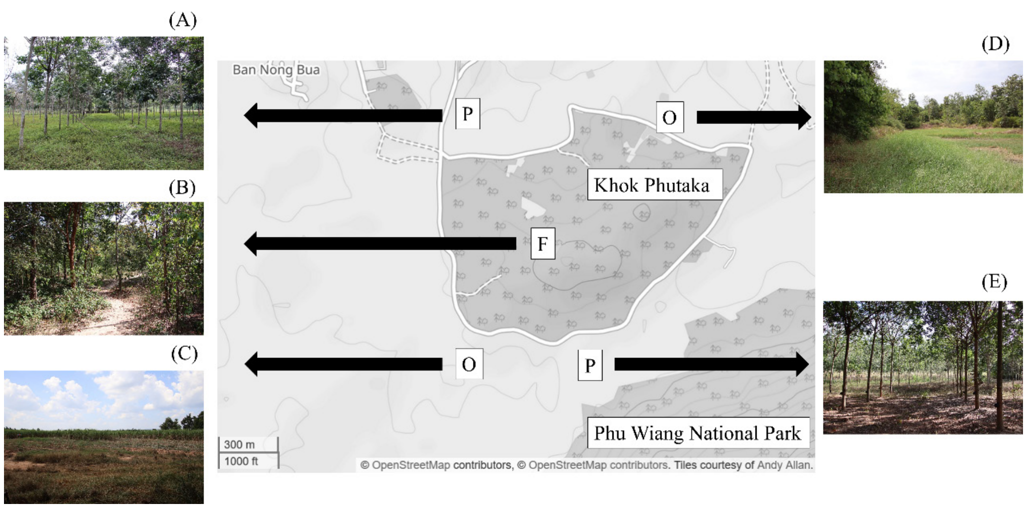

Fig. 2 Map showing locations of sample sites of each habitat type and pictures of each study location, where F = dipterocarp forest, Fig. 2B; O = open area, Fig. 2C and 2D; P = rubber plantation, Fig. 2A and 2E. Source: © OpenStreetMap

Butterfly sampling

The butterflies in each habitat type were sampled using the netting technique. Seven 5 m × 100 m transects were established within each habitat type. The transect surveys were established on forest trails, grasslands or dirt roads adjacent to agricultural areas, or directly within the rubber plantations.The distance between each transect was at least 50 m. Two collectors caught butterflies found within the transect using a sweep net with a diameter of 30 cm in all transects. The two collectors walked at a constant pace along each transect and collected butterflies for 15 min per transect on average. Each butterfly was preliminarily identified to the species level in the field and the number of individuals of each species was recorded. To avoid double counting, all butterflies caught in a transect were kept in a plastic box until the transect survey had been completed. Butterfly species that could not be identified in the field were preserved using 95% ethanol and then identified based on morphology using Jeratthitikul et al. (2009), Kimura et al. (2011, 2014, 2016) and Ek-Amnuay (2012) in the laboratory. These transect surveys were carried out between 10:00 a.m. and 04:00 p.m. on calm weather days from January to December 2019. Each transect was visited four times, twice in the dry season (January–March and October–December) and twice in the wet season (April–September).

Environmental factors

The coordinates and elevation were measured of each transect using a global positioning system at the start and end points of each transect. Air temperature (degrees Celsius), light intensity (lux), and relative humidity (percentage) were measured at the start and end positions and averaged for each transect. A human disturbance score was assigned to each transect as described in Chaianunporn and Chaianunporn (2019). In this scoring system, the score ranges from 1 (no apparent disturbance) to 7 (highest levels of disturbance). The percentages of ground cover, percentages of litter cover, and litter depths were measured on two square plots (each 1 m × 1 m) randomly placed within each transect. Litter depths were measured at the four corners of each square plot and averaged for each plot. A percentage canopy cover for 10 m^2 at the beginning and end of each transect was estimated using a densiometer. The number of vegetation layers (emergent trees, upper canopy, lower canopy, shrub understory and ground layer) was counted at areas beside the start and end points of each transect. Tree density and diversity were surveyed in June 2019 on two 10 m^2 plots (one at the start point and one at the end point) for each transect and the values from the two plots were averaged. The Shannon-Wiener index of tree diversity (described below) was calculated for each plot.

Ethics statements

This study was approved by the Ethics Committee of the Institutional Animal Care and Use Committee of Khon Kaen University (Approval no. IACUC-KKU-92/61).

Statistical analyses

For statistical analyses, the ‘vegan’ package (version 2.5-3; Oksanen et al., 2018) in the R software package (version 3.5.2; R Core Team, 2018) was utilized. Species diversity and species evenness were estimated using the Shannon-Wiener index (H) and Pielou’s evenness (P), respectively, based on Equations 1 and 2:

$$H = -\Sigma_{i=1}^{s} p_i \ln(pi) \tag{1}$$

where p_i is the proportional abundance of species i in each habitat type and S is the total number of species in each habitat type, and

$$P = \frac{H}{\ln(s)} \tag{2}$$

Sample- (transect) and individual-based rarefaction curves and extrapolation based on 95% confidence intervals of each habitat type were constructed to compare species richness among habitats using the function ‘iNEXT’ in the ‘iNEXT’ package in the R software package (Hsieh et al., 2016). Butterfly communities were compared using the Bray-Curtis distance (B) to quantify dissimilarity between habitat types. Then, the habitats were hierarchically clustered using an average linkage clustering strategy (Oksanen, 2015).

Constrained correspondence analysis (CCA) was performed to relate the distribution of butterfly species to environmental variables (ter Braak, 1986; Oksanen, 2015). It was assumed that land use change in the form of conversion to agricultural areas would affect the microclimate of the habitats, so weather variables were included in the analysis. Nine environmental variables (elevation, percentage of ground cover, percentage of litter cover, percentage of canopy cover, litter depth, number of vegetation layers, degree of human disturbance, tree density, and tree diversity) and three weather variables (air temperature, light intensity and relative humidity) were selected for use in the constrained model. The best model was chosen based on stepwise model selection using a permutation test with 999 permutations and the Akaike Information Criterion (AIC) as the selection criterion (Oksanen et al., 2018). The selected model was assessed using a permutation test for CCA with 999 permutations (Oksanen, 2015).

Results

In total, 685 individuals from 56 butterfly species were identified (Table S1). *Catopsilia pomona* (Pieridae) was the most abundant species (Pieridae, 14.5% of all observations), followed by *Eurema hebace hebace* (Pieridae, 13.0%), *Chilades pandava pandava* (Lycaenidae, 7.3%) and *Acraea terpsicore* (Nymphalidae, 6.4%). The number of individuals was greatest in the rubber plantations; however, the number of species, Shannon-Wiener's diversity index and Pielou's evenness were greatest in the open areas (Table 1). Both individual and sample-based (transect) rarefaction analyses showed the same trend, with the open areas having the greatest degree of species richness, followed by the dipterocarp forest and rubber plantations, respectively (Figs. 3A and 3B). However, the extrapolation and 95% confidence intervals of individual-based rarefaction curves (Fig. 3A) indicated that an increased sample size might lead to different results in which the species richness in the dipterocarp forest would possibly be equal to that in open areas while species richness in the rubber plantations was apparently lower than in these two habitat types.

The dissimilarity (measured based on *B* = Bray-Curtis distance) of butterfly species composition between dipterocarp forest and the other habitat types (*B* = 0.44 for open areas and *B* = 0.58 for rubber plantations) was higher than the dissimilarity between open areas and rubber plantations (*B* = 0.32; Fig. 4). Of the 56 butterfly species identified, 16 species were found only in a single habitat type, while 7 of the 16 species (43.8%) were recorded only in the dipterocarp forest. In comparison, there were 5 species (31.3%) and 4 species (25%) found only in the open areas and the rubber plantations, respectively.

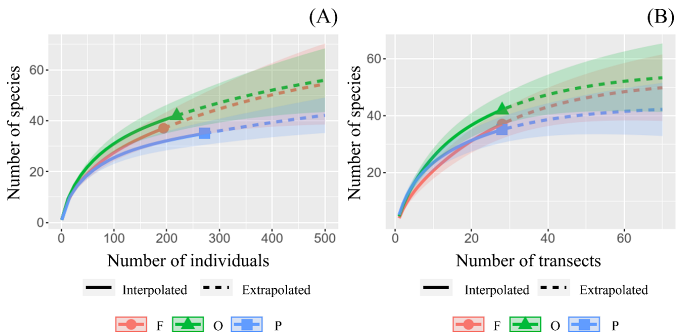

Fig. 3 Individual-based and sample-based rarefaction curves (solid line segment) and extrapolation (dashed line segment) with 95% confidence intervals (shaded areas) of butterfly communities in dipterocarp forest (red circle line), open areas (green triangle line); and rubber plantation (blue square line): (A) individual-based rarefaction curves of butterfly communities plotted against number of individuals; (B) sample-based (number of transects) rarefaction curves of butterfly communities of each habitat type plotted against number of transects, where F = dipterocarp forest; O = open areas; P = rubber plantations.

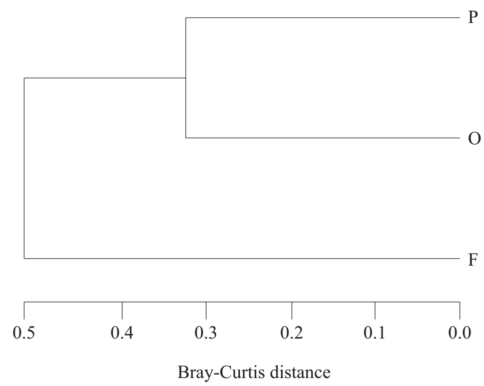

Fig. 4 Hierarchical clustering tree based on Bray-Curtis distance between habitat types, where F = dipterocarp forest; O = open areas; P = rubber plantations

Table 1 Number of species, individuals, Pielou's evenness and Shannon-Wiener's diversity index of butterfly communities in three different habitat types in Khok Phutaka area

Habitat type	Number of species	Number of individuals	Pielou's evenness	Shannon–Wiener's diversity index
F	37	194	0.80	2.88
O	42	219	0.83	3.10
P	35	272	0.81	2.89
Total	56	685	0.80	3.22

F = dipterocarp forest; O = open areas; P = rubber plantations

CCA was applied to relate butterfly species to environmental data. From the 12 environmental and weather variables, only 6 were kept in the final model after model selection based on the AIC values for elevation (p = 0.001), air temperature (p = 0.05), litter depth (p = 0.046), degree of human disturbance (p = 0.005), tree density (p = 0.007) and tree diversity (p = 0.002). These six significant variables explained 41.7% of the species composition (*pseudo-F* = 1.668, p = 0.001 for the whole model; sum of all constrained eigenvalues = 1.188, total inertia = 2.849).

The ordination diagram of the CCA presented differences among sites (site scores) in relation to the environmental variables (Fig. 5A). A graphical overlay of habitat types on the ordination showed that all three habitat types were clearly distinguished based on many environmental variables. The open areas had greater variation in different environmental variables than the other habitat types. The dipterocarp forest had the highest elevation, highest tree diversity and lowest degree of human disturbance. The litter depth was highest in the rubber plantations where the tree diversity was equal to 0 (only rubber trees were planted here). The trajectories of arrows indicate that tree diversity was positively associated with air temperature but negatively correlated with litter depth, forming a tree diversity-litter depth gradient for butterfly distribution. In addition, elevation was negatively associated with the degree of human disturbance. Therefore, there was an elevation-degree of human disturbance gradient.

Fig. 5B presents the species scores in the ordination diagram. The diagram shows that butterfly species were widely distributed on the biplot, which indicated that different butterfly species were found based on different environmental factors. From the diagram, it can be inferred that some butterfly species were closely associated with high elevation and low human disturbance (dipterocarp forest habitat), such as *Amblypodia anita anita* (L1), *Cigaritis syama peguanus* (L5) and *Yoma sabina vasuki* (N20). Some species were closely associated with low tree density and high litter depth (rubber plantation habitat), such as *Pelopidas mathias* (H5), *Acraea terpsicore* (N1) and *Papilio clytia clytia* (Pa6). Some species could be found in habitats with a high degree of human disturbance, such as *Hasora chromus chromus* (H4) and *Euploea core godartii* (N7). Some butterfly species, such as *Graphium doson axion* (Pa2) and *Cepora nerissa dapha* (Pi6), were found in habitats with high tree density.

Discussion

This study investigated the effects of land use changes on butterfly communities by comparing butterfly distribution among three different habitat types—conserved dipterocarp forest, open areas and rubber plantations—to explore the effects of land use change on butterfly communities and environmental factors associated with butterfly diversity and distribution.

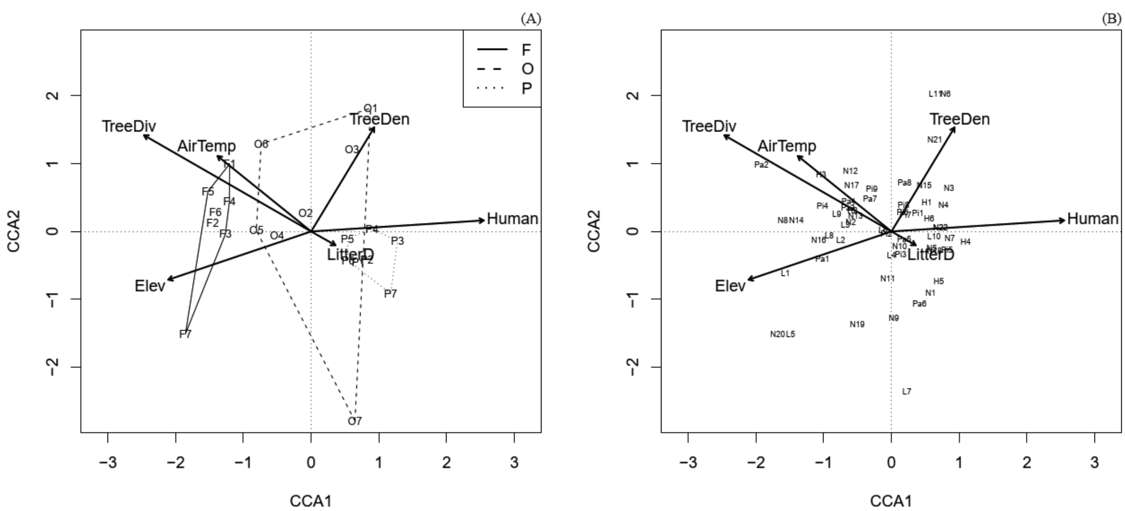

Fig. 5 Ordination diagram biplots of constrained correspondence analysis: (A) Biplot of site scores with transects in different habitat types (letters) and environmental variables (arrows), where Elev = elevation, AirTemp= air temperature, LitterD = litter depth, Human = degree of human disturbance, TreeDen = tree density and TreeDiv = tree diversity, polygons represent convex hulls enclosing all points in each habitat type, with solid line for dipterocarp forest, dashed line for open area and dotted line for rubber plantation; (B) biplot of species scores of each butterfly species (letters) and environmental variables (arrows). See Table S1 for species abbreviations

Although the Khok Phutaka area is close to Phu Wiang National Park, which is a part of the Phu Khieo-Nam Nao forest complex, the number of butterfly species reported in this study was much lower than in other studies of this region, such as a study around the the Chulabhorn Dam in 2018 (130 butterfly species; Chaianunporn and Chaianunporn, 2019) and a study in Nam Nao National Park between 1996 and 1997 (323 butterfly species; Chondamrongkun and Chamnankid, 1998). The relatively low butterfly diversity in the Khok Phutaka area might have been caused by the small size and isolation of the forest area of Khok Phutaka, emphasizing the effects of habitat fragmentation on biodiversity (Fahrig, 2003). The forest in the Khok Phutaka area was only approximately 113 ha and Khok Phutaka forest has been separated from Phu Wiang National Park by roads and agricultural areas for at least 30 yr. For comparison, the size of the forest area in the Chulabhorn dam study was 130 ha, with that forest directly connecting to the Nam Nao National Park and Phu Khieo Wildlife Sanctuary, while the Nam Nao National Park covers over 100,000 ha of forest. This isolation of the Khok Phutaka forest has hindered the direct dispersal of forest butterflies from surrounding forests, with the small forest size resulting in a lower discovery rate by dispersing butterflies and limiting microhabitats and larval food plants (Krauss et al., 2003; Koh and Sodhi, 2004; Steffan-Dewenter and Tscharntke, 2004).

The comparison of habitat types identified a trend similar to that reported in other studies (Spitzer et al., 1993; Lien and Yuan, 2003; Fermon et al., 2005; Chaianunporn and Chaianunporn, 2019), with the butterfly diversity and species richness being higher in open areas with high disturbance than in natural forest areas. Open areas likely attract butterfly species adapted to open environments, such as *Acraea terpsicore*, *Eurema hecabe hecabe* and *Catopsilia pomona*, due to abundant ground flora that can provide nectar for adult butterflies, such as *Asystasia gangetica* (Acanthaceae), *Passiflora foetida* (Passifloraceae), *Chromolaena odorata* (Asteraceae) and *Praxelis clematidea* (Asteraceae). Notably, in the current study, there was abundant ground flora with nectar in the rubber plantations as well. For this reason, this group of butterflies was also frequently found in rubber plantations. Furthermore, some agricultural plants in the open areas could attract certain butterfly species because they can be used as larval food plants for some butterfly species, such as rice *Oryza sativa* (Poaceae; larval food plant for *Ampittia dioscorides camertes*), passion fruit *Passiflora edulis* (Passifloraceae; for *Acraea terpsicore*) and coconut *Cocos nucifera* (Arecaceae; for *Elymnias hypermnestra tinctoria*) (Robinson et al., 2010).

Interestingly, the butterfly community composition in the dipterocarp forest was unique, although the butterfly number, diversity and species richness were not highest in this habitat type. Seven butterfly species (Table S1) were found only in this habitat. Although the ground flora in the dipterocarp forest were less dense and diverse than those in the open areas and the rubber plantations, there were more vegetation layers in the dipterocarp forest (3 layers in the dipterocarp forest compared to 1–2 layers in the open areas and the rubber plantations), and the vegetation structures in this habitat were more complex and heterogeneous. In addition, shrub, sapling and tree species in the dipterocarp forest were unique and could provide larval food plants of diverse butterfly species, for example *Xylia xylocarpa* (Fabaceae; larval food plant for *Chilades pandeva pandeva*), *Olax psittacorum* (Olacaceae; for *Amblypodia anita anita*), *Atalantia monophylla* (Rutaceae; for *Papilio polytes romulus*), and *Euphorbia lacei* (Euphorbiaceae; for *Danaus chrysippus chrysippus*) (Robinson et al., 2010; Kesonbua and Chantaranothai, 2011). Furthermore, some tree, shrub and vine species provided nectar and attracted many adult butterflies in the forest, such as *Euonymus cochinchinensis* (Celastraceae), *Cratoxylum cochinchinense* (Hypericaceae) and *Aganonerion polymorphum* (Apocynaceae).

The ordination diagram of the CCA showed two axes of environmental factors associated with butterfly distribution, namely the tree diversity-litter depth gradient and the elevation-degree of human disturbance gradient. The elevation-degree of human disturbance gradient might have been caused by the structure of the study side because the dipterocarp forest was located on a small hill surrounded by agricultural areas. Human activity in the forest has been limited, with the degree of human disturbance being low because the forest has been a protected area. In contrast, agricultural areas are located at lower elevations, where human disturbance was higher; for example, local people constantly visited the area and herbicides and pesticides were used in the agricultural landscape from time to time. This might have also affect butterfly distribution, as reported in other studies (Sambhu et al., 2017; Zingg et al., 2018; Goded et al., 2019). The presence of a tree diversity-litter depth gradient was consistent with the findings in other studies, showing that litter depth could be correlated with butterfly distribution in tropical areas because it is generally associated with the microclimate and light intensity of habitats (Koh and Sodhi, 2004; Checa et al., 2014; Chaianunporn and Chaianunporn, 2019). Generally, low litter depth is caused by low canopy cover that results in a high sunlight intensity, high temperature and low humidity. Different canopy covers and microclimates can lead to different butterfly assemblages in tropical areas, as reported in other studies (Hill et al., 2001; Checa et al., 2014). High tree diversity on another site of the gradient can provide diverse larval food plants, shelters, and nectar sources that attract butterflies. It should be noted that in the current study, litter depth was negatively associated with tree diversity because the highest litter depth was found in monocultural rubber plantations where the tree diversity was zero.

This study highlighted the effects of land use conversion from dipterocarp forest to agricultural area on butterfly communities in tropical southeast Asia. Habitat conversion from forest to agroecosystem creates habitat types with new characteristics (open habitat or monocultural plantations with diverse invasive plant species), which attract certain butterfly species, especially wide-ranging, well-dispersed butterfly species or other butterfly species that adapt to open environments. However, such habitat conversion does not always lead to a decrease in butterfly number or butterfly diversity, although it often results in a change in butterfly assemblage in the community (Koh and Sodhi, 2004; Koh, 2007; Sambhu et al., 2017; Chaianunporn and Chaianunporn, 2019). This finding emphasized the importance of land management to conserve ecosystem diversity for the conservation of species diversity. Lack of conservation of forest areas might threaten habitat specialist butterfly species when their larval food plant and nectar plant species are destroyed through habitat conversion. In addition, the lack of a butterfly monitoring scheme in this region makes it difficult to keep track of changes in butterfly diversity. Thus, it is essential to conduct long-term studies and to develop systematic databases for butterfly species in this region for the assessment of the large-scale effects of environmental changes on tropical butterfly communities.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

This work was part of the Plant Genetic Conservation Project under the Royal Intuitive of Her Royal Highness Princess Maha Chakri Sirindhorn and financially supported by research grants from Khon Kaen University (KKU; grant no. 6200012003). KC thanks for financially supported by faculty of Medicine, Mahasarakham University. Assist. Prof. Dr. Sarun Keithmaleesatit facilitated the study, Mr. Tanawit Sirijaree, Ms. Thitaporn Thitiyan, Mr. Sarayoot Khemla, Mr. Thong-In Kummee and Ms. Kornkanok Wongwila assisted with field work and Ms. Pantita Yiangsrirong, Ms. Sirikate Sumphawong and Ms. Naritsara Roopkhan assisted with laboratory work.

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