



# Functional and Species Diversity of Butterflies in Relationship to Vegetation Cover of Kiarapayung Biodiversity Park, West Java, Indonesia

W. Asfiya<sup>1</sup>(✉), R. P. Narakusumo<sup>2</sup>, A. Winara<sup>1</sup>, D. Dwibadra<sup>2</sup>, Darmawan<sup>2</sup>, Sarino<sup>2</sup>,  
Y. Budiasih<sup>3</sup>, A. Ruswandi<sup>1</sup>, D. A. Samsudin<sup>1</sup>, D. Peggie<sup>2</sup>, A. D. Sutadian<sup>1</sup>,  
and H. Gunawan<sup>3</sup>

<sup>1</sup> Research and Development Agency, West Java Provincial Government, JalanKawalayaan  
Indah Raya 6, Bandung 40286, West Java, Indonesia  
wara.asfiya@jabarprov.go.id

<sup>2</sup> Research Centre for Biosystematics and Evolution, National Research and Innovation Agency,  
Jalan Raya Jakarta - Bogor Km. 46, Cibinong 16911, Indonesia

<sup>3</sup> Environmental Protection Agency, West Java Provincial Government, JalanKawalayaan Indah  
Raya 6, Bandung 40286, West Java, Indonesia

**Abstract.** Anthropogenic disturbances due to increasing industrialization, human population, and urbanization are reducing biodiversity worldwide. Over the past decades, Indonesia has invested significant effort in reforestation to compensate for the loss of forest resources, such as through Biodiversity Park (Taman KEHATI) in the urban areas. However, the specific impact of revegetation on ecological communities needs to be better understood. To address this knowledge gap, we investigated butterflies (Lepidoptera: Papilionoidea) communities in the Kiara-Payung Biodiversity Park, quantifying both functional and species diversity. We surveyed 4 transects along the park and found 41 species from 5 families of butterflies. Transect 3 has the most diverse butterfly community according to the Shannon-Wiener (3.12) and Simpson index (0.95). Meanwhile, functional diversity richness revealed that transect 3 has higher values than other transects. These results confirm the fact that transect 3 has the most successful revegetation area along the KiaraPayung Biodiversity Park.

**Keywords:** Insect · Revegetation · Functional traits · Intensive agroforestry

## 1 Introduction

Anthropogenic disturbances due to increasing industrialization, human population, and urbanization are reducing biodiversity worldwide. Indonesia, a well-known hotspot of biodiversity and endemism, is also threatened by a variety of drivers, including deforestation and forest fragmentation [1]. Many forest habitats are considerably reduced in size, 20.3% between 1973 and 2011, driving a direct loss of biodiversity [2]. Biodiversity loss in the tropics is frequently assessed using species richness-based diversity

measures (e.g. [3, 4]). However, because these metrics do not measure the different roles of individual species in an ecosystem, they may understate true biodiversity loss [5]. In recent years, there has been a rise in interest in functional diversity as a tool for better assessing the effects of land-use change on functional composition. Functional diversity is defined as the variety of traits that allow species to carry out ecosystem functions and move or adapt to new environments [6]. Despite increases in the use of functional diversity indices, research on functional diversity in insect communities is still limited in the European landscape [7–9], and more work is necessary to comprehend how landscape change affects various species fully. Here, we investigated how vegetation structure drives butterfly functional and species diversity levels in KiaraPayung Biodiversity Park. The Biodiversity Park is to conserve the biodiversity of the West Java region, including the extinct and endangered plants. Butterflies are an ideal taxon for assessing functional recovery because they are widely distributed, highly diverse in traits, carry out pollination, are widely used as sensitive indicators of environmental change and are one of the well-studied invertebrate groups [10].

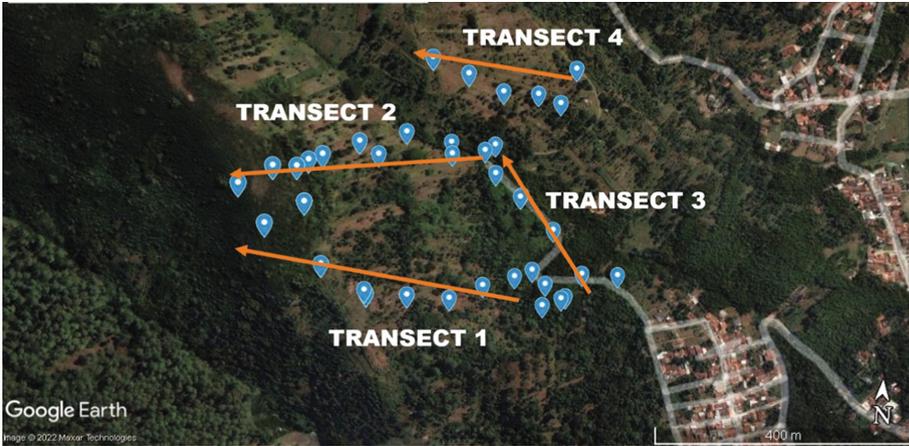
## 2 Methods

### 2.1 Location and Sampling Methods

Butterflies collected in KiaraPayung Biodiversity Park, Sumedang, West Java, from 7<sup>th</sup> to 12<sup>th</sup> February 2022. We set 4 transects along the park to represent the vegetation of the area (Fig. 1). Transect 1 is an intensive agroforestry vegetation that is dominated by champaca (*Magnolia champaca*), toona (*Toona sureni*), avocado (*Persea americana*), Indonesian bay-leaf (*Syzigium polyanthum*), cardamom (*Amomum compactum*) and chili (*Capsicum frutescens*). Transect 2 is a mixed forest vegetation with lower stand density dominated by jabon (*Anthocaphalus cadamba*), *Cassia spectabilis* and devil tree (*Alstonia scholaris*). Transect 3 is a mixed forest with high stand density for both trees and shrubs. The trees dominated by east african mahogany (*Khaya anthoteca*), large leaf rosemallow (*Hibiscus macrophyllus*), Bamboo (*Gigantochloa* spp.) while shrubs dominated by *Eupatorium odoratum* and *Lantana camara*. Transect 4 is a mixed vegetation which ranged from trees, fruits and fodder grass. The trees dominated by avocado (*Persea americana*), mango (*Mangifera indica*) and beechwood (*Gmelina arborea*). On each of the transects we walked and used butterfly net to catch any visible butterflies.

### 2.2 Location and Sampling Methods

The butterfly specimens were then brought to Entomology laboratory in Museum Zoologicum Bogoriense (MZB), Research Center for Biosystematics and Evolution, National Research and Innovation Agency. Each of the specimens was dry-preserved and mounted on an insect pin before being identified. The identification process used identification books [11–15] and compared them with the MZB reference specimens. Traits were then measured after each of the species was identified. We used 5 traits for the functional diversity measurement: maximum wingspan, total body length, size at imago, host, and food type. The details of each trait and their unit of measurement are shown in Table 1.



**Fig. 1.** Map showing locations of 4 transects along Kiara Payung Biodiversity Park (Map generated by Google Earth)

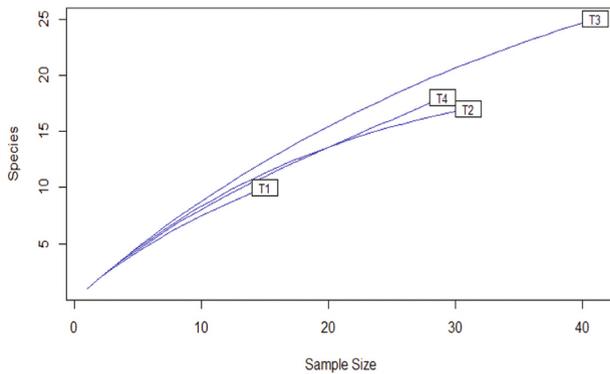
**Table 1.** Description of functional traits measurements

Functional traits	Trait measurement	Unit
Maximum Wingspan	Measure from left to right apex of front wings	Cm
Total Body Length	Measure from tip of the head to the tip of abdomen	Cm
Size Imago	> 16.13 cm (Body1) 16.13–25.12 cm (Body2) > 25.12 cm (Body3)	NA
Host	Single family host (Host1) Multifamily host (Host2)	NA
Food	Nectar (Food1) Fruit (Food2)	NA

### 2.3 Species and Functional Diversity Indices

Species diversity indices consist of indexes that are used to measure species richness and coverage in the ecosystem [16]. These quantitative measurements are using species richness, presence, and total abundance in the ecosystem. For species diversity indices we used species richness (S), Shanon-Wiener index (H'), Simpson index (D), and species evenness (E). These species diversity indices were calculated using Vegan Package in R 4.1.0 [17, 18].

Functional diversity indices are used to measure the diversity of species traits in the ecosystem [19]. Different from the species diversity, the functional diversity uses traits from each species that being weighted on each other. There are a variety of functional diversity indices and there is no standard consensus to assessing functional traits



**Fig. 2.** Rarefaction curve of butterfly species along 4 transects in KiaraPayung Biodiversity Park

[20]. Here we choose functional dispersion (FDis), functional richness (FRic), functional divergence (FDiv), functional evenness (FEve), functional specialization (FSpe), functional mean pairwise distance (FMPD), functional mean nearest neighbor distance (FNND), functional identity (Fide) and functional originality (FOri).

Functional traits from each species were then calculated using Gower distance and then to weight the multidimensionality from the distance we used PCOA. Best functionality axes will be scored by using mean absolute deviation score and also plotted to evaluate. The Kruskal-Wallis tests were then used to know what traits are significance along the best functional axes. Each of the functional diversity index, PCOA and Kruskal-Wallis tests were calculated using mFD package [21] in R 4.1.0 [18].

## 3 Result

### 3.1 Butterflies Species

We collected 116 individuals belonging to 41 species from 5 families of butterflies (Table 1). Transect 3 has the most individual and species richness followed by transect 4, 2, 1 respectively (Fig. 2). Nymphalidae is the most common family with 74 individuals followed by Pieridae and Papilionidae. *Mycalesishorsfieldi* (N = 11) is most common butterfly followed by *Doleschalliabisaltide* (N = 9), *Euremablanda* (N = 8) and *Prosotapia* (N = 8).

There are 20 singleton species in our samples (49%), it is indicated that the survey is not yet done. Rarefaction curve (Fig. 2) shows that the samples are not yet saturated on each transect. More survey is needed to show the true diversity of the butterfly's community in the KiaraPayung Biodiversity Park. However, in this study we provide species list as a baseline for further study and also to show the potential species and functional diversity.

### 3.2 Species Diversity Index

The highest Shanon-Wiener index ( $H'$ ) is on transect 3 compared by transect 4, 2, and 1 (Table 2). It is indicated that transect 3 has the highest butterfly diversity. These result

**Table 2.** Species diversity indices of butterfly communities in KiaraPayung Biodiversity Park

Indexes	Transect 1	Transect 2	Transect 3	Transect 4
S	10	17	25	18
H'	2.253	2.793	3.117	2.717
D	0.875	0.933	0.948	0.918
N	15	31	41	29

S: species richness; H': Shanon-Wiener Diversity index;  
D: Simpson Index; N: Total individual.

**Table 3.** Evaluation of PCOA on gower distance from functional traits using mean absolute deviation

PCOA	Mad score
pcoa_1d	0.125
pcoa_2d	0.048
pcoa_3d	0.058
pcoa_4d	0.067
pcoa_5d	0.074
pcoa_6d	0.077
pcoa_7d	0.079
pcoa_8d	0.080
pcoa_9d	0.081
pcoa_10d	0.081
tree_average	0.097

also congruence with the Simpson index, which is transect 3 has the highest relative abundance compared with the other transect. Transect 3 has successful trees revegetation and the habitat can hold more butterfly diversity compared with the mixed vegetation of vegetables plantation and scattered trees (transect 2 and 4). Meanwhile transect 1 that have mixed vegetation of chili plantation and grass field showed the lowest diversity scores either in its abundance and richness.

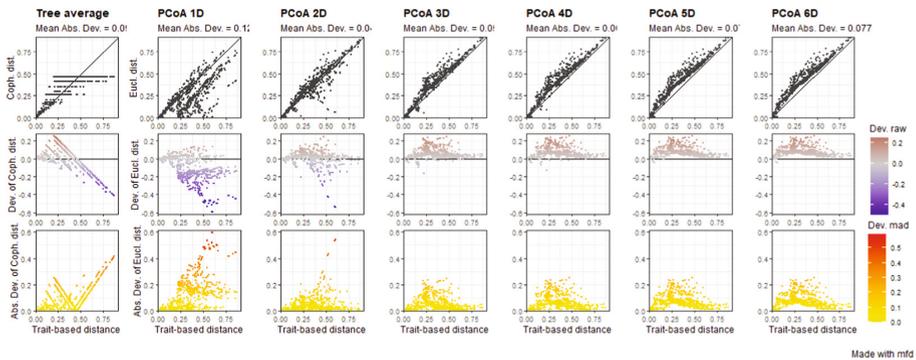
### 3.3 Functional Diversity Index

Mean absolute deviation showing that 2 dimensionality of PCOA from the Gower distance of functional traits is the best dimension (Table 3). It is also shown from the PCOA evaluation plots, in which in the 2d space, the points are the closest to the 1:1 line on the top row, and the closest to the x-axis for the two bottom rows, which reflects a better quality compared to other functional spaces (Fig. 3). P-value from Kruskal-Wallis tests

**Table 4.** Species diversity indices of butterfly communities in KiaraPayung Biodiversity Park

Trait	Axis	Test	Stat	Value	p-value
Max Wingspan	PC2	Linear Model	r2	0.034	0.2489
Total Body Length	PC2	Linear Model	r2	0.047	0.1729
Size Imago	PC2	Kruskal-Wallis	eta2	0.012	0.2923
Host	PC2	Kruskal-Wallis	eta2	0.612	0*
Adult Feeding	PC2	Kruskal-Wallis	eta2	0.321	0.0002*

Note: \*  $P < 0.05$

**Fig. 3.** Evaluation plot of PCOA from the trait-based distance

and linear models indicated that principal component 2 mostly driven by larval host and adult feeding (Table 4). These two traits significantly affected the functional axes along the ecosystem in the transects.

The result of functional diversity indices values can be seen in Table 5. The Pearson correlation of species and functional diversity are summarized in Fig. 4. There are positive and negative correlation between the species diversity with functional diversity. Dendogram showing similarities among transects based on functional diversity is shown in Fig. 5. Transect 4 and 2 are similar to each other followed by transect 3 and the most dissimilar is transect 1.

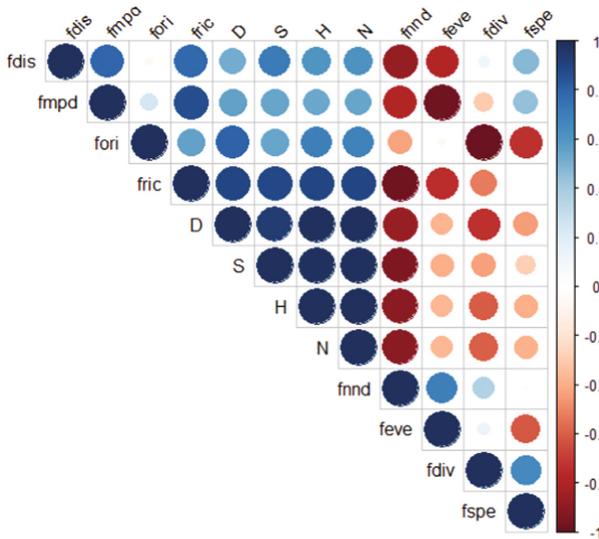
## 4 Discussion

This study supports the role of butterflies as indicators of anthropogenic activities on terrestrial ecosystems because their diversity was strongly influenced by vegetation cover as there were differences in butterfly diversity between sites.

Larval host plant and adult feeding were significant traits in the ecosystem in the transects as shown by PCOA test in this study. Larval food quality and quantity have been assumed to drive changes in dispersal capacity and or propensity in adult insects. The example of this case is shown by a recent study on Monarch butterflies that indicates

**Table 5.** Functional diversity indices from the butterfly communities in 4 transects of KiaraPayung Biodiversity Park

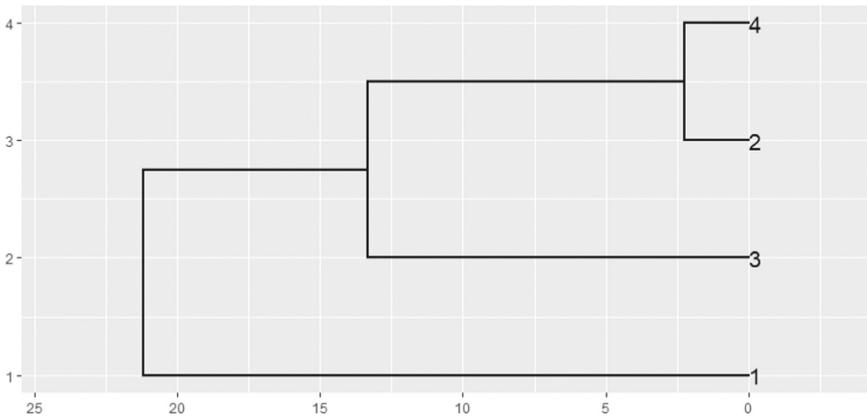
Transects	fdis	fmpd	fnnd	feve	fric	fdiv	fori	fspe
T1	0.548	0.6	0.331	0.656	0.4	0.833	0.099	0.551
T2	0.55	0.646	0.261	0.611	0.748	0.695	0.158	0.483
T3	0.582	0.65	0.192	0.608	0.877	0.765	0.136	0.503
T4	0.588	0.697	0.212	0.521	0.871	0.788	0.115	0.612



**Fig. 4.** Pearson correlation plot of functional diversity and species diversity. Positive correlations are shown in dark blue and negative correlations are shown in dark red.

that host plant species have an impact on Monarchs butterflies’ flight by affecting its fuel requirements [22]. Adult food sources were either nectar or fruit. Previous research suggest that fruit-feeding butterflies are more sensitive to anthropogenic land-use change than nectar-feeders [23]. Based on dendrogram (Fig. 5), transect 2 and 4 showed similarities of transects. Vegetations in both transect were dominated by trees. Transect 3 has mixed vegetation which is dominated by trees and shrubs (*Lantana camara*). *Lantana camara* is known to attract butterflies for its nectar. Species diversity and functional richness in transect 1 showed the lowest number compared to other sites. We assumed this is because transect 1 is the intensive agroforestry vegetation which is exposed to continually pesticides used for agricultural plant (Chili).

Correlation analysis (Pearson) showed that FDis, FMPD, FOrI and FRic are positively correlated with diversity indices (D, S, H and N). On the other hand, FNND, FEve, FDiv and FSpe have negative correlations. Functional richness (FRic) has very significance positive correlation with the species diversity, as the species diversity increases so



**Fig. 5.** Dendrogram showing similarities of transects according to Euclidean distance with clustering analysis based on functional diversity by using average method.

the functional traits in the ecosystem also increasing. Interestingly functional dispersion (FDis) also has significance positive correlation with the species diversity. It means that the dispersion of traits along the Biodiversity Park is increasing as the butterfly more diverse.

Moreover, there are functional diversity indices that show negative correlation such as FNND, FEve, FDiv and FSpe. Functional mean nearest neighbor distance (FNND) has the most significance negative correlation with the species diversity indices. It means that the packing, or density, of species within functional space decreased with increasing species diversity. The result almost congruence with the deep-sea fish community that have their FNND decreased with increasing depth [24].

## 5 Conclusion

We found 41 species from 5 families of butterflies along 4 transects in Kiara Payung Biodiversity Park. Transect 3 has the most diverse butterfly community according to the Shannon-Wiener (3.12) and Simpson index (0.95). Meanwhile functional diversity richness revealed that transect 3 has higher values than other transects.

Though this short survey could not justify the actual diversity of butterflies in Kiara Payung Biodiversity Park, this report presents the butterfly fauna in the park to facilitate the authorities for the conservation and better management actions.

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**Authors' Contributions.** WA, RPN, AW, DD, D, S, YB, AR conceived the ideas, performed data collection, data analysis and interpretation as well as drafted the paper and revisions to manuscript. DAS helped administration of the study. DP, ADS, HG drafted the paper and provided revision to manuscript. All authors read and approve and approved the final manuscript.

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