

Butterfly (Lepidoptera) community structure in several habitat types of Tancak Maesan Forest, Bondowoso, East Java, Indonesia

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Abstract. Rohman A, Subchan W, Buana YC. 2025. *Butterfly (Lepidoptera) community structure in several habitat types of Tancak Maesan Forest, Bondowoso, East Java, Indonesia. Biodiversitas 26: 651-661.* Butterflies are one of the biota in Tancak Maesan Region, Perhutani, Forest Management Unit (FMU) Bondowoso, East Java, Indonesia. The region encompasses several habitat types. Habitat-type variations can influence butterfly diversity and dispersion. Butterfly species may be impacted by habitat loss, modification, degradation, fragmentation, and the escalation of human population and activities. Alterations in species diversity and richness composition directly influence particular regions as producers of ecological services. This study aimed to analyze the composition of the butterfly community in Tancak Maesan Region, Perhutani, FMU Bondowoso. We documented 29 species of butterflies. The safeguarded forest and waterfall ecosystems (28 species) exhibited the highest butterfly species diversity. Protected forest habitats offer critical components for butterfly survival, including ample nectar supplies for adults, host plants for larvae, and stable microclimatic conditions. *Symbrenthia lilaea* exhibited the most significant population density and importance value (IVI: 11.11). The Nymphalidae family exhibited the most significant species diversity relative to the other families. The safeguarded forest ecosystem exhibited the highest diversity index (H': 3.291). The residential area exhibits the highest bird evenness index (E: 1.19). The agricultural habitat exhibited the highest dominance index (D: 0.072). The abiotic parameters fall within the acceptable tolerance limit. A total of 49 plant species were identified in the vegetation study. Canonical Correspondence Analysis (CCA) of butterflies indicated that the species *Tanaecia* sp., *Appias albina*, *Miletus* sp., *Papilio memnon*, *Eurema blanda*, *Tanaecia palguna*, *Udara akasa*, and *Oriens gola* had a positive correlation with light intensity and wind speed in forest and agricultural environments. In conclusion, butterfly communities exhibit a significant relationship with diverse habitats, particularly protected forest areas, serving as ecological indicators of habitat alteration.

Keywords: Argopuro, diversity, insect, jungle, plant

INTRODUCTION

Butterflies constitute a biota in Tancak Maesan Region, Perhutani, Bondowoso Forest Management Unit, East Java, Indonesia. This area encompasses diverse habitat types, including residential zones, agricultural fields, production forests, coffee plantations, conservation forests, and waterfalls. Butterflies serve as markers of habitat and climate change (Oliver et al. 2015; Stuhldreher and Fartmann 2018; Kwon et al. 2021). This demonstrates the capacity of butterflies to respond to environmental disruptions and harm (Riva et al. 2018). Butterflies offer ecosystem services, including pollination (Butler and Johnson 2020; Da Silva et al. 2020). Butterflies exhibit a wide range of preferences for pollinating plants (Harris et al. 2016). Research by Santhosh and Basavarajappa (2016) demonstrated that four butterfly species frequented various flowering plant species. Each habitat type possesses distinct environmental factors that can influence the quantity and distribution of butterfly species. Consequently, land use patterns influence the number and diversity of butterflies and jeopardize their conservation if

suitable management methods are not adopted (Sagwe et al. 2015).

Butterfly species may be impacted by habitat loss, change, degradation, fragmentation, and the rise of human populations and activities (Addo-Fordjour et al. 2015; MacDonald et al. 2018), including habitat utilization for habitation, agriculture, forest exploitation, and coffee plantations. Settlement environments frequently endure elevated ecological pressures from human activities and may exclusively sustain butterfly species that exhibit tolerance to disturbance. Agricultural ecosystems, primarily utilized for cultivation, may also undergo biodiversity degradation due to agricultural intensification methods. Conversely, the use of forest ecosystems and coffee plantations, despite human intervention, may yield more intricate vegetation and facilitate a greater diversity of butterfly species. Melo et al. (2023) indicate that large-bodied, crown-dwelling butterflies exhibit greater abundance in highly disturbed habitats. In contrast, ocellus-bearing species that inhabit the forest floor and consume monocots during their larval stage respond adversely to disturbance but thrive in environments with diverse tree species. Protected natural environments, such as forests and

waterfall regions, generally sustain more stable ecological conditions and promote the existence of species that are more susceptible to environmental alterations. Protection forests, designated as protected areas, are anticipated to provide crucial habitats for endemic and uncommon butterfly species. Conversely, regions surrounding waterfalls frequently exhibit distinct microclimatic conditions that may benefit specific butterfly species.

Alterations in species diversity and richness composition directly influence particular regions as suppliers of ecosystem services. Massolo et al. (2022) assert that climate change influences the habitat suitability of butterflies, particularly of host plants. Riparian vegetation and grasses are seen in open settings. Concurrently, secondary forests are characterized by woody species, including *Castanopsis javanica*, *Syzygium* sp., and *Ficus* sp., and production facilities such as *Coffea* sp. Mori et al. (2017) asserted that significant human impact would result in considerable forest alterations, perhaps leading to new ecosystems characterized by alternate stable states. Thom et al. (2017) asserted that the progressive maladaptation of forests to climate and the extended durations required for autonomous adaptation should be more explicitly acknowledged in current initiatives to preserve biodiversity and deliver ecosystem services. Consequently, forest management necessitates more adaptable and innovative measures to mitigate the damage.

A study was undertaken to examine the community structure of butterflies across several habitat types in Tancak Maesan Area, as outlined in the preceding background. We performed a comprehensive inventory to record butterflies' diversity and species richness along paths in various habitat types inside Tancak Maesan Area, Perhutani, Forest Management Unit. Currently, there is no available information regarding the community structure of

butterflies across various habitat types from these sites. This project is to ascertain the richness of butterfly species, enhance understanding of butterfly communities, ecology, and distribution in the region, and produce information to aid future conservation efforts. The study's results are anticipated to constitute primary data. They serve as a reference for managing and preserving the ecosystem in Tancak Maesan Region, Perhutani, Bondowoso Forest Management Unit, East Java, Indonesia.

MATERIALS AND METHODS

Study area

This study was conducted from July to September 2024 in the Tancak Maesan Region, Perum Perhutani, Bondowoso Forest Management Unit, East Java, Indonesia. The approach employed for determining sampling points was purposive sampling. Butterfly data was gathered along the Tancak Maesan route and categorized into six habitats: domestic habitat, agricultural land, utilization forest, coffee plantation, protected forest, and waterfall (Figure 1, Table 1).

Procedures

Butterfly survey

Using the cruising method, data collection on butterflies is conducted by systematically surveying sampling zones measuring 100 meters in length and 10 meters in width, utilizing standardized sweeping procedures to ensure accurate and consistent observations. Sampling is repeated three times across different periods. The parameters considered include butterfly species and the population numbers of each species, with adult butterflies identified through the Kuponesia program.

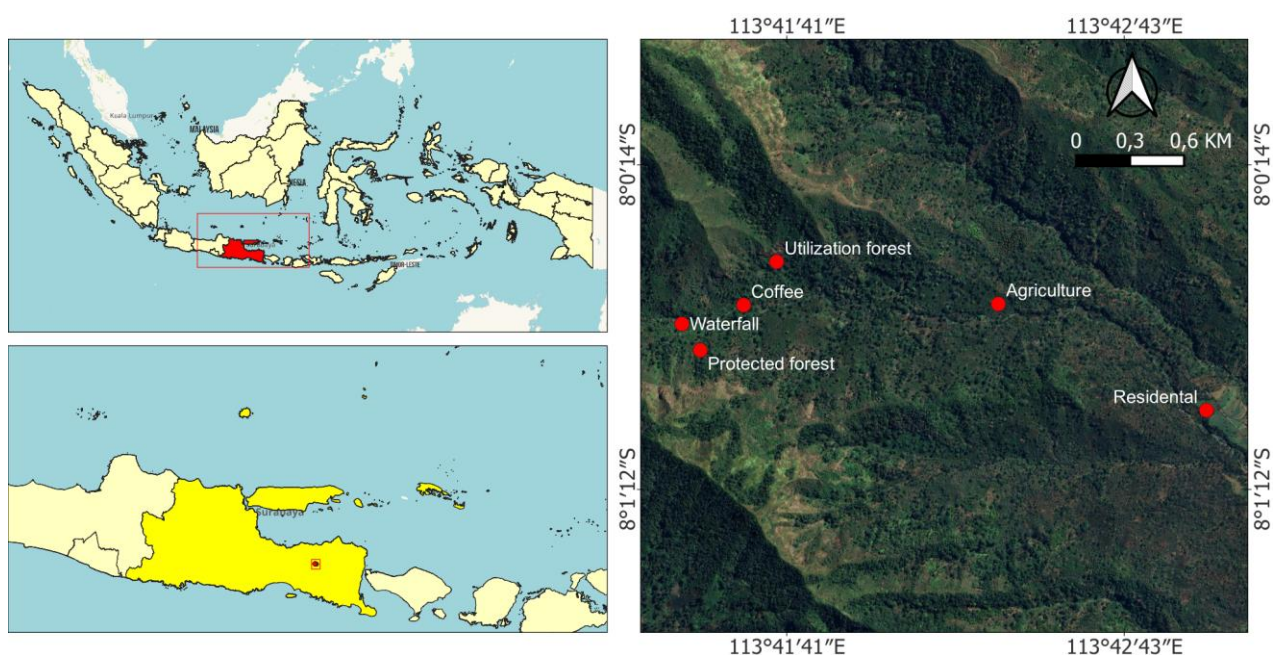


Figure 1. Tancak Maesan Area, Bondowoso Forest Management Unit, East Java, Indonesia

Table 1. Description of the six research sites in Tancak Maesan Area, Bondowoso Forest Management Unit, East Java, Indonesia

Location	Coordinate point		Elevation (m asl)	Description
	Latitude	Longitude		
Residential	8°0'57.704" S	113°42'57.601" E	686	House settlement habitat with some shade plants
Agriculture	8°0'38.604" S	113°42'19.825" E		Rice paddy habitat
Utilization forest	8°0'31.000" S	113°41'39.599" E	816	Secondary forest habitat with mixed agricultural crops
Coffee	8°0'38.801" S	113°41'33.601" E	998	Secondary forest habitat with coffee dominant
Protected forest	8°0'46.923" S	113°41'25.728" E	1130	Protected habitat with a variety of mixed forest trees
Waterfall	8°0'42.199" S	113°41'22.402" E	1117	Forest flowing water habitat with dense vegetation cover

Abiotic data measurement

Abiotic assessments evaluate abiotic conditions in the Tancak Maesan Region, Perhutani, and Bondowoso Forest Management Unit. Abiotic data were collected directly at six locations, each sampled three times to ensure accuracy and consistency. The parameters measured included light intensity, air temperature, humidity, and wind speed. Light intensity was recorded using a lux meter; air temperature was measured with a digital thermometer; the moisture was assessed using a hygrometer; and wind speed was determined with an anemometer.

Plant data collection

Biotic variables were assessed by analyzing riparian plant vegetation at each observation station (Pramadaningtyas et al. 2023). The checkerboard line technique was employed to gather vegetation data. This is accomplished by generating plots at each observation site. The designated plots comprised 2x2 m² for seedlings, 5x5 m² for saplings, 10x10 m² for poles, and 20x20 m² for trees. The collected data encompasses the species and the number of individuals of each species identified within the plot. Plant data were collected once per plot by documenting morphological characteristics and collecting leaf samples for species identification. Identification was conducted by referencing trusted botanical literature (Van Steenis 2008). Photographic documentation was also carried out to support the identification process and ensure data accuracy.

Data analysis

Conservation status assessment refers to the International Union for Conservation of Nature's (IUCN) red list of threatened species (www.iucnredlist.org), the Convention on International Trade in Endangered Species (CITES) of wild fauna and flora (cites.org), and Indonesian Regulations (P.106/MENLHK/SETJEN/KUM.1/12/2018). The butterfly community was analysed using the Shannon-Wiener diversity index (H'), Evenness index (E'), Simpson's dominance (C), relative abundance (Rdi) and Importance Value Index (IVI). The Shannon-Wiener diversity index (H') (Odum 1996) can be calculated using the formula:

$$H' = - \sum \left\{ \left(\frac{n_i}{n} \right) \ln \left(\frac{n_i}{n} \right) \right\}$$

Where,

H' : Shannon-Wiener diversity index

n_i : Number of individuals of type i

N : Number of individuals of all types

The evenness index (E/evenness) is used to determine the evenness of the number of individuals that make up a community (Magurran 2004) as follows:

$$e = \frac{H'}{\ln S}$$

Where,

e : Uniformity index

H' : Shannon-Wiener diversity index

S : Number of species found

Species dominance was determined using Simpson's Index (Odum 1996) using the formula:

$$C = \sum_{i=1}^s \left(\frac{n_i}{n} \right)^2$$

Where,

C : Dominance index

n_i : Number of individuals of type i

n : Number of individuals of all types

The study locations' similarity degree was assessed using the Bray-Curtis index. The parameter employed was the makeup of butterflies at each study site. Environmental elements (abiotic) were analyzed using Canonical Correspondence Analysis (CCA) to demonstrate the impact of abiotic factors on butterfly presence in a habitat.

RESULTS AND DISCUSSION

Butterfly diversity

The butterfly research in Tancak Maesan Region was categorized into six sites according to habitat type. Species composition differs across habitat types. The study recorded 645 individuals across 29 butterfly species from 5 families in Tancak Maesan Area. Among these, 11 species were identified across all habitat categories. In contrast, seven species were exclusively identified in five habitat types, nine species in four habitat types, three species in three habitat types, and two species in two habitat types (Table 2).

Table 2. List of butterflies in Tancak Maesan area, Bondowoso Forest Management Unit, East Java, Indonesia

Family, species	N	Relative abundance						IUCN	CITES	NS
		R	A	UF	C	PF	W			
Pieridae										
<i>Delias belisama</i> (Db)	46	10.00	0.00	8.54	11.43	6.43	5.56	NE	NA	NP
<i>Eurema simulatrix</i> (Es)	32	6.67	6.45	3.66	5.71	3.57	6.25	NE	NA	NP
<i>Eurema blanda</i> (Eb)	23	6.67	8.06	1.83	2.86	3.57	3.47	LC	NA	NP
<i>Appias albina</i> (Aal)	30	6.67	6.45	4.27	4.76	3.57	4.86	NE	NA	NP
<i>Leptosia nina</i> (Ln)	28	10.00	4.84	4.88	5.71	2.14	3.47	NE	NA	NP
<i>Captosilia pomona</i> (Cp)	37	0.00	3.23	7.32	6.67	5.00	6.25	LC	NA	NP
Nymphalidae										
<i>Ariadne ariadne</i> (Aar)	22	0.00	9.68	2.44	1.90	5.00	2.08	NE	NA	NP
<i>Tanaecia palguna</i> (Tp)	27	0.00	6.45	7.32	1.90	2.86	3.47	NE	NA	NP
<i>Tanaecia</i> sp. (Tsp)	20	6.67	4.84	3.66	3.81	1.43	2.08	NE	NA	NP
<i>Moduza procris</i> (Mp)	14	0.00	0.00	3.05	0.00	5.00	1.39	NE	NA	NP
<i>Hypolimnas bolina</i> (Hb)	17	0.00	0.00	2.44	2.86	3.57	3.47	LC	NA	NP
<i>Junonia iptha</i> (Ji)	30	6.67	0.00	7.93	4.76	5.00	2.08	NE	NA	NP
<i>Junonia erigone</i> (Je)	11	0.00	0.00	2.44	2.86	2.14	0.69	NE	NA	NP
<i>Ypthima nigricans</i> (Yn)	26	0.00	0.00	3.66	7.62	5.71	2.78	NE	NA	NP
<i>Ypthima horsfieldii</i> (Yh)	17	10.00	0.00	1.83	3.81	0.00	4.86	NE	NA	NP
<i>Symbrenthia lilaea</i> (Sl)	49	3.33	6.45	7.32	6.67	6.43	11.11	NE	NA	NP
<i>Symbrenthia</i> sp. (Ssp)	16	6.67	0.00	0.61	0.00	3.57	5.56	NE	NA	NP
<i>Mycalasis sudra</i> (Ms)	18	0.00	0.00	2.44	5.71	2.14	3.47	NE	NA	NP
<i>Mycalasis moorei</i> (Mm)	30	0.00	0.00	3.05	7.62	5.71	6.25	NE	NA	NP
<i>Elymnias</i> sp. (Esp)	12	3.33	1.61	0.61	1.90	3.57	1.39	NE	NA	NP
Papilionidae										
<i>Papilio memnon</i> (Pm)	5	3.33	0.00	0.00	1.90	1.43	0.00	NE	NA	NP
<i>Papilio helenus</i> (Ph)	4	0.00	0.00	0.61	0.95	0.71	0.69	LC	NA	NP
<i>Graphium agamemnon</i> (Ga)	2	0.00	0.00	0.00	0.95	0.71	0.00	NE	NA	NP
<i>Graphium doson</i> (Gd)	4	0.00	0.00	1.22	0.00	0.71	0.69	NE	NA	NP
Lycaenidae										
<i>Udara akasa</i> (Ua)	45	6.67	14.52	9.15	3.81	5.71	4.86	NE	NA	NP
<i>Miletus</i> sp. (Mp)	16	6.67	3.23	3.66	1.90	1.43	1.39	NE	NA	NP
<i>Heliophorus epicles</i> (He)	17	0.00	3.23	1.22	0.00	5.71	3.47	NE	NA	NP
Hesperiidae										
<i>Oriens gola</i> (Og)	28	6.67	14.52	1.83	0.00	3.57	6.25	NE	NA	NP
<i>Koruthaialos</i> sp. (Ksp)	19	0.00	6.45	3.05	1.90	3.57	2.08	NE	NA	NP

Note: N: Amount; R: Residential; A: Agriculture; UF: Utilization Forest; C: Coffee; PF: Protected Forest; W: Waterfall; NE: Not Evaluated; DD: Data Deficient; LC: Least Concern; NT: Near Threatened; VU: Vulnerable; EN: Endangered; CR: Critically Endangered; EW: Extinct in the Wild; EX: Extinct; NA: Not Appendix; P: Protected; NP: Not Protected

Protected forest and waterfall settings exhibited the highest butterfly species diversity, encompassing 28 species. Protected forest and waterfall regions have greater biodiversity complexity than places subjected to land degradation or conversion, including plantations and agricultural zones. Changes in land use, such as converting forests into agricultural or plantation areas and rapid urbanization, actively lead to the loss of natural habitats essential for butterfly survival. The results indicate that secondary and protected forests can sustain high butterfly variety and species richness, but agricultural land and settlements may adversely affect butterfly communities over time. Research by Orimaye et al. (2016) indicates that butterfly variety is more significant in protected regions. Butterfly diversity in protected forest regions is generally more significant due to critical survival elements, including various food sources, secure oviposition locations, and stable microclimatic conditions. Protected forests, characterized by diverse vegetation, sustain the food chain and offer ample nectar sources for adult butterflies and host plants for larvae. Elevated forest cover can enhance butterfly abundance (Toivonen et al. 2017).

Symbrenthia lilaea (49) exhibited the highest population, succeeded by *Delias belisama* (46), while *Graphium agamemnon* (2) recorded the lowest count. The species *S. lilaea* was discovered in the forest of Pagar Alam City. Devi et al. (2017) state that *S. lilaea* is an insect that facilitates pollination. Furthermore, Badoni and Arya (2022) identify medicinal plants of the genus *Berberis*, which are prevalent in the forests of Pagar Alam City. This species is frequently among the most prevalent in particular forest ecosystems, particularly in regions with significant floral diversity. The proliferation of *S. lilaea* as the species with the most significant population can be ascribed to various ecological causes. Initially, *S. lilaea* exhibits significant adaptability to diverse habitat types, encompassing primary, secondary, and even degraded forests. This species is commonly located in diverse tropical forest regions, characterized by various food sources, including nectar and host plants. *Symbrenthia lilaea* employs a variety of host plant types in forested regions. Variations in species richness, abundance, and Composition are present among sites with differing nectar supply. Coffee cultivation crops may function as a

substitute habitat for woodland butterflies during the dry season of their life cycle. Nonetheless, it does not constitute an appropriate environment that supplies all the necessary materials for effective larval growth (Habel et al. 2018). *Graphium agamemnon* exhibits lower population densities relative to other species. *Graphium agamemnon* prefers deep, humid forest ecosystems with specific host flora. Fadlia's research (2018) identified four host plants in the experiment: (*Michelia alba*, *Polyalthia longifolia*, *Annona muricata*, *Cananga odorata*) *G. agamemnon* ladies preferred *A. muricata* for oviposition over other host plants (Fadlia 2018).

The International Union for Conservation of Nature (IUCN) designates four species as Least Concern: (*E. blanda*, *C. pomona*, *H. bolina*, *P. elenus*). Currently, according to the conservation status outlined by the Convention on International Trade in Endangered Species (CITES), no species are listed in the attachment or National Status (NS).

Composition of butterfly families

The identified families were Pieridae, Nymphalidae, Papilionidae, Lycaenidae, and Hesperidae. The Nymphalidae family was the most prevalent, comprising 14 species and 309 individuals (48%), followed by the Pieridae family had 6 species and 196 individuals (31%). Lycaenidae includes three species and 78 individuals, representing 12%. The Hesperidae family exhibited the lowest species count, comprising two species and 47 individuals (7%). Papilionidae (four species) comprising 15 individuals (2%) (Figure 2.A). Figure 2.B illustrates the makeup of butterfly families identified in this study, indicating the presence of the Pieridae, Nymphalidae, Lycaenidae, and Hesperidae families across the study location. The Papilionidae family was absent in agriculture. Basavarajappa et al. (2018) research indicates that Nymphalidae exhibits the highest species diversity among other groups. Mandal, S. Nymphalidae, constitutes the largest share of rice fields. Khan and Perveen (2015) posited that the Nymphalidae family exhibits a broad habitat distribution, encompassing thickets, grasslands, plantations, botanical gardens, and nurseries. Luis-Martínez et al. (2022) exhibit a distribution across various vegetation types. Shrestha et al. (2018) assert that the family

Nymphalidae exhibited the most incredible abundance and diversity of butterflies, dominating all sacred woods.

Analysis of Lepidoptera index in Tancak Maesan Area

Figure 3 displays data analysis computations employing the Shannon-Wiener, Evenness, and Dominance indices to evaluate butterfly species in Tancak Maesan Area. The safeguarded forest habitat exhibits the highest diversity index (3.291) compared to other habitats. The butterfly diversity index is classified as high, indicating a significant dispersion of individual species and a stable community structure. Orimaye et al. (2016) demonstrated an elevated diversity index in conserved regions. Protected woods with distinct microclimatic conditions can sustain butterfly species, considered crucial habitats for endemic and uncommon butterflies. Consequently, they serve as ecological markers of climate change (Sharma and Sharma 2017).

The evenness indices are as follows: Residential (1.19), Agriculture (0.97), Utilization Forest (0.87), Coffee (0.96), Protected Forest (0.96), and Waterfall (0.90). Based on the standard of elevated evenness. A lower evenness index result indicates a more uneven distribution of hides within a community dominated by specific species.

The dominance index indicated that the agricultural habitat (0.072) surpassed the other habitats. All six environments exhibited a low dominance index ($0 < D \leq 0.5$). A lower dominance score signifies the absence of a dominant species in the area, indicating a stable condition. This scenario is facilitated by vegetation diversity, establishing a balanced ecology in which no particular moth species predominates, leading to a moderate Shannon-Wiener index. Despite the agricultural habitat exhibiting a greater dominance index, Mandal (2016) notes that disturbances from degradation persist, although it continues to display significant butterfly variety. Asmah et al. (2017) demonstrated that polyculture farming did not enhance butterfly diversity owing to the restricted variety of plant types. Goded et al. (2021) assert that organic farming offers better habitat quality for butterflies than conventional farming by fostering specific grassland plants advantageous to butterflies and creating more extensive niche spaces, promoting functionally diverse butterfly communities.

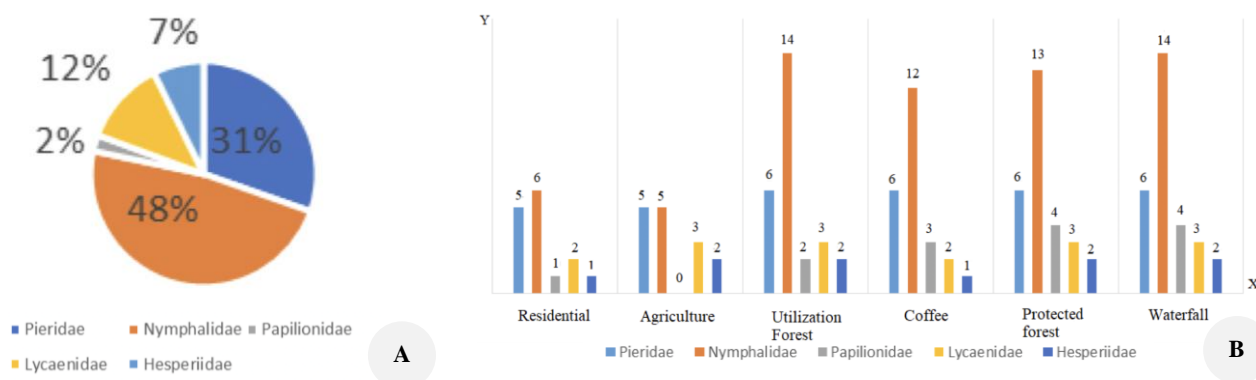


Figure 2. A. Butterfly family composition; B. Butterfly family composition in several habitats in Tancak Maesan area, Bondowoso Forest Management Unit, East Java, Indonesia

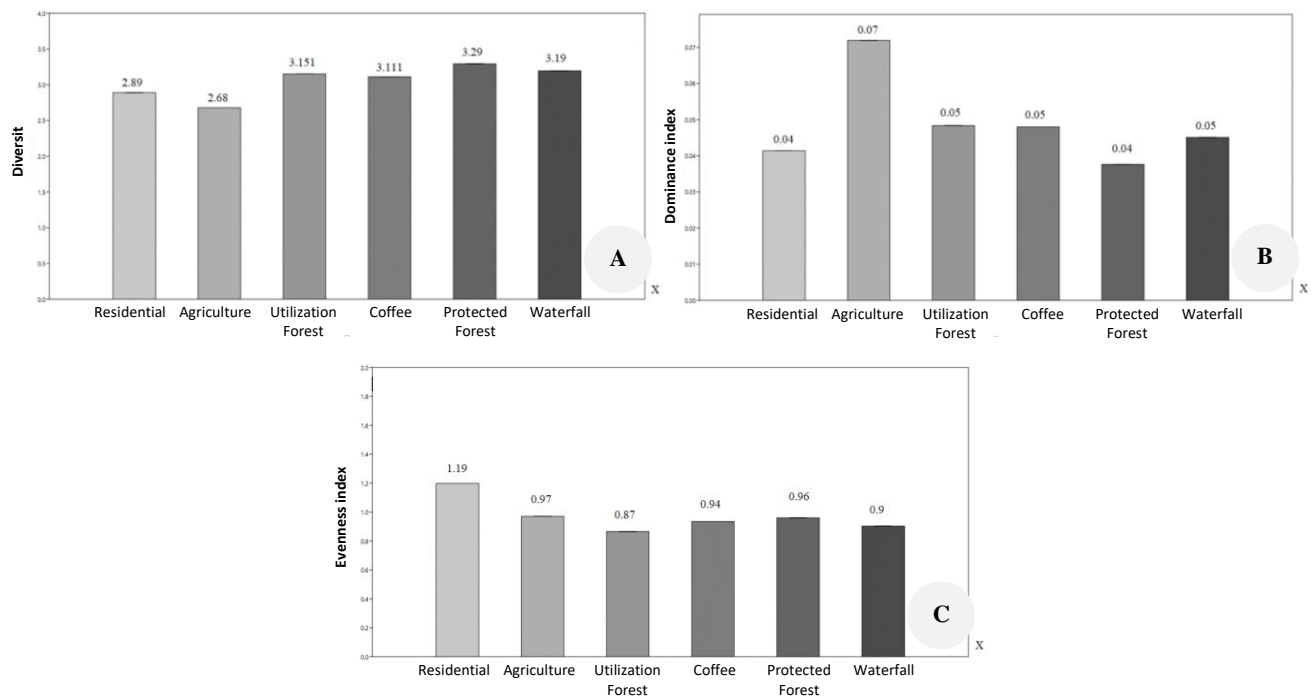


Figure 3. Analysis of butterfly index in Tancak Maesan area, Bondowoso Forest Management Unit, East Java, Indonesia. A. Diversity Index; B. Dominance Index; C. Evenness Index

Similarities in butterfly composition across habitats

Analysis of butterfly composition across several habitats reveals two distinct groups. The initial category comprises agricultural, forest utilization, Coffee, protected forests, and waterfalls; the subsequent category is residential. The agricultural environment contains fifteen species present in the area. The second group exhibits an equivalent degree of similarity in butterfly makeup. Thirteen species are identified in the two locations: *Eurema simulatrix*, *Eurema blanda*, *Appias albina*, *Leptosia nina*, *Captosilia pomona*, *Ariadne Ariadne*, *Tanaecia palguna*, *Tanaecia sp.*, *S. lilaea*, *Elymnias sp.*, *Udara akasa*, *Miletus sp.*, and *Koruthaialos sp.* Group two is subdivided into four subgroups: Subgroup 1, which includes a protected forest and a waterfall, exhibiting a similarity value of 56% (27 species). Subgroup 2 encompasses protected forests, waterfalls, and coffee, with a similarity value of 48% (21 species). Subgroup 3 comprises protected forest, waterfall, coffee, and utilization forest, with a similarity value of 98% with 21 species. Subgroup 4 encompasses protected forests, waterfall coffee, utilization forests, and farmland, with a similarity score of 85% (16 species) (Figure 4).

Importance Value Index (IVI) of butterflies in Tancak Maesan Area

The Importance Value Index (IVI) is a holistic statistic that combines relative abundance, relative frequency, and relative dominance, offering a complete evaluation of a species' relevance within a community (Figure 5). *Delias belisama*, *L. nina* and *Ypthima horsfieldii* exhibited the

most excellent significance index (IVI: 10.04) in the residential area. *Ariadne* possesses the most significant importance index (9.7) in the agricultural sector. It is frequently observed among meadow flowers, riparian zones, and low-lying trees. *Ariadne ariadne* exhibits a broad distribution up to 900 meters above sea level. This species favours *Ricinus communis* as its host plant (Han 2014). *Delias belisama* possesses the highest significance index in the Utilization Forest (8.59), Coffee (11.48), and Protected Forest (6.48). It possesses an extensive distribution range. Afandi et al. (2023) indicate that this species inhabits the Ranu region. *Symbrenthia lilaea* possesses the most excellent significance index at the waterfall, recorded at 11.11. *Symbrenthia lilaea* is typically located in solitary environments among mountainous forests and adjacent to water sources. Butterflies exhibiting the highest significance score demonstrated considerable abundance at each location. Butterflies exhibit varying functional and species diversity concerning vegetation shape and land use (Aguirre-Gutiérrez et al. 2017). Land cover influences butterfly diversity (Han et al. 2021). The proliferation of butterflies correlates with the accessibility of plant resources (Castro and Espinosa 2015). The number and diversity of butterflies have been associated with the availability of plant resources capable of blossoming and fruiting (Nacua et al. 2014). The prevalence of nectar-producing blooming plants is directly correlated with butterfly populations. Furthermore, the presence of host plants may restrict butterfly dispersion under specific climatic conditions (Hanspach et al. 2014).

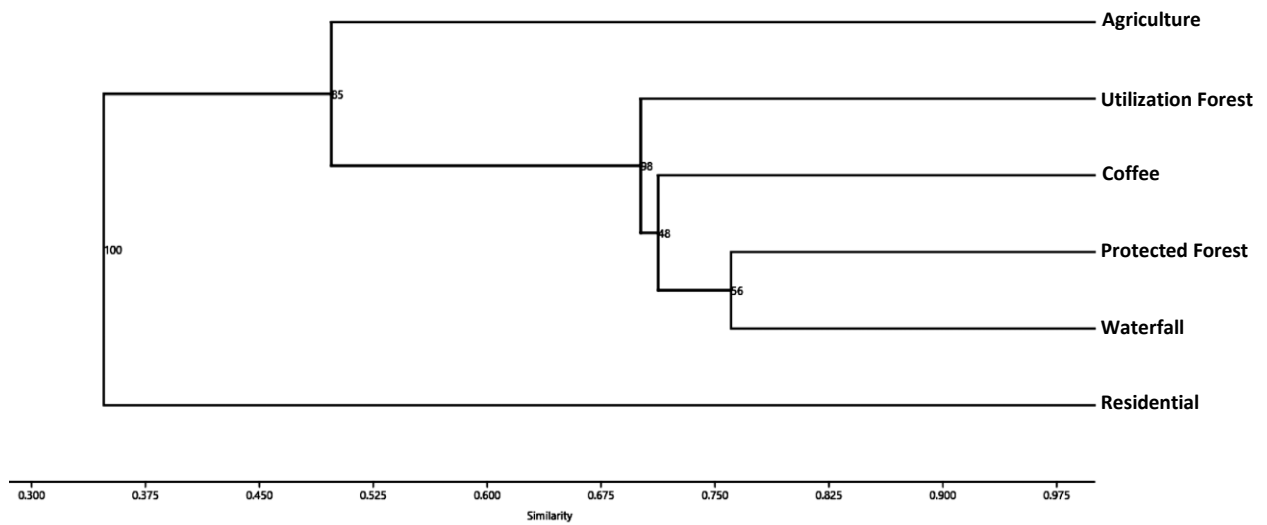


Figure 4. Similarity of butterfly composition in several habitats in Tancak Maesan area, Bondowoso Forest Management Unit, East Java, Indonesia

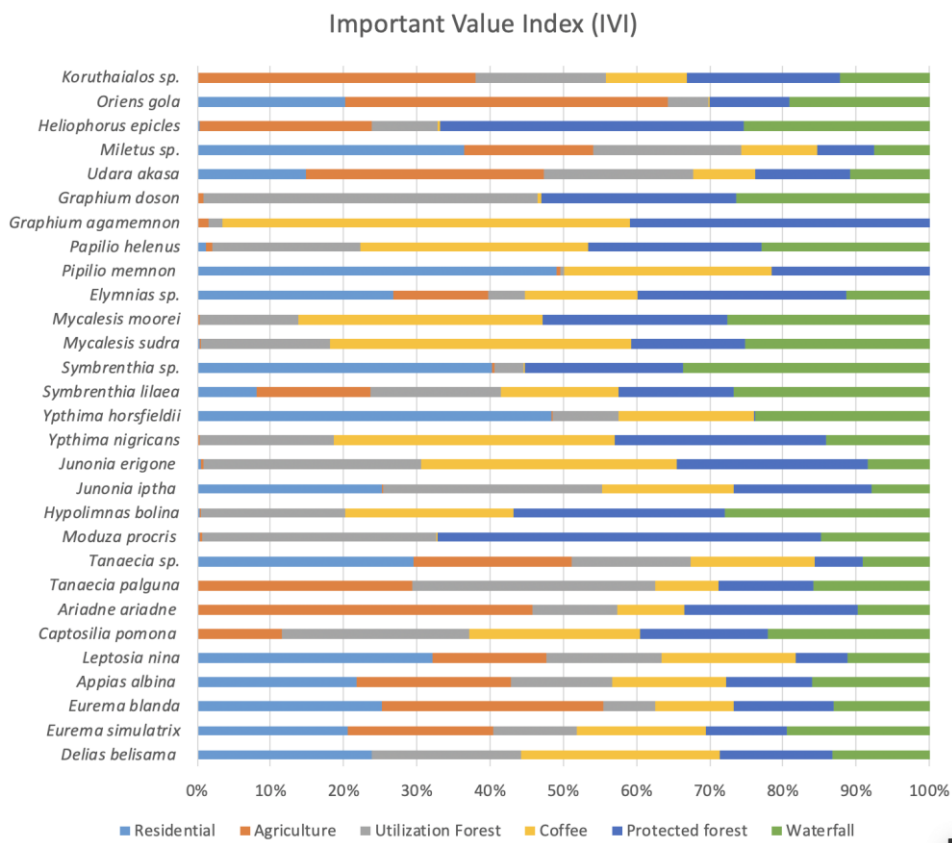


Figure 5. Important Value Index (IVI) of butterflies in the Tancak Maesan area, Bondowoso Forest Management Unit, East Java, Indonesia

Plant diversity

Forty-nine (49) plant species were identified in Tancak Maesan area (Table 3). The variation in plant species composition and vegetation cover across each study site may significantly influence butterfly diversity. Utilization Forest has the most incredible diversity of plant species, with 41 kinds. Subsequently, residential areas comprise 16

species; coffee plantations encompass 15 species; agricultural zones include 13 species; protected forests harbor 11 species; and waterfalls also contain 11 species. The Utilization Forest region comprises forest vegetation and wild riparian flora. Humans also employ it to satisfy economic requirements for horticulture.

Table 3. List of plant species in Tancak Maesan area, Bondowoso Forest Management Unit, East Java, Indonesia

Family	Species	R	A	UF	C	PF	W
Rubiaceae	<i>Coffea arabica</i>	0	30	0	49	30	22
Anacardiaceae	<i>Mangifera indica</i>	2	5	5	0	0	0
Lauraceae	<i>Persea americana</i>	4	5	5	0	0	0
Lauraceae	<i>Cinnamomum verum</i>	0	0	7	0	0	0
Lauraceae	<i>Anarium asperum</i>	0	0	0	14	0	0
Fabaceae	<i>Leucaena leucocephala</i>	1	3	6	0	0	0
Fabaceae	<i>Calliandra calothyrsus</i>	0	0	12	0	0	0
Fabaceae	<i>Senna spectabilis</i>	0	0	4	0	0	0
Fabaceae	<i>Caesalpinia pulcherrima</i>	0	0	2	0	0	0
Fabaceae	<i>Parkia timoriana</i>	3	0	0	32	0	0
Fabaceae	<i>Flemingia lineata</i>	0	0	0	22	5	6
Solanaceae	<i>Solanum torvum</i>	0	0	10	0	0	0
Solanaceae	<i>Datura metel</i>	0	0	18	0	0	0
Solanaceae	<i>Capsicum frutescens</i>	0	0	5	0	0	0
Verbenaceae	<i>Stachytarpheta jamaicensis</i>	0	0	35	0	0	0
Verbenaceae	<i>Lantana camara</i>	3	23	44	0	0	0
Acanthaceae	<i>Justicia gendarussa</i>	11	0	41	0	0	0
Annonaceae	<i>Cananga odorata</i>	0	2	2	0	0	0
Apocynaceae	<i>Catharanthus roseus</i>	5	2	6	0	0	0
Araceae	<i>Scindapsus aureus</i>	0	2	30	0	0	0
Araceae	<i>Monstera deliciosa</i>	8	0	2	0	0	0
Araceae	<i>Colocasia esculenta</i>	0	0	8	6	0	0
Asteraceae	<i>Ageratum conyzoides</i>	13	33	85	0	0	0
Asteraceae	<i>Pseudelephantopus spicatus</i>	0	22	35	0	0	0
Asteraceae	<i>Elephantopus scaber</i>	13	0	45	13	12	10
Asteraceae	<i>Chromolaena odorata</i>	22	0	14	18	12	10
Balsaminaceae	<i>Impatiens balsamina</i>	0	23	67	16	0	0
Costaceae	<i>Costus speciosus</i>	0	0	23	0	0	0
Cycadaceae	<i>Cycas rumphii</i>	0	0	0	3	3	3
Dioscoreaceae	<i>Dioscorea hispida</i>	0	0	0	10	7	3
Lecythidaceae	<i>Bareingtonia sp.</i>	0	0	0	9	9	9
Malvaceae	<i>Durio sp.</i>	4	2	7	0	2	3
Meliaceae	<i>Melia azedarach</i>	0	0	3	0	0	0
Moraceae	<i>Artocarpus heterophyllus</i>	2	0	3	0	0	0
Moraceae	<i>Ficus sp.</i>	0	0	5	1	3	4
Moraceae	<i>Ficus hispida</i>	0	0	2	3	1	2
Musaceae	<i>Musa acuminata</i>	5	0	5	0	0	0
Myrtaceae	<i>Syzygium cumini</i>	0	0	4	0	0	0
Phyllanthaceae	<i>Sauropus androgynus</i>	0	0	33	0	0	0
Piperaceae	<i>Peperomia pellucida</i>	0	0	76	0	0	0
Poaceae	<i>Bambusa sp.</i>	0	0	10	0	0	0
Poaceae	<i>Oryza sativa</i>	68	0	0	0	0	0
Poaceae	<i>Pennisetum purpureum</i>	0	0	4	0	0	0
Pteridaceae	<i>Adiantum peruvianum</i>	0	0	27	0	0	0
Pteridaceae	<i>Pteris sp.</i>	2	0	1	0	0	0
Rutaceae	<i>Melicope lunu-ankenda</i>	0	0	0	23	0	0
Selaginellaceae	<i>Sellaginella doederleinii</i>	0	12	47	24	14	12
Zingiberaceae	<i>Alpinia galanga</i>	11	0	10	0	0	0
Euphorbiaceae	<i>Acalypha indica</i>	0	0	43	0	0	0

Note: R: Residential; A: Agriculture; UF: Utilization Forest; C: Coffee; PF: Protected Forest; W: Waterfall

The region cultivates fruiting plants such as *Mangifera indica*, *Persea americana*, *Citrus maxima* and crops like *Capsicum frutescens*. The Utilisation Forest area exhibits the highest plant biodiversity compared to other regions. Tara and Gupta (2016) assert that *M. indica* is the host plant for *Euthalia aconthea* (Nymphalidae). *Cricula trifenestrata* Helfer (Lepidoptera: Saturniidae) further damage *M. indica*. *Capsicum* sp. species serves as a host plant for *Spodoptera litura* F. larvae (Movva and Pathipati 2017).

Coffea arabica and *Ageratum conyzoides* exhibited the highest population density among the plants. *Coffea arabica* is cultivated on the slopes of Tancak Maesan. Insects are among the visitors of *C. arabica* flowers (Hafsah et al. 2021). Moreover, butterflies serve as pollinators for Coffee (Paramita et al. 2018). Santiago-Salazar et al. (2021) indicate that Coffee is a host plant for butterflies (*Leucoptera coffeella*). Mahata et al. (2019) assert that coffee plantations represent the optimal habitat for butterflies among the three agroforestry environments examined.

Ageratum conyzoides is a riparian species extensively found across many habitat types and exhibits resistance to arboreal shade (Kaur et al. 2023). The plant is a weed located in the Maesan Tancak region. Kaur et al. (2023) indicate that it can disrupt crops, meadows, and forest soil flora, as well as its capacity to supplant native plant species. *Ageratum conyzoides* is a polymorphic fragrant perennial plant indigenous to tropical America (Thorat et al. 2018). It possesses flowers that range from white to light purple (Ray et al. 2019). The blossoms are appealing to butterflies as a source of nourishment. This plant is a natural host for multiple aphid species (Martins et al. 2016).

Abiotic parameters

Light intensity readings varied from 45 to 2045 lux. Li et al. (2019) and Liao et al. (2020) assert that light intensity influences mating behaviour and butterfly reproductive success by impacting their flight behaviour. The air temperature varies between 22 and 31°C. The maximum temperature occurs in agricultural areas (31°C), and the minimum is near waterfalls (22°C) (Table 4). Butterflies influence species responses to climate change concerning temperature and altitude in habitat utilization (Ashton et al. 2009). Elevated temperatures in agricultural environments signify open ecosystems that permit unobstructed light penetration, whereas waterfalls exhibit dense vegetation that may obstruct light access. Air humidity fluctuates

between 50% and 92% and is correlated with temperature. High temperatures correlate with low humidity, whilst low temperatures correspond with high humidity. Wind velocities vary from 4-15 m/s. Wind can directly influence flying behavior, dispersal, and daily activity (Leitch et al. 2021). Butterflies are lightweight insects; thus, fluctuations in wind velocity can substantially impact their flight and maneuverability in natural environments.

Canonical Correspondence Analysis (CCA)

Canonical Correspondence Analysis (CCA) of butterflies is segmented into four quadrants. Quadrant 1 indicates that the species *Tanaecia* sp., *A. albina*, *Miletus* sp., *Papilio memnon*, *E. blanda*, *T. palguna*, *U. akasa*, *Oriens gola* are associated with light intensity and wind speed at forest utilization and agricultural locations. Quadrant two species associated with Coffee and residential areas include. *Eurema simulatrix*, *Ypthima nigricans*, *Mycalesis sudra*, *D. belisama*, *Y. horsfieldii*. Quadrant three includes, *Symbrenthia* sp., *S. lilaea*, *Y. nigricans*, *C. pomona*, *Papilio helenus*, *Mycalesis moorei*, *Hypolimnas bolina*, *Graphium doson* which are connected with air temperature and humidity at the waterfall site. Quadrant 4 species include *Koruthaialos* sp., *Junonia iptha*, *Junonia erigone*, *Elymnias* sp., *Graphium gamemnon*, *Heliophorus epicles*, *Miletus* sp. coincide with the protected woodland (Figure 6).

Table 4. Abiotic parameters

Abiotic parameters	Residential	Agriculture	Utilization Forest	Coffee	Protected Forest	Waterfall
Light intensity (lux)	1596	2045	806	1061	345	45
Air temperature (°C)	29	31	28	26	23	22
Air humidity %	58	50	67	68	90	92
Wind (m/s)	10	15	8	8	9	4

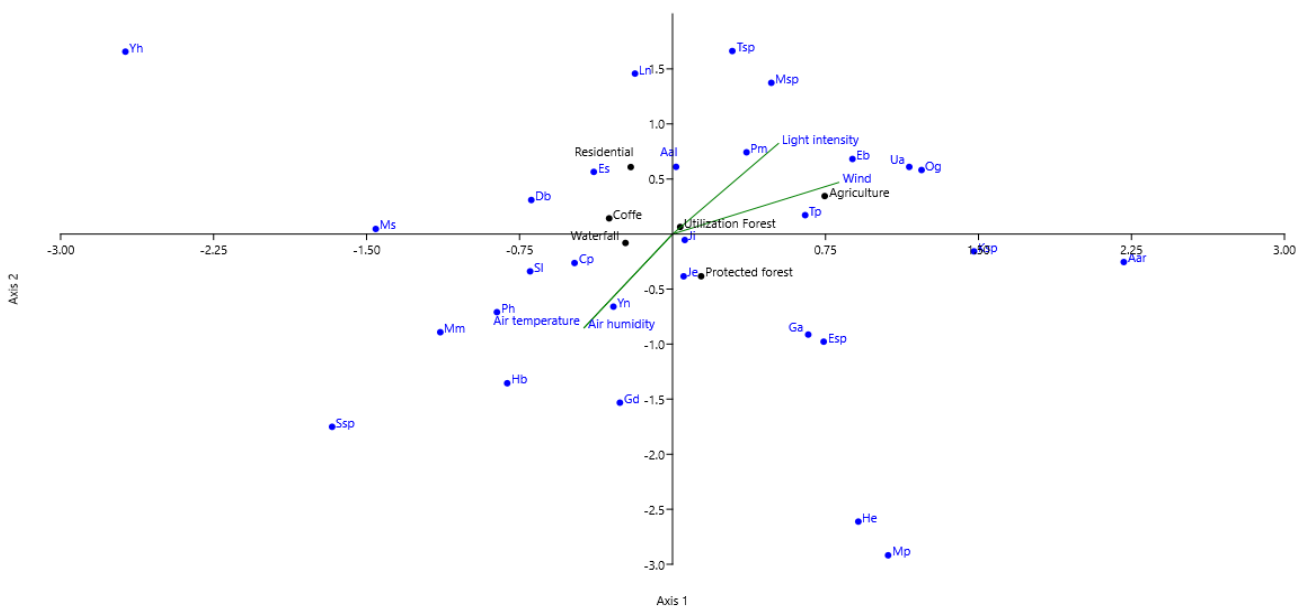


Figure 6. Canonical Correspondance Analysis of butterflies in Tancak Maesan area, Bondowoso Forest Management Unit, East Java, Indonesia

Highlighting quadrants one and three, the link between species in quadrant one and the characteristics of light intensity and wind speed at forest and agricultural sites indicates that light intensity and wind speed can directly influence the utilization of these areas. Utilization forests exhibit lower vegetation density than protected forests, allowing light to penetrate unobstructed, influencing butterflies' flight activity. Conversely, wind velocity can influence the dispersal of butterflies. Quadrant three indicates that related species correlate with air temperature and humidity due to the waterfall's location, which has a higher vegetation density than other areas. Therefore, it is clear that it influences air temperature and humidity. The field findings demonstrate that microclimatic conditions are more stable and supportive of the survival of specific species.

In conclusion, there is a correlation between butterfly communities and diverse habitats, particularly protected forest habitats, which are ecological indicators of habitat alteration. Protected forest areas are crucial to safeguard life support systems for butterfly populations and natural resources. Various habitat types offer essential support for butterfly communities, providing valuable insights for sustainable habitat management and conservation. Furthermore, policymakers must preserve ecosystem quality in regions increasingly threatened by human activities.

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