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The effect of land use type on butterfly diversity at Masako Forest Reserve, Kisangani, Democratic Republic of Congo

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The effect of land use type on butterfly abundance, species richness, and biodiversity was studied at Masako Forest Reserve in Kisangani, Democratic Republic of Congo. The study was conducted in a primary (PF) and secondary forest (SF), fallow (FW), and an agricultural field (AF). Three bait traps were used; each trap had a cylinder consisting of two metal rings of 30.48 cm diameter and 106.68 cm length with a 15.24 cm cone top. The cylinder and top were nylon mosquito netting with a 55.88 cm zipper sewn into the seam of the cylinder to provide access into the trap to remove butterflies. Traps with rotten bananas as baits were placed at three sites in each of the land use type for 24 h. Trapped butterflies were counted, identified, photographed and released. Results showed that land use type significantly affected butterfly species abundance (p=0.0003) and alpha biodiversity (p=0.0001). The fallow had the highest butterfly species abundance and biodiversity. *Cymothoe caenis* was the most dominant and *Acrea lycoa* the least abundant species. Butterflies biodiversity indices significantly correlated with longitude (0.58 to 0.79). These results suggested that land use type and geographic coordinates may have an impact on butterflies at Masako Forest Reserve. More studies are needed to better understand the effect of land use type and longitude on butterfly biodiversity.

Key words: Butterfly, forest, land use type, species, abundance, biodiversity.

INTRODUCTION

Butterflies are very important to ecosystems. They play significant ecological roles, perform essential ecosystem services (Schmidt and Roland, 2006), especially in the recycling of nutrients (N, P, K) highly needed by crops (Munyuli, 2012). Butterflies are well-known indicator taxa due to their sensitivity to environmental perturbations, relevance to ecosystem functioning and relative ease in sampling (Brown and Freitas, 2002; Blair, 1999; Hamann and Curio, 1999). They are considered as good ecological indicators for other invertebrate taxa and as surrogate representatives of environmental quality changes (Kumar et al., 2009; Kremen, 1992; Munyuli, 2012). It has been estimated that about 90% of butterfly species live in the tropics (Munyuli, 2012). However, despite their diversity, ubiquity and importance particularly with regards to their ecology, behaviour and functional role, they remain relatively less studied in the tropics as compared to temperate ecosystems (Marchiori and Romanowski, 2006; Van Swaay et al., 2012). The relative scarcity of studies on tropical butterfly species hampers the ability to effectively conserve them, particularly as pollinating agents in agricultural systems (Munyuli, 2012). Butterflies are also known to be highly sensitive to climate change (Parmesan and Yohe, 2003) and recent studies showed that they react faster than other groups such as birds (Devictor et al., 2012). A reason for this is because butterflies have relatively short generation times and are ectothermic organisms, meaning that their population dynamics may respond to temperature changes more directly and more rapidly (Van Swaayet al., 2012). Therefore, changes in environmental conditions caused by deforestation and forest disturbance have negative effects on butterflies, including declines in diversity and abundance (Hamer et al., 1997; Hamer et al., 2003; Nkwabi et al., 2017), changes in species assemblages (Hamer et al., 2003), loss of species guilds (Canaday, 1997), and extinction (Magsalay et al., 1994; Castelletta et al., 2000; Brook et al., 2003). However, modified habitats may still actually retain some forest biodiversity (Hughes et al., 2002; Horner-Devine et al., 2003; Sodhi et al., 2005), but their conservation value still needs to be assessed. It has also been reported that the numbers of butterfly species and individuals were high in disturbed and regenerating forests and low in natural forests (Spitzer et al., 1993; Van Lien and Yuan, 2003). There were few butterfly species in the habitat with thick forest canopy and, vice versa, more butterfly species in the habitat with less forest canopy (Warren, 1985). The diversity of butterflies increased with increasing habitat scale and vegetation structure complexity (Schmidt and Roland, 2006). Finally, it has been suggested that our understanding of which types of disturbance most adversely affect tropical biota and which taxonomic groups are most susceptible to disturbance is still poor (Dunn, 2004). Therefore, to protect and conserve the remaining biodiversity effectively, it is essential to understand how biological communities such as butterflies respond to land use change as caused by anthropogenic disturbances. The objective of this study was therefore to assess the effect of land use type on butterfly abundance, species richness and biodiversity at Masako Forest Reserve, Kisangani, Democratic Republic of Congo.

METHODOLOGY

Study area

The study was conducted from April to August 2014 at Masako Forest Reserve near the City of Kisangani in the Tshopo province of the Democratic Republic of Congo (Figure 1). Masako Forest Reserve (2.105 ha) is located 15 km north-east of Kisangani, on the old Buta's road. One third of the reserve is occupied by primary forest; the remainder consists of old-growth secondary forests, fallow lands and crops. Its geographic coordinates are 0°36'N; 25°13'E. The Masako forests are in the category of equatorial evergreen rainforests (Nyakabwa et al., 1990). It is listed among the biodiversity protected areas of the Democratic Republic of Congo.

Land use types studied

The four major land use types found at Masako Forest Reserve were used in this study. Primary forest (PF) is a land use type essentially composed of *Gilbertiodendron dewevrei* and *Scaphopethalumthonneri*as undergrowth throughout Masako Forest Reserve. However, the wetter areas of the reserve are heterogeneous with *G. dewevrei, Coelocaryonbothryoides, Piptadeniastrum africanum* and *Celstis mildbraedtii*. The undergrowth is dominated by *Cyathogynaviridis* and *Pycnocomainsularis* (Nyakabwa et al., 1990). Secondary forest (SF) is the old-growth secondary forests at Masako Forest Reserve are very diverse, composed of a mixture of trees also occurring in old fallow lands and primary forest (Lomba and Ndjele, 1998). They are characterized by *Zanthoxylum gilletii, Cynometra hankei, Peterstiantus macrocarpus, Musanga cecropioides*, *Terminalia superba, Scorodophloeuszenkeri, Albizia adiantifolia, Uapaca guineensis, Cynometra alexandrii, Panda oleoza, M. cecropioides*, etc. (Mosango, 1991). Fallow (FW) are fallow lands formed essentially by herbaceous groupings consisting of *Panicum maximum, Pennisetum purpureum, P. polystachyon, Spermacoce latifolia* and of shrub associations of *Cnestis ferruginea, Craterispemum cerinanthum, Afromomum laurentii* and *Costuslucanisianus, Triumpheta cordifolia* and *Selaginella myosurus*. Agricultural fields (AF) were composed of a mixture of crops such as cassava, corn, and plantain banana

Butterfly collection and identification

Three bait traps designed for the tropics and sub-tropical parts of the world were used in this study. They were purchased from a limited liability company (LLC), Georgetown, Kansas, United States of America (http://www.leptraps.com). Each trap had a cylinder consisting of two metal rings of 30.48 cm diameter and 106.68 cm length cylinder with a 15.24 cm cone top. The cylinder and top were nylon mosquito netting with a 55.88 cm plastic zipper sewn into

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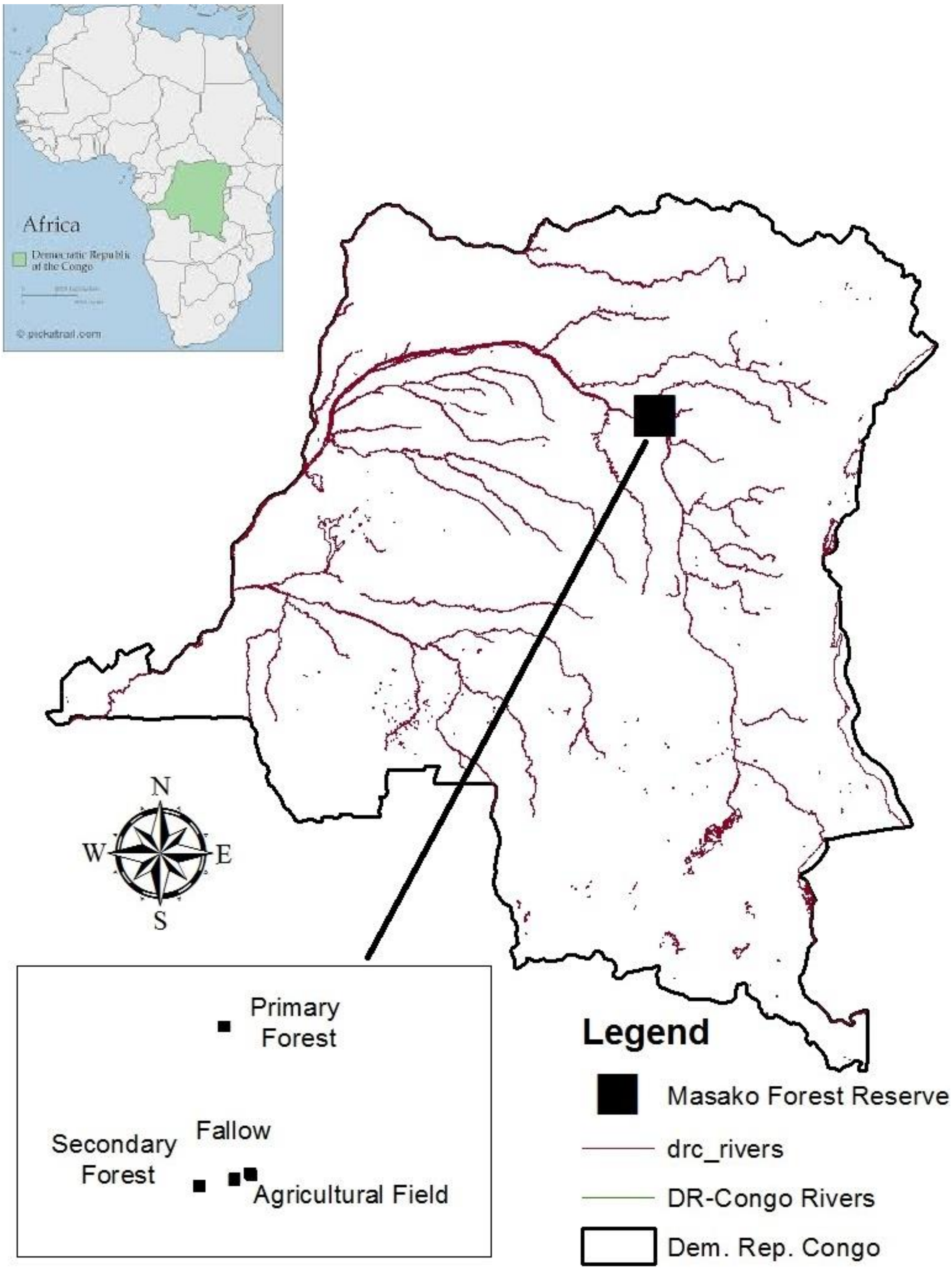

Figure 1. Study site.

the seam of the cylinder to provide access into the trap to remove butterflies. The flat bottom ring was high-density polyethylene (HDPE) white plastic. The ring did snap in and out. The platform was also HDPE white plastic and was suspended from the bottom of the cylinder with "S" hooks and "eye" bolts. The "eye" bolts allowed the opening between the bottom of the cylinder and the

Table 1. Coordinates of the sampling sites.

Site	No.	Latitude	Longitude	Elevation
Agricultural field (AF)	1	0.617091	25.258641	433.118286
Agricultural field (AF)	2	0.617176	25.258728	424.863586
Agricultural field (AF)	3	0.617323	25.258781	423.867889
Fallow (FW)	1	0.617649	25.260882	434.796692
Fallow (FW)	2	0.617861	25.260788	434.241241
Fallow (FW)	3	0.61793	25.260641	433.65683
Primary forest (PF)	1	0.636671	25.25739	405.400513
Primary forest (PF)	2	0.636647	25.257313	427.721039
Primary forest (PF)	3	0.636657	25.257515	426.547058
Secondary forest (SF)	1	0.616287	25.254344	427.766968
Secondary forest (SF)	2	0.616274	25.254264	428.435028
Secondary Forest (SF)	3	0.616286	25.254164	427.698669

platform to be adjustable (1.91 to 0.64 cm). The platform had a 15.24 cm diameter hole in the center for a rubber-maid type 3.2 cup container with a snap seal lid was the bait container. A package of four containers was included with each trap. A bait was prepared with rotten bananas and put in each of the tree containers. The bait could remain in the container with the lid sealed tight and stored in a secure storage bag while traveling. Traps were totally collapsible for easy packing during the travel and the bait could travel with the trap. The sampling started in the primary forest. The white cone top provided a light source. Butterflies were attracted to the bait by the sense of smell. They walked into the shaded area of the trap to feed on the bait. Once they had finished feeding they flew upward towards the light area of the white cone top and became entrapped. Butterflies appeared very reluctant to fly down into the dark screened area of the trap and even when they did, they rested with their head facing up towards. For each of the four of the land use types, traps were installed at three sites at 12:00 pm and removed at 11:00 am the next day. The geographic coordinates of each site in each land use type are shown in Table 1. Butterflies collected within the traps were counted and identified *in situ* and released. Butterflies that could not be identified were stored into zip log bags and identified later. This identification protocol was repeated at all sites for each land use type. Overall, 14 butterfly species were collected. These species were not unique to neither Masko Forest Reserve nor the Democratic Republic of Congo, but are also found in other African countries as well. Their distribution throughout Africa is as shown in Figure 2. None of the 14 butterfly species collected at Masako Forest Reserve was found in the IUCN "Red List" of endangered species as their conservation status has not yet been assessed. However, many of them are listed in the Catalog of Life. Overall, the preferred land use type for all of them was the forest (dry, moist or costal) with a few exceptions for the farmland (http://www.catalogueoflife.org).

Calculation of butterfly abundance, richness and biodiversity indices

Measurement of biodiversity over spatial scales is described in three terms: alpha, beta, and gamma biodiversity (Whittaker, 1972; Hunter, 2002). A biodiversity index is a quantitative measure that reflects how many different types (such as species) there are in a dataset, and simultaneously takes into account how evenly the basic entities (such as individuals) are distributed among those types. Alpha diversity refers to the diversity within a particular area or ecosystem, and is usually expressed by the number of species in that ecosystem. Beta diversity is the change in species diversity between these ecosystems. Gamma diversity is a measure of the overall diversity for the different ecosystems within a region. Three biodiversity indices were calculated: Shannon (SHI) and Simpson (SI) indices for alpha biodiversity and the Absolute Beta Value (ABV) index for beta biodiversity. These indices were calculated using the freely available biodiversity calculator: http://www.alyoung.com/labs/biodiversity_calculator.html. Gamma biodiversity was taken as the total number species. Butterflies abundance was calculated as the total number of butterflies caught at each of the three sites in each of the four land use type while butterfly species richness was the total number of different species present at each site.

RESULTS

The summary of statistics for butterfly abundance, richness and biodiversity in four land use types at Masako Forest Reserve is shown in Table 2. Overall, butterfly abundance ranged from 4 to 173 with an average of 53.67. There was a high variability in butterfly abundance among the land use types as shown by a coefficient of variation of 109.51%, the highest among all parameters studied. The means for butterfly species richness and that of ABV were closer with same standard deviation. The means for SHI and SI indices were closer along with their standard deviations and coefficients of variation (CV). Although land use types were far away from each other, the range in their elevations was only 29.40 m. Overall, the fallow had the highest butterfly species abundance and biodiversity. *Cymothoe caenis* was the most dominant and *Acrea lycoa* the least abundant species.

Butterfly abundance

Data on butterfly abundance was checked for normality

Figure 2. Butterfly species distribution map.

before further analysis. The probability plots for butterfly abundance are as shown in Figure 3a and b. The original data on butterfly abundance (Figure 3a) fitted the line with slight deviations from the straight line at the bottom of the graph, suggesting that it was not normally distributed. After the failure of additional normality checks with the Shapiro-Wilk test and a log transformation of the data as shown in Figure 3a and b, Bartlett test was used and found that the variances were not homogenous (K-squared = 15.35, df = 3, P = 0.0015). Therefore, Kruskal-Wallis non-parametric test was used to compare butterfly abundance among land use types. Table 3 shows the effect of land use type on butterfly abundance at Masako Forest Reserve. There was a significant difference in butterfly abundance among land use type (P=0.0003, F=23.40). A mean separation test suggested that the fallow (FW) had higher butterfly abundance as compared to the primary forest. However, the fallow (FW), agricultural field (AF) and the secondary forest (SF) did not significantly differ in butterfly abundance. Similarly, the agricultural field (AF), primary forest (PF) and SF were also not significantly different in their butterfly abundance.

Butterfly species richness

The probability plots for butterfly richness are as shown in Figure 4a and b. The original data on butterfly richness fitted well the probability plot, but with a slight deviation from the straight line at the top of the graph, suggesting that it was not normally distributed. Therefore, a log transformation of the data was done after a Shapiro test and this improved the degree of normality as shown in Figure 4a and b and also confirmed by the Shapiro test on the transformed data (W = 0.9408, p-value = 0.5089).

Table 2. Summary of statistics for butterflies biodiversity in four land use types at Masako Forest Reserve, Kisangani, Democratic Republic of Congo (May-June 2014).

Variable	Abundance	Richness	SHI[1]	SI[2]	ABV[3]	Elevation
N	12.00	12.00	12.00	12.00	12.00	12.00
Mean	53.67	5.50	1.14	0.97	4.50	427.34
SD	58.77	2.02	0.86	0.75	2.02	7.85
C.V.	109.51	36.78	75.18	77.38	44.95	1.84
Minimum	4.00	3.00	0.15	0.00	2.00	405.40
Median	26.50	5.00	0.98	0.76	4.00	427.75
Maximum	173.00	9.00	2.59	1.85	8.00	434.80
Skew	0.82	0.59	0.28	0.08	0.59	-1.85
Kurtosis	-0.63	-0.67	-1.47	-1.79	-0.67	3.26

[1]SHI: Shannon index; [2]SI: simpson index, [3]ABV: absolute beta value.

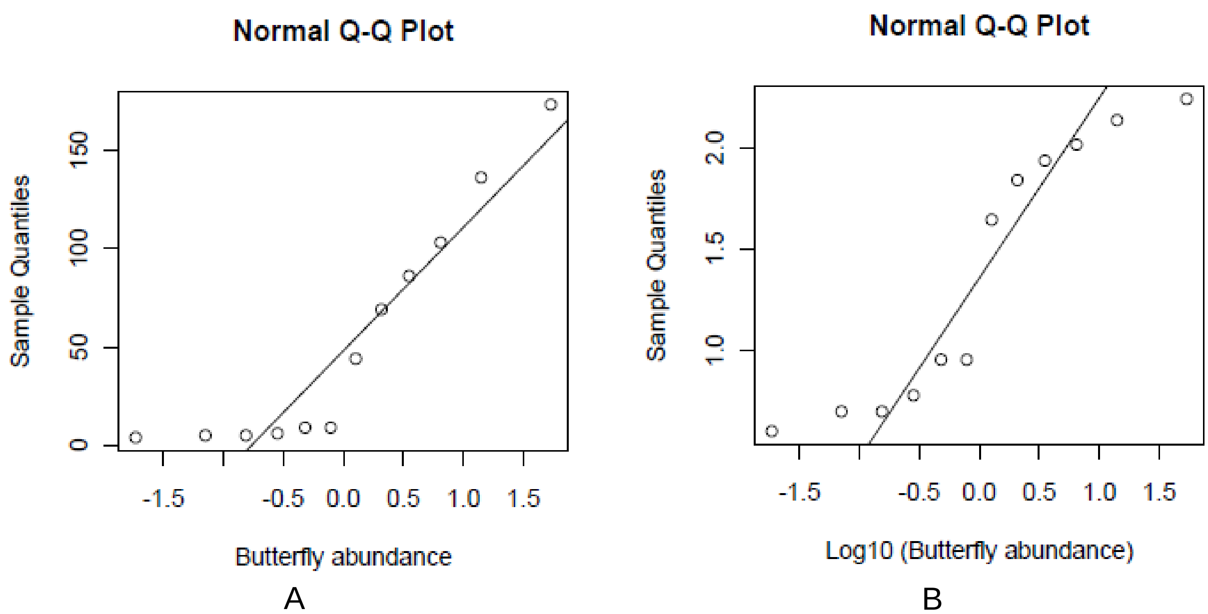

Figure 3. (A) Butterfly species abundance (original data); (B) Log transformed data on butterfly species abundance.

Later, an analysis of variance was conducted followed by means separation, but the results showed that there were no significant differences among land use types for butterfly richness.

Butterfly alpha biodiversity

Butterflies species alpha biodiversity was calculated using the Shannon and Simpson indices. Similarly to data on butterflies abundance and richness, graphical method was also used to determine if the data on butterflies diversity for the SI was normally distributed. The probability plots are as shown in Figure 5a and b. It was observed that the original data (Figure 5a) on SI deviated from the straight line at the bottom as well as at the top of the graph, suggesting that it was not normally distributed. A Shapiro-Wilk test confirmed the lack of normality and the log transformation failed to make the data more normally distributed (Figure 5b). Therefore, as in previous analyses, Kruskal-Wallis test was used to check whether SI was different among land use types. The analysis of variance (Table 4) revealed that there was a significant effect of land use type on butterfly biodiversity as characterized by the Simpson index (P=0.0001, F=35.8). The comparison of means showed that FA had the highest biodiversity as compared to the PF. However, the PF, SF and the AF were not different in their butterfly

Table 3. Effect of land use type on butterfly abundance at Masako Forest Reserve, Kisangani, Democratic Republic of Congo.

Land use type (LUT)	Mean
Agricultural Field (AF)	8[ab]
Fallow (FW)	11[a]
Primary Forest (PF)	2.5[b]
Secondary Forest (SF)	4.5[ab]

Analysis of variance					
Source	**DF**	**SS**	**MS**	**F**	**p**
LUT	3	127.500	42.5000	23.4	0.0003
Site	8	14.500	1.8125		
Total	11	142.000			

There are 2 groups (a and b) in which the means, are not significantly different from one another.

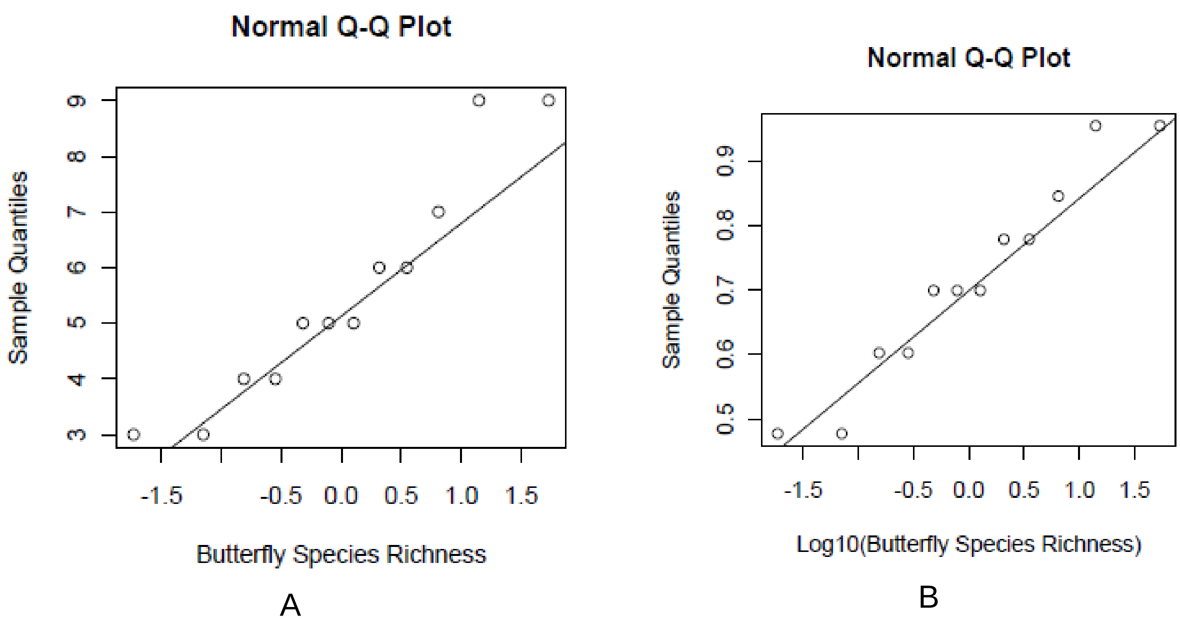

Figure 4. (A) Butterfly species richness (original data); (B) Log transformed data on butterfly species richness.

biodiversity. Finally, AF, FW and SF were also equal in their butterfly biodiversity. Like the Simpson index, data for the SHI was not normally distributed (Figures not showed). Therefore, a further analysis of the data was continued using the Kruskal-Wallis non-parametric test to evaluate whether butterfly biodiversity differed among land use types as assessed by the Shannon index. The analysis of variance (not showed) revealed that there was a significant difference among land use types for butterfly alpha biodiversity (P=0.0074, F=8.40). However, a separation of means test showed that all land use types were equal for their butterfly alpha biodiversity as assessed by the Shannon index.

Butterflies beta biodiversity

Butterfly beta biodiversity was characterized using ABV. The data was checked for normality as shown in Figure 6a and 6b. ABV data was normally distributed. This was also confirmed by the Shapiro-Wilk test (W = 0.9085, p = 0.2039). However, given the little deviation shown in Figure 6a, the data was transformed to improve its fitting of the line. As showed in Figure 6b, the transformation

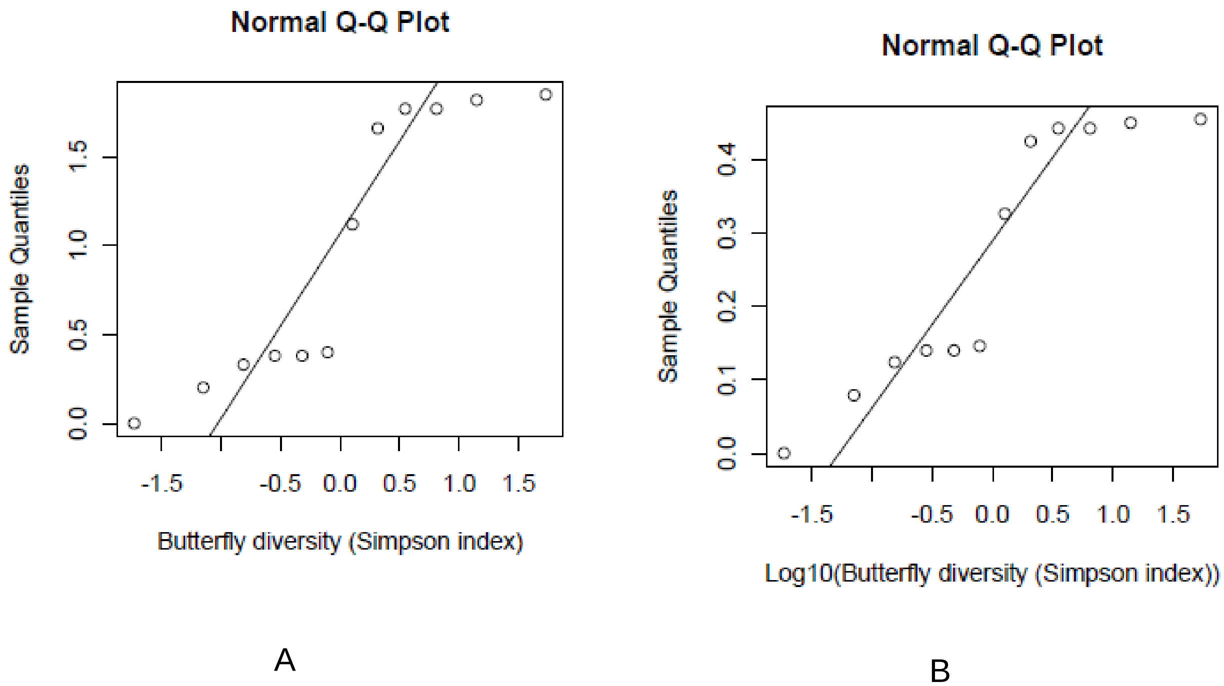

Figure 5. (A) Butterfly alpha diversity (original data); (B) Butterfly alpha diversity (log transformed data).

Table 4. Effect of land use type on butterfly biodiversity (SI) at Masako Forest Reserve, Kisangani, Democratic Republic of Congo.

Land use type (LUT)	Mean
Agricultural field (AF)	8.17^{ab}
Fallow (FW)	10.83^{a}
Primary forest (PF)	2.00^{b}
Secondary forest (SF)	5.00^{ab}

Analysis of variance					
Source	**DF**	**SS**	**MS**	**F**	**p**
LUT	3	132.167	44.0556	35.8	0.0001
Site	8	9.833	1.2292	-	-
Total	11	142.000	-	-	-

improved the normality and this was also confirmed by Shapiro-Wilk test (W = 0.9395, P = 0.4919). Finally, the homogeneity of variance was checked and the result confirmed that this third assumption for normally distributed data was not violated (Bartlett's K-squared = 0.963, df = 3, P = 0.8102). Therefore, the analysis of variance was further used to evaluate whether butterfly beta biodiversity (ABV) was different among land use types. The analysis of variance showed that there was no significant difference among land use types for the beta biodiversity as characterized by ABV.

Correlation between butterfly abundance, richness, biodiversity and sampling site

Table 5 shows the correlation matrix (Pearson correlation) for butterfly abundance, richness, biodiversity and site geographic coordinates. Butterfly abundance positively correlated species richness (R^2=0.34), SI (R^2=0.82) and ABV (R^2=0.34), but negatively with SHI (R^2=0.64). Therefore, 18 to 64% of variability in butterfly species richness, alpha biodiversity (SI) and ABV, respectively, was due to parameters other than abundance.

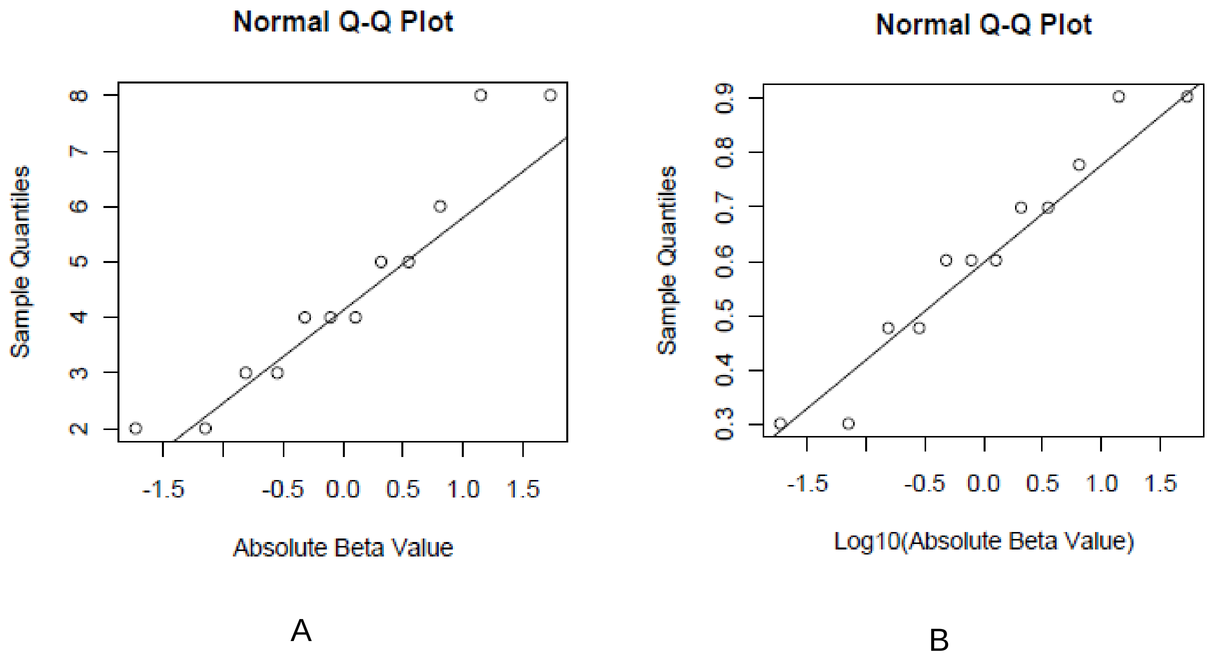

Figure 6. (A) Butterfly beta diversity (original data). (B) Butterfly beta diversity (log transformed data).

Table 5. Correlation matrix for butterflies abundance, richness, biodiversity and sampling site.

Variable	Abundance	Richness	SHI	SI	ABV	Longitude	Latitude
Richness	0.582						
p-value	0.0471						
SHI	-0.7744	-0.5513					
	0.0031	0.0632					
SI	0.9043	0.5353	-0.9222				
	0.0001	0.0729	0.0001				
ABV	0.582	1.0000	-0.5513	0.5353			
	0.0471	0.0001	0.0632	0.0729			
Longitude	0.8303	0.5858	-0.738	0.7896	0.5858		
	0.0008	0.0453	0.0061	0.0023	0.0453		
Latitude	-0.4477	-0.3183	0.5647	-0.5898	-0.3183	-0.0294	
	0.1444	0.3133	0.0558	0.0435	0.3133	0.9277	
Elevation	0.5501	0.4669	-0.2864	0.4831	0.4669	0.2954	-0.5557
	0.0639	0.1259	0.3668	0.1116	0.1259	0.3512	0.0606

Butterflies richness was perfectly and positively correlated with ABV (R^2=1.00). A similar strong correlation was also observed between SI and SHI, although both indices were negatively correlated (R^2 = 0.85). All butterfly parameters were also significantly correlated with longitude, but not latitude and elevation

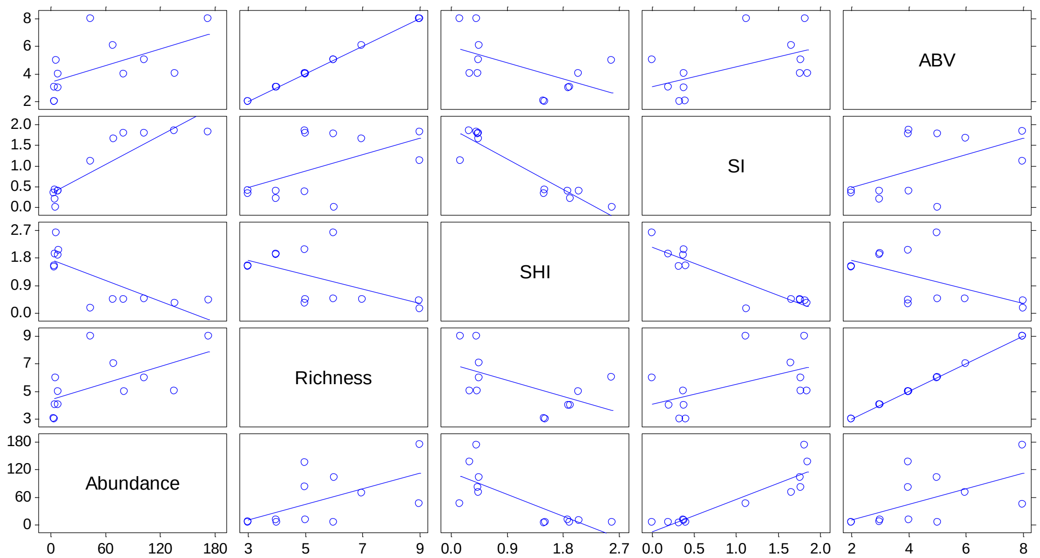

Figure 7. Relationships (linear) between butterflies abundance, richness.

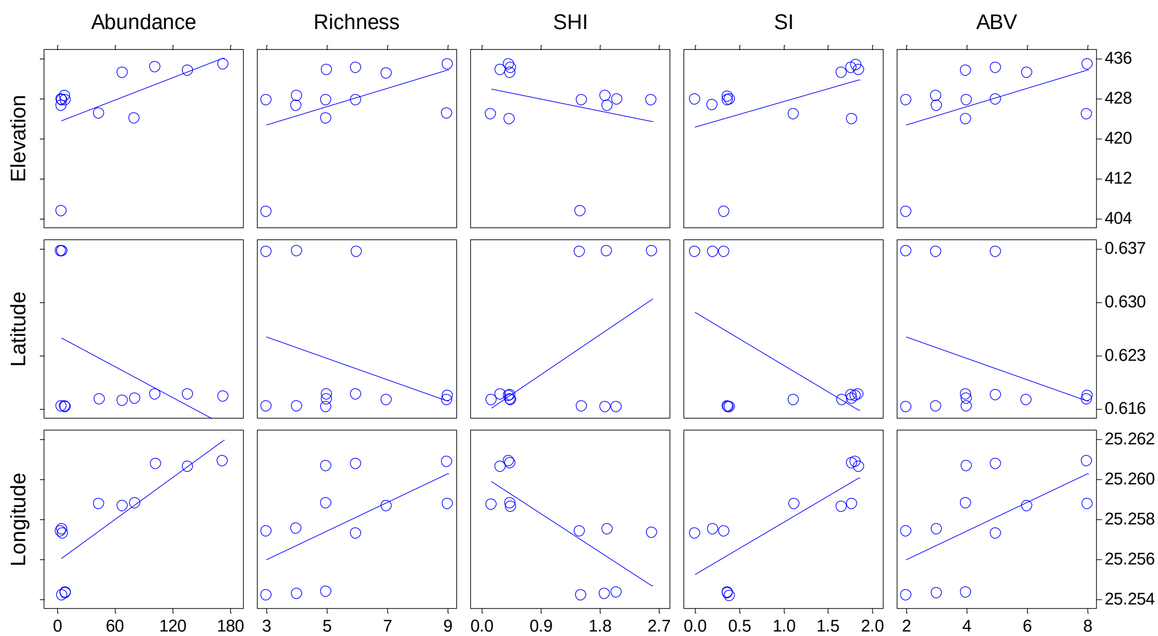

Figure 8. Relationships (linear) between butterflies abundance, richness, and geographic coordinates.

with the exception of SI which negatively correlated with latitude (R^2=0.35). Abundance, richness, SI and ABV either positively or negatively correlated with longitude with coefficient of determination (R^2) ranging between 0.34 and 0.69, implying that 34 to 69% of the variability in butterfly species abundance, richness and biodiversity was due to longitude. The linear relationships between butterflies abundance, species richness and biodiversity are as shown in Figure 7 (among themselves) and Figure 8 for their relationships with geographic coordinates.

Effect of land use type on butterfly abundance and biodiversity as affected by sampling site

To better assess the effect of land use type on butterfly

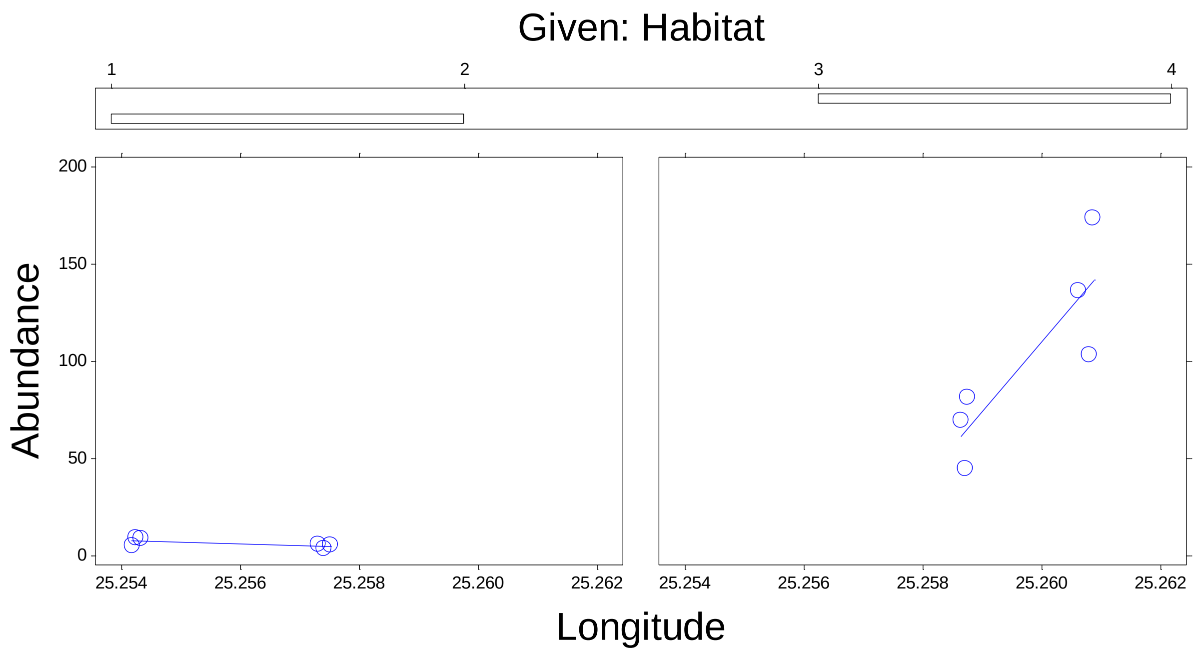

Figure 9. Effect of land use type (LUT) on butterflies abundance as affected by geographic coordinates (longitude). LUT: 1=Primary forest, 2=Secondary forest, 3=Agricultural field, 4=Fallow.

abundance by sampling site as represented by geographic coordinates (longitude), a co-plot was produced (Figure 9). The plot shows that in the primary forest and secondary forest (land use types 1 and 2), butterfly abundance decreased as longitude increased, but the relationship was not strong enough. However, in the agricultural field and the fallow (land use types 3 and 4), butterfly abundance increased as longitude increased with a very clear linear trend. Similar to abundance, a co-plot was also produced (Figure 10) to better assess the effect of land use type on butterfly biodiversity (SI) as affected by geographic coordinates (longitude). The figure shows a similar trend to that observed for abundance in Figure 9, but with more clear results. As for abundance, in the primary forest and the secondary forest (land use types 1 and 2), SI decreased as longitude increased. However, in the agricultural field and the fallow (land use types 3 and 4), SI increased with increasing longitude. It is therefore clear that longitude is a controlling factor for butterfly abundance and biodiversity at Masako Forest Reserve.

DISCUSSION

Butterflies abundance and biodiversity were higher in the fallow as compared to the primary forest. This is understandable as the fallow contained more flowering plants at this time of the year, greater plant diversity and therefore attracted more butterflies. However, our results disagree with those reported by Stork et al. (2003) who studied butterfly diversity and silvicultural practices in lowland rainforests of Southern Cameroon. Their plots included a cleared and unplanted farm fallow, cleared and replanted forest plots, and uncleared forest plots. The replanted plots were line-planted with *Terminalia ivorensis*, but differed in the degree and method of clearance. They found that sites with the greatest degree of disturbance and lowest level of tree cover had the lowest number of individuals and species of butterflies. The farm fallow had substantially fewer individuals and species of butterflies than the other plots. The replanted plots were intermediate between the farm fallow and uncleared forest in terms of abundance, richness and composition. Barlow et al. (2007) evaluated the value of primary, secondary and plantation forests for fruit-feeding butterflies in the Brazilian Amazon. They recorded 10587 butterflies and 128 species in 3200 trap-days. Species richness was the highest in primary forest and lowest in plantations, while butterfly abundance showed the opposite response. Finally, Hamer and Hill (2000) analysed a number of studies comparing tropical butterfly communities in logged and unlogged forests and found that in some studies butterflies abundance and diversity were greater in unlogged forests (Holloway et al., 1992; Hill et al., 1995) while in other studies were less in unlogged forests (Raguso and LLorente-Bousquets, 1990; Hamer, 1997) and sometimes the same in both

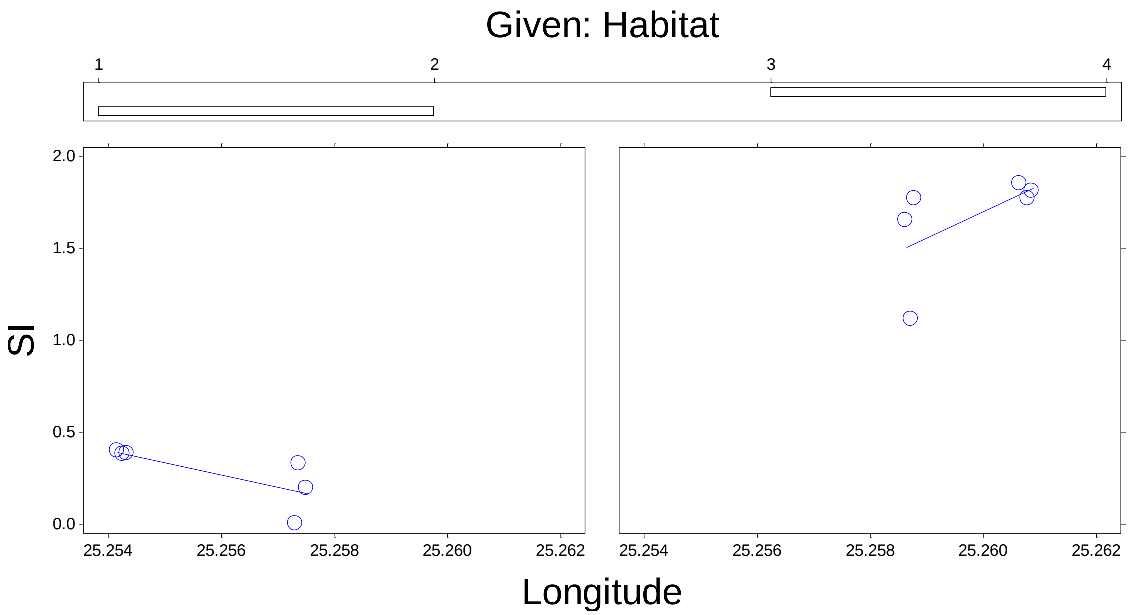

Figure 10. Effect of land use type (LUT) on butterflies biodiversity (SI) as affected by geographic coordinates (longitude). LUT: 1=Primary forest, 2=Secondary forest, 3=Agricultural field; 4=Fallow.

logged and unlogged forests (Wolda, 1987). Their analyses of these studies showed that the effects of forest disturbance on species diversity are heavily scale dependent. They found that both species richness and species evenness increased at a significantly greater rate with spatial scale in unlogged forest than in logged forest. Although, not significantly different, but in magnitude, butterflies abundance and diversity were higher in secondary as compared to the primary forest. Other studies have also examined butterflies in secondary vs. native forest and reported both higher (Bowman et al., 1990; Lawton et al., 1998; Ramos, 2000; Fermon et al., 2005; Bobo et al., 2006) and lower (Schulze et al., 2004; Veddeler et al., 2005) levels of species diversity and richness in the secondary forest as compared to native forest. Butterflies abundance, species richness and biodiversity were all correlated with longitude. Although the latitudinal gradient of species richness is well documented for a variety of taxa in both terrestrial and aquatic environs (Willig, 2000; Brown et al., 1996) and that both environmental and geographical factors affect the distribution of species (Dennis et al., 2000), no study was found assessing the relationship between longitude and butterflies species. However, Storch et al. (2003) studied the distribution patterns in butterflies and birds of the Czech Republic, separating the effects of habitat and geographical position. They reported that latitude and longitude invariably accounted for a large proportion of total variance for butterfly distribution, and their effect was highly significant even after controlling for the effect of all other environmental factors.

Implications for conservation

Previous studies have yielded opposing results as to the effect of land use type on butterfly abundance, species richness and biodiversity (Stork et al., 2003; Barlow et al., 2007; Hamer and Hill, 2000; Holloway et al., 1992; Hill et al., 1995; Raguso and Llorente-Bousquets, 1990; Hamer et al., 1997; Wolda, 1987; Bowman et al., 1990; Lawton et al., 1998; Ramos, 2000; Fermon et al., 2005; Bobo et al., 2006; Schulze et al., 2004; Veddeler et al., 2005). This study has found that the fallow (disturbed) had the highest butterfly abundance and biodiversity as compared to the primary forest (undisturbed), therefore confirming some of the previous results while contracting other ones. The study also found that geographic coordinate (longitude) was a controlling factor for butterfly abundance, species richness and biodiversity, but this relationship varied with land use type. Although similar and opposed results to the findings of this study have been reported by other researchers, it is suggested that further studies be conducted at Masako Forest Reserve.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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