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Inventory of diurnal butterflies in tropical agroecosystems as bioindicators of environmental quality

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ABSTRACT

The research study was carried out at the Tiktik Kaanu Indigenous Community, specifically at the Agroforestry Transfer Center (CeTAF as in Spanish), to describe the taxonomic distribution of the diurnal Lepidoptera captured about their different agroecosystems. As well as to make known, the wealth, abundance, and ecological functions of each taxonomic group. Through exploratory and descriptive research, an inventory was made to identify the diversity of species existing in the site. The sampling reflected a total of 409 individuals with 41 species of butterflies belonging to 8 subfamilies. the most representative family and subfamily in some species and abundances were Nymphalidae and Heliconae respectively, being the most abundant *Heliconius Herato*. *Petiverana*. There were significant differences in the richness and diversity of the research locations, existing a decrease as the landscape structure changes according to characteristics that influence the butterfly community. The change of natural habitats into areas of agricultural use may become a factor that modifies the structure of butterfly communities in the region. The inventory of diurnal butterflies in the CeTAF area is the first inventory of Lepidoptera that is carried out in the Caribbean area, which is within the Cerro Silva natural reserve in the Rama-Kriol territory that undoubtedly generates a base of important data for the region.

INTRODUCTION

Research that focuses on the relationships between biodiversity and the physical structure of ecosystems is of broad interest because it provides important information for the knowledge of landscape ecology and generates the basis for the design and implementation of plans and programs aimed at the conservation of biota. Determining the richness and its relationship with the physical environment helps to specify the appropriate management of populations and could be a tool in conservation plans for certain areas (Fagua, 2001). The transformation of natural habitats generates alteration of their physical conditions, a situation that can affect the availability of resources. Consequently, some species of animals and plants can be negatively affected. One of the main causes of the global loss of diversity is the transformation of tropical forests due to human activities (Kattan, 2002), as a result, forest fragments are immersed in a modified matrix which may represent different qualities for the fauna.

Of all the insect orders present in nature, the diurnal butterflies are the most studied, because they are characterized by being highly sensitive to changes resulting from disturbances in their habitat, and can reflect the state of conservation of a biota, its diversity, endemism, and degree of intervention. Lepidoptera is an important indicator and constitutes a fundamental element in the food chain; they are abundant, stable, diverse, easy to handle in the field and the laboratory, have short life cycles and have sensitivity and high ecological fidelity (Brosi, 2008).

In Nicaragua, studies are still being carried out to date that shows the diversity and composition of Lepidoptera in some natural areas, but even so, there is still much to be investigated, not only in natural protected areas but in different parts of our country. The importance of this study lies in the fact that it can contribute to characterize the diversity of Lepidoptera in the Agroforestry Transfer Center, Tiktik Kaanu Community. This to complement the inventories of species, to be able to estimate their richness that in turn will be used as bioindicators of the state of the quality of the evaluated agroecosystems to focus efforts on the maintenance of these areas.

The conservation of the biodiversity of the Agroforestry Transfer Center (CeTAF) is being affected by the advance of the agricultural frontier and the loss of habitats. This situation leads to the fragmentation of the tree masses and the replacement of the flora and fauna populations typical of the agro-ecosystems that need adequate conditions to be present. Besides, the population is unaware that the existence of modifications in the agro-ecosystems does not contribute to the adequate use of the diversity of organisms and the potential of resources that the center has, which can cause the extinction or decrease of species and cause an imbalance in the ecosystem. In this context lies the importance of obtaining information on the taxonomic identification at the level of order and family of the butterflies that inhabit the site, the importance and ecological benefits they provide since there is no information in the center. Therefore, by characterizing the butterfly community present in the landscape and different agro-ecosystems, the study will provide taxonomic information on the Lepidoptera fauna of this region of the country which is little documented for use as biological indicators.

MATERIALS AND METHODS

The Agroforestry Transfer Center (CeTAF) of Bluefields Indian & Caribbean University (BICU), is located 32 km southwest of the city of Bluefields at the geographic coordinates; N 11º 53’ 50. 4” and W 83º 55’ 53.9”, which is within the Cerro Silva Natural Reserve; in the Rama - Kriol Territory, in front of Tiktik Kaanu (La Zompopera), one of the nine communities that make up the territory (BICU, 2014).

The study area is characterized by a humid tropical jungle climate with temperatures ranging from 24 °C to 30 °C. It is considered a humid zone based on Holdridge’s classification of life zones, with an annual rainfall of 2,000 to 4,000 mm distributed over 9 to 10 months, the rainiest month being May. The region is low and swampy, along the coast not exceeding 30 meters. It is located between the coordinates 12”14’ North latitude and 83”45’ longitude (Flores-Pacheco et al., 2017; Rivas et al., 2018).

This study is descriptive because through it the current state of conservation and the composition of the communities of diurnal butterflies in the study area were characterized for their association as bioindicators. Because of them, it has a quantitative approach that using biodiversity and distribution indexes are compared with statistical tests that allowed identifying the relationship between species, communities, their abundance and distribution with the state of the corresponding agro-ecosystem (Martínez et al., 2019). It is of transversal cut due to its development in a time-limited to the dry season of a single year.

Description of the study area

The area where CeTAF is located presents a great floristic and faunistic biodiversity, and varieties of crops, in which insects are present; since they cover all ecosystems, presenting greater importance in pollination and as biological controllers. The forest mass of CeTAF is classified according to its physical characteristics as a secondary forest that has been intervened since it is subject to human intervention in the planting of crops, extraction of wood for construction and firewood for fuel mainly by the indigenous Rama people, this being the most prevalent ethnic group in the area (López, & Aburto, 2010). The areas subjected to sampling are:

Zone I. Pineapple - Citrus Association

Zone 1, which includes the Pineapple-Citrus association, is geographically located at the following coordinates: N 11° 54' 19.6¨ and W 083° 55' 46.6 which correspond to a total area of 3.6 ha. The pineapple plant (*Ananas comosus* L.) is a monocotyledonous, herbaceous and perennial, native to South America in the region of Mattogroso, between Uruguay and Brazil and reported in this research in the study area, which indicates that the climatic conditions of the humid tropics are appropriate for the succession of the species. In this area, the species was in a scarce production of fruits.

Zone II. Coconut - Rambutan Association

Zone II is made up of two species of plants that are different from each other, as they are: Coconut (*Cocos nucifera*), and rambutan (*Nephellium lappaceum* L.), and is located in the geographical coordinates N 11°53'58.6¨ and W 083°55'48.6¨ and represent 1. 5 ha; where the stage is made up of trees with medium canopies, due to the biology of the plant species in the area, in this zone a system of chapia management was applied, filming at the base of the rambutan and coconut trees; also the application of organic fertilizer and pruning was done; This was done with two purposes, to guarantee the penetration of sunlight for smaller species such as pineapples and to make a protective cover for the soil since its function is to cover the bare soil, to prevent surface runoff, to regulate the temperature of the soil, to conserve humidity and to prevent the growth of weeds due to lack of light. In this scenario, there was an evident production in the rambutan and coconut fruits.

Zone III. Cocoa-Almond Association

Zone III is represented by 3.3 ha corresponding to the association of cocoa (*Teobroma cacao* L.) with almond (**Dipteryx oleifera**) which is located in the following coordinates: N 11°54'23.8¨ and W 083°55'39.7¨, where the ecosystem is composed of young individuals up to 10 meters high. In this association, management systems such as pruning were carried out; to allow the penetration of the sun's rays to the smaller species, also the application of organic fertilizer and cleaning of the entire area.

Zone IV: Forest Area

As zone number IV, the wooded area was assigned, which represents an intervened forest of 65.88 ha georeferenced in the coordinates N 11°54'07.3¨ and W 083°55'36.2¨. In this area, there is a community of plants that can be from timber to medicinal species, among others, for both humans and animals, in which there are reciprocal influences between plant species, soil, atmosphere, environment, and the geographical landscape, but not only that but also are the main source of energy and natural habitat of wildlife.

In each case, three 500 m^2 (50 m x 10 m) sampling plots were established, for a total of 12 sampling plots for a useful area of six ha. Taking into account that CeTAF has 75 ha, we will work at a sampling intensity of 6.33% based on the total area of the experimental farm.

Research techniques and instruments

Van Someren-Rydon Traps

These traps consist of a tubular net with plastic rings at both ends. The upper ring has a transparent mica and the lower ring is open, at the top, it has a rope attached to it so that it can be tied to an object or tree. The ring where the butterflies enter is of 10 cm approximately and it is here where the insects enter attracted by the smell of the ferment and are trapped. For the collection of butterflies, 12 Van Someren-Rydon traps were installed, 3 traps for each of the 4 sampling stations distributed throughout the established site (Bañol, 2006). The traps were placed in the morning between 6:00 am and 7:00 am and were monitored twice a day to obtain the sample corresponding to the butterflies captured in the different transepts of the selected agroecosystems. Ripe banana, pineapple, and sugar were used for the elaboration of the attractant; on the other hand, other types of fermented fruits were tried, which were less effective than those mentioned above. The process consisted of cutting the fruit into multiple pieces until it was left in the form of a purée, after which it was placed in a bucket with a lid to let it ferment for 24 hours before being used in the field. In this process, other attractants can be used (mangoes, guava, papaya, etc.).

Use of blender net or hand net

A beating net was used to be able to sample between transects in the course that the traps were checked to catch those butterflies that were flying out of the hanging trap. These species that were captured in the transept of the road are classified for being nectarivorous which is their trophic group to which they belong and for this reason, they never enter the Van Someren - Rydon trap model.

Species Sacrifice

The ways of killing the insects in the field at the time of collection depend directly on the collection techniques used. When traps with baits are used, they normally have 70% ethyl alcohol as a preservative liquid, which kills the organisms. The species captured in the different models of traps were sacrificed using a lethal chamber containing chloroform that causes more or less rapid asphyxiation in the insects. The species were transported in an airtight glass container, inside which there was a base of sawdust, plaster and on which 10 ml of chloroform was applied to avoid the proliferation of fungi due to excess humidity and to be able to maintain the species. The use of chloroform is recommended because it can be detected by its smell and because it kills organisms quickly without causing damage to their color (Dennis, 1974). The specimens were punctured in the center of the thorax with an entomological pin number zero (0), later they were mounted in sheets of airplanes, after that, they were extended wings with the help of flat-tipped tweezers and pins that hold cardboard strips that protect the wings above. This assembly remained for 24 hours, allowing stability to the wings of the species.

To identify the diurnal specimens, each species was captured and photographed for identification through the Nicaraguan Butterflies guides (Maes 2001) and based on the work of Jean-Michel Maes related to Nymphalidae, Pieridae, and Papilionidae of Nicaragua Maes, 1999. The identification was complemented with the online database of other comparative information, to confirm the species.

Estimation of richness and abundance

Diversity

Methods were used to estimate diversity, site-specific richness, and the quantification of the number of species present, which is a simple measure of species richness or diversity (Krebs, 1985). The Shannon-Wiener index is an index based on the concept of equity also known as the uncertainty index because it predicts to which species an individual chosen at random from an agglomeration will belong, and it is based on the assumption that individuals are chosen at random and that species are represented in the sample. This index acquires values between zero and one when only one species is found.

Equation 1. Shannon Biodiversity Index

$$H' = -\sum p_i \ln p_i$$

Where: *H'*: Shannon Diversity. *S:* Total number of species in the community.

pi: Proportion of S formed by the species

Equation 2. Pielou Equity.

$$J' = \frac{H'}{H'max}$$

Where: H': Shannon Diversity.

$H' max$: Maximum diversity expressed =ln (S)

Similarity

The index proposed by Chao, Chazdon, Colwell, & Shen (2005) is based on Jaccard and Sorensen's Classic similarity/dissimilarity models that focus only on the presence or absence of the species, resulting in no accurate estimators for them and poor performance in measuring similarity of beta biodiversity (applied to sampling data), since they make the erroneous assumption that sampling includes all species in the assemblage i.e. the total population. This new index adds a focus on species richness, relative abundance, and adopts a non-parametric strategy incorporating the effect of unseen shared species, thus the new Jaccard index based on abundance is:

Equation 3. New Jaccard index.

$$\hat{J} = \frac{\hat{U}.\hat{V}}{\hat{U} + \hat{V} - \hat{U}.\hat{V}}$$

Where U and V equal the total abundances of the shared species in the assemblages, and the indexes tend to 1 when the landscape similarities are identical and tend to 0 when the assemblages are different or dissimilar.

Information processing

To process the data, it was carried out with the support of the SPSS v. 25 program for descriptive and inferential statistical analyses. Non-normal distribution of the data was identified, so statistical asymptotic significance was used for each variable. It was evaluated using the nonparametric Chi-square (X^2) test (Sokal & Rohlf, 1981) and Shapiro-Wilk (Di Rienzo et al, 2005), with the Chi-square (X^2) test and Spearman's correlation (García-Pérez, 2010), for which the assumptions of Non-Parametric Test Related Samples from the SPSS version 25 program (IBM® Statistical SPSS®, 2016) were analyzed, a posteriori comparisons were made of the

Shannon Biodiversity and Equitability indexes that allowed identifying which agroecosystems present significant differences (α = 0.05) between them.

RESULTS AND DISCUSSION

Table 1. Taxonomic distribution of the diurnal butterflies present in CeTAF agroecosystems

Agro-ecosystems	Family	Subfamilies	Identified species	Frequencies	
				Absolute	Relative
Citrus	PAPILIONIDAE	Papilionidae	*Papilio rumiko*	7	5.79
			Parides eurimedes. mylotes	2	1.65
			Parides sesostris .zestos	5	4.13
			Archaeoprepona demophon. gulina	1	0.83
		Charaxinae	*Prepona dexamenus*	2	1.65
			Zaretis itys	1	0.83
			Hamadryas arinome arienis	5	4.13
			Hypna clytemnestra	1	0.83
		Nymphalidae	*Nessaea aglaura*	1	0.83
			Adelpha cocala lorzae	2	1.65
			Dryas iulia ssp. moderata	7	5.79
			Heliconius hecale zuleika	10	8.26

table continues on next page »

Agro-ecosystems	Family	Subfamilies	Identified species	Frequencies	
				Absolute	Relative
Cítrus	NYMPHALIDAE	Heliconinae	*Heliconius erato ssp. petiverana*	16	13.22
			Heliconius cydno galantus	6	4.96
			Lycorea cleobaea atergatis	9	7.44
			Heliconius sara ssp. fulgidus	14	11.57
			Morpho helenor narcissus	2	1.65
		Morphinae	*Caligo brasiliensis. sulanus*	6	4.96
		Brassolinae	*Pierella luna ssp. luna*	1	0.83
		Satyrinae	*Magneuptychia libye*	1	0.83
			Parides eurimedes. mylotes	2	1.65
	PAPILIO-NIDAE	Papilionidae	*Parides sesostris ssp.zestos*	3	2.48
			Phoebis sennae. marcellina	1	0.83
	PIERIDAE	Coliadinae	*Colobura dirce*	1	0.83
		Nymphalidae	*Nessaea aglaura*	3	2.48
			Heliconius hecale zuleika	12	9.92
Coco-Rambután	NYMPHALIDAE	Heliconinae	*Heliconius erato. petiverana*	25	47.17
			Heliconius sara. fulgidus	10	18.87
			Heliconius cydno galantus	4	7.55
			Lycorea cleobaea atergatis	5	9.43
		Morphinae	*Morpho helenor narcissus*	2	3.77
		Brassolinae	*Caligo brasiliensis. sulanus*	1	1.89
		Satyrinae	*Magneuptychia libye*	1	1.89
			Pierella luna	1	1.89
		Charaxinae	*Memphis xenocles*	1	1.89
			Heliconius hecale zuleika	3	5.66

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Agro-ecosystems	Family	Subfamilies	Identified species	Frequencies	
				Absolute	Relative
Cacao-Almendro	NYMPHALIDAE	Heliconinae	*Heliconius erato. petiverana*	5	7.58
			Lycorea cleobaea atergatis	2	3.03
			Papilio rumiko	2	3.03
			Parides eurimedes. Mylotes	7	10.61
	PAPILIONIDAE	Papilionidae	*Parides sesostris. zestos*	8	12.12
	PIERIDAE	Coliadinae	*Phoebis sennae .marcellina*	1	1.52
			Archaeoprepona demophon. Gulina	4	6.06
			Prepona dexamenus	2	3.03
		Charaxinae	*Memphis mora. Orthesia*	10	15.15
	NYMPHALIDAE	Nymphalidae	*Memphis eurypyle confusa*	3	4.55
			Memphis xenocles	4	6.06
			Memphis sp	3	4.55
			Hamadryas feronia	1	1.52
			Hamadryas arinome arienis	1	1.52
			Historis acheronta	2	3.03
			Historis odius. Dious	4	6.06
			Colobura dirce. Dirce	3	4.55
			Nica Favilla	1	1.52
			Nessaea aglaura. Aglaura	1	1.52
			Dynamine postverta mexicana	1	1.52
			Hypna clytemnestra	1	1.52

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Agro-ecosystems	Family	Subfamilies	Identified species	Frequencies	
				Absolute	Relative
Bosque	NYMPHALIDAE	Heliconinae	*Pyrrhogyra neaerea hypsenor*	1	0.59
			Dryas iulia. Moderata	3	1.78
			Dryas iulia	1	0.59
			Heliconius hecale zuleika	19	11.24
			Heliconius erato. petiverana	52	30.77
			Heliconius sara. fulgidus	27	15.98
			Heliconius cydno galantus	20	11.83
			Philaethria diatonica	2	1.18
			Philaethria dido	2	1.18
			Lycorea cleobaea atergatis	10	5.92
		Morphinae	*Antirrhea miltiades*	1	0.59
			Morpho helenor narcissus	3	1.78
			Caligo brasiliensis. Sulanus	2	1.18
			Opsiphanes quiteria	2	1.18
	NYMPHALIDAE	Brassolinae	*Opsiphanes cassina*	1	0.59
			Pierella luna	3	1.78
			Magneuptychia libye	7	4.14
			Pareuptychia ocirrhoe	11	6.51
		Satyrinae	*Pierella helvetia*	1	0.59
			Dynamine postverta mexicana	1	0.59

The sampling reflected a total of 409 individuals with 41 species of butterflies belonging to eight subfamilies, distributed in three families corresponding to Papilionidae (3), Pieridae (1), and Nymphalidae (37) that represent the specific richness of the diversity of Lepidoptera in the evaluated agroecosystems. This diversity is distributed as follows. In the citrus area, 99 individuals were captured with 20 species (24% of the species sampled). For the area where the Coconut and Rambutan are established, 71 individuals were captured with 14 species (17% of the species sampled). For the Cocoa and Almond site, it was the least rich with 11 individuals and four species representing 3% of the species sampled. Unlike the previous agroecosystems, the forest area represented the greatest richness with 228 individuals that represent 56% of the species sampled.

Nymphalidae was the most representative family with 364 individuals (88%) which constitutes 90% of the families identified (37 species), followed by the family Papilionidae which constitutes 7% of the diversity (3 species) with 42 individuals in the richness (10.26%), the family Pieridae is the least representative with three individuals (0.73%) and comprises 2.43% of the richness of the sampling (1 species). Of the eight subfamilies found in all CeTAF agroecosystems, the one that stood out for its high representativeness in some species and number of individuals was Nymphalidae with 11 species and 27% of the total abundance in the sampling, followed by Heliconinae in some species with nine and Charaxinae with seven. In terms of the number of species, the other subfamilies showed lower values; Satyrinae with five species, Brassolinae and Papilionidae with three, Morphinae with two, and Coliadinae with one species.

The species that predominated in the agroecosystems sampled in general were *Heliconius erato. Petiverana.* (98 ssp), *Heliconius sara. Fulgidus* (51 ssp) and *Heliconius hecale zuleika* (44 ssp), *Heliconius cydno galantus* (30 ssp) all from the trophic guild Nectarivores. The other taxa such as: *Pierella helvetia, Nica Flavilla, Dryas iulia, Zaretis itys* among other species that appear with unique values, that is, they are less common species during sampling, represented abundances lower than 2%. It is worth mentioning that the species *Prepona dexamenus* was recently reported for the lepidopterous fauna of Nicaragua and so far not reported between Mexico and Panama (Van den Bergue, 2016). All this indicates that the Agroforestry Transfer Center presents a high diversity of interesting species and with a greater effort of capture, the figures could be increased with the same line of research. If studies continue, new species could be discovered because the Caribbean Coast is a site shortly studied in Lepidoptera. Each one of the species captured in the different agroecosystems showed an affinity for the type of habitat and according to the conservation criteria or disturbance in which the different areas were found, in table 2 it can be seen that the forest presents a greater abundance of species, which indicates that the site presents the adequate characteristics, climatic condition, food availability and a good state of conservation for each one of these species. On the other hand, the Nymphalidae family, which is the most representative, shows the majority of species that are usually used as indicators of environmental quality, which means that the area has the ecological characteristics to host species that are indicators of forests in a good state of conservation.

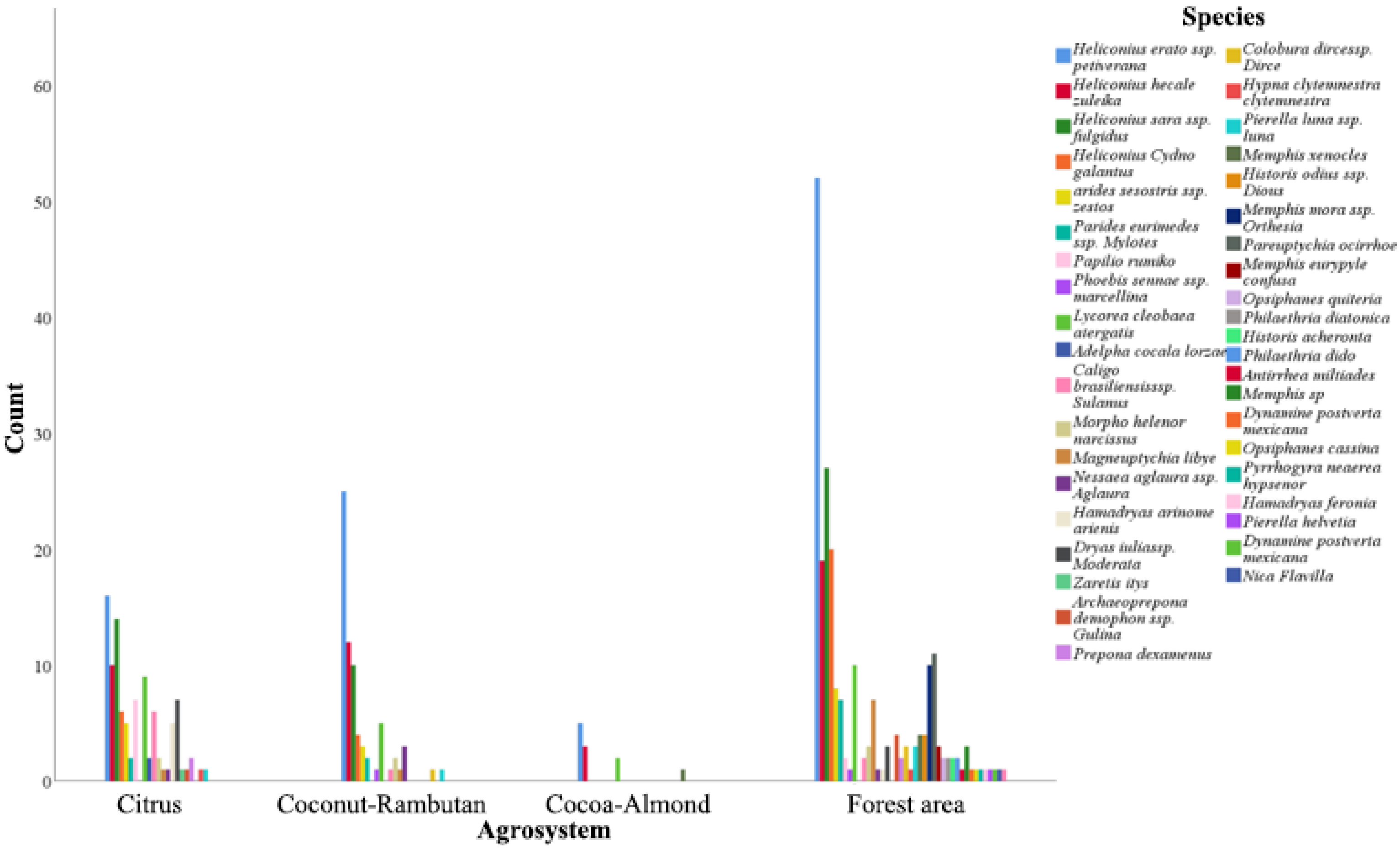

Figure 1. Distribution of butterflies according to CeTAF agroecosystems.

In general terms of richness and abundance, the distribution of species varies proportionally according to the state of conservation of the agroecosystems, the highest values were observed in zone IV of the forest with 228 individuals and 39 species. This is the largest area and presents the appropriate characteristics that species need for their survival, this type of habitat with complex characteristics in the structure of ecosystems provides greater ecosystem services for the subsistence of wildlife, here is a high community of plants, and soil conditions, atmosphere and environment that makes possible the existence of many species.

Unlike the previous site in zone III of the Cocoa-Almond Association, which was less representative, many of the species established in the habitats that are degraded or have little availability of food tend to move to the more conserved ones in search of food and shelter (Galindo, 2004), which also varies according to the butterfly food guild. Another hypothesis is that there is little penetration of sunlight at this site, which may affect the development of certain crops and plants that are hosts to the butterflies. In the area of citrus and rambutan, it can be observed in table 2, that these present a high similarity in the diversity and abundance of species that are indicators of quality and habitat disturbance, these areas have a close relationship because both have been occupied to establish certain crops.

The distribution of species appears proportionally according to the conservation of habitats, from the most complex to the least complex. Species behavior has preferences for one type of habitat, which may indicate changes in environmental systems. The forest has the highest rate of biodiversity because this habitat does not have a high impact of disturbance, which makes the presence of multiple species possible. This gives us the idea that as the forest cover (space and food) increases and the fragments decrease, the richness increases, and therefore most of the species are found in these habitats. The answer to why some areas are more diverse than others is since there are intervened areas, allowing certain species to disappear or move to more conserved areas in search of food and shelter, which depends on the type of feeding of the species. Each individual presents adaptability that is classified according to their response to the fragmentation of the landscape since they present a close relationship between plant and species and when an area is altered they are the first to feel the change.

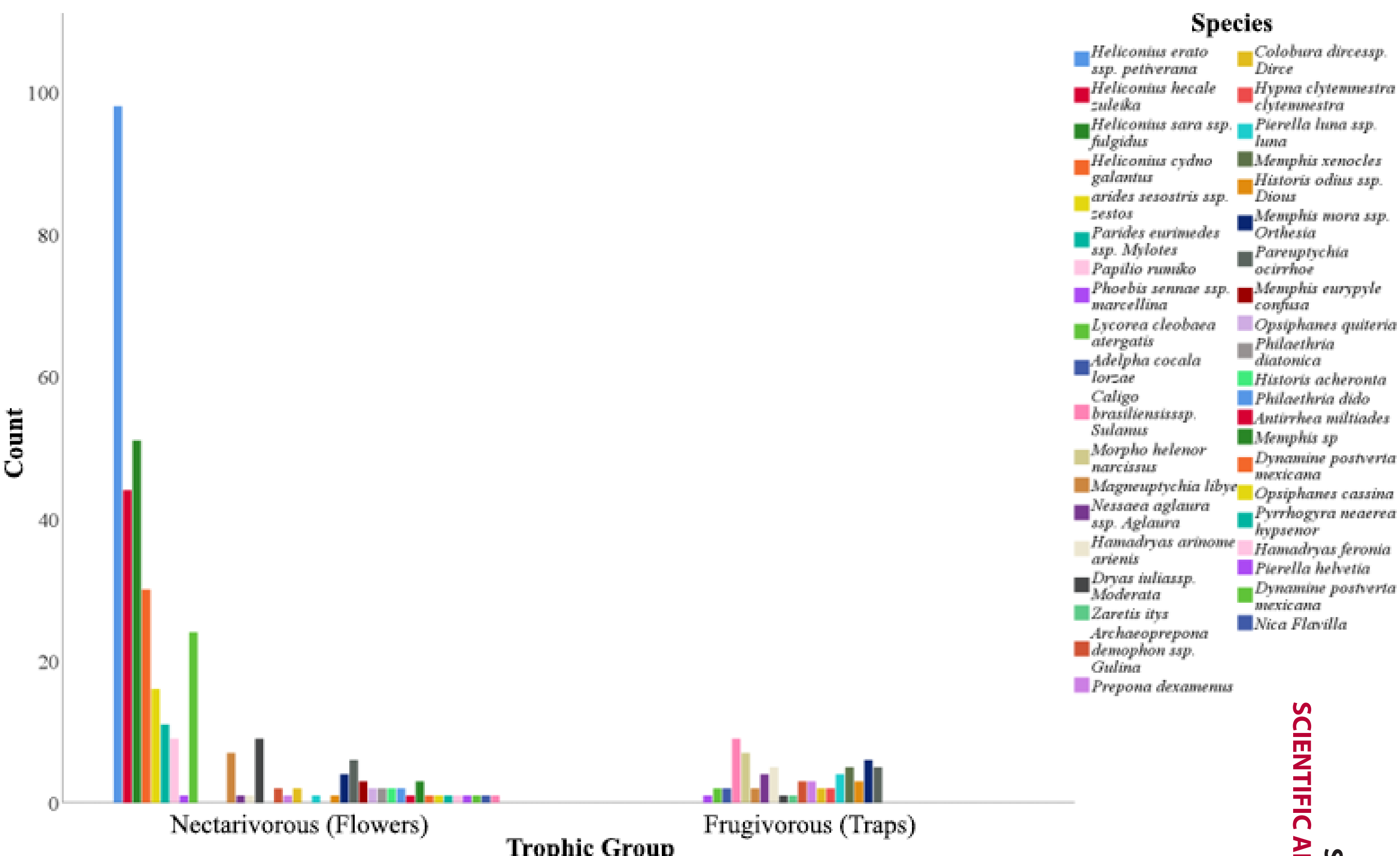

Figure 2. Distribution of the butterfly species captured in CeTAF according to the trophic group.

In the study, the structure of the distribution of the butterfly species captured in CeTAF according to the trophic group varied proportionally, twelve species are nectarivorous and correspond to 29% of the registered species, these are classified according to their feeding because this type of species never enters the Van Someren Rydon traps that contain bait inside; The main function of these species is pollination since they feed on flower nectar, playing an important role in the environment and allowing the production of cultivated plants (Manson, 2008). On the other hand, 29 species of the fruit-eating guild correspond to this group and comprise 71% of the registered species. Unlike the previous group, these species usually feed on the decomposition of fruits that fall from the trees and often on salts dissolved in wet sand, which is why they are usually captured with fermented fruit attractant (Andrade, 1998).

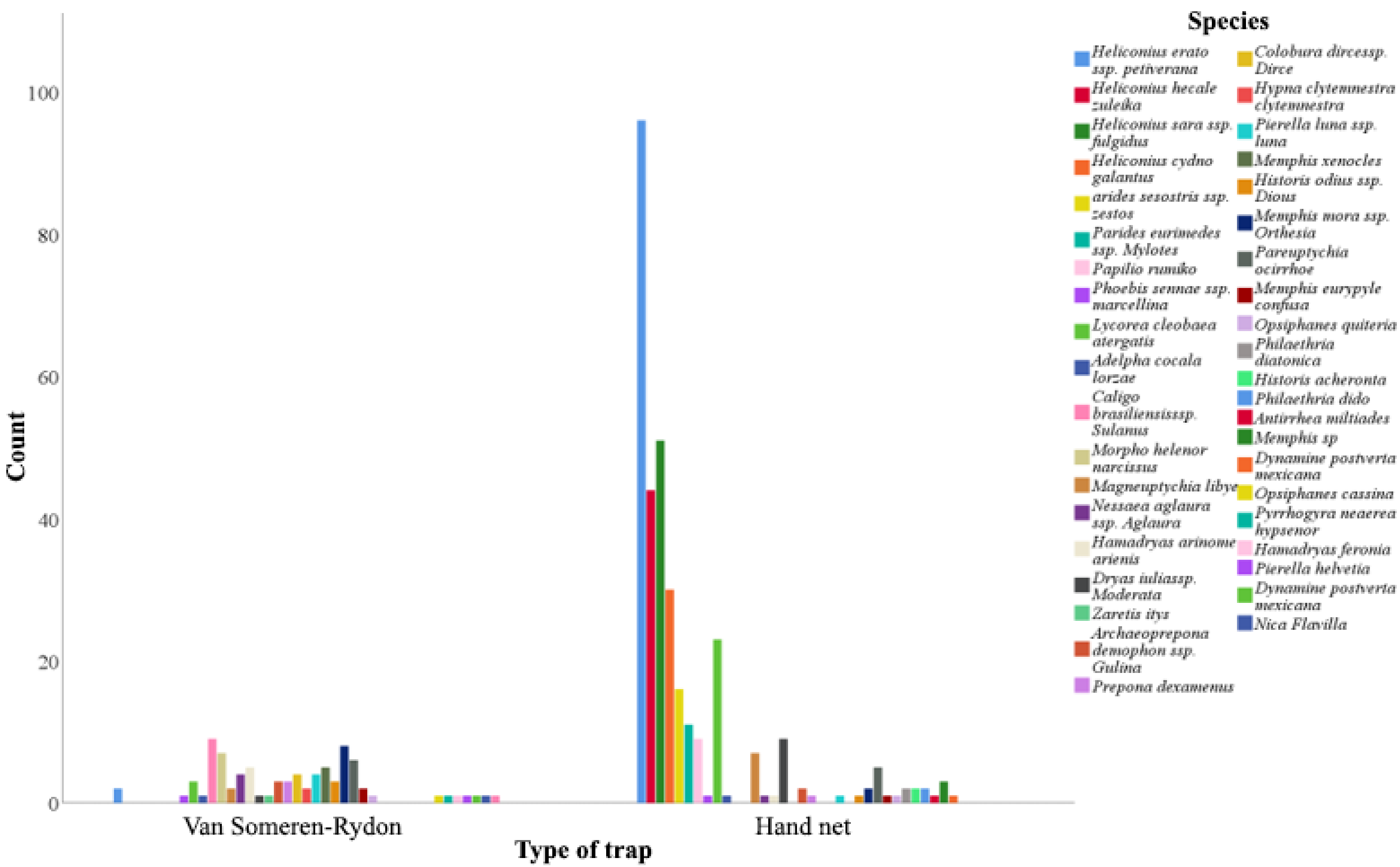

Figure 3. Distribution of butterfly species captured in CeTAF according to the type of trap.

The distribution of butterfly species captured in CeTAF according to the type of trap varied significantly, in the case of the Van Someren Rydon trap it presented a high diversity of species, but was low in abundance. In the case of the hand net, this was used to capture those species that were outside the established trap transects, being an effective method and presenting a high abundance of species, but little diversity. Both traps are effective, but with the Van Someren Rydon trap, it was confirmed that it attracts more interesting species and that at first glance they cannot be monitored with the other type of trap. The type of attractant is another method that can be alternated to evaluate its effectiveness using different types of fermented fruits. This diversity of species plays an important role in the food chain being fundamental for the feeding of other organisms in the food chain and contributes to the balance of the ecosystem.

Table 2. Spearman non-parametric correlations for the variables under study

Agroecosystem	Species	Tropic group	Type of trap
Cítrus	1.000	0.635**	-0.584**
	0.635**	1.000	-0.946**
	-0.584**	-0.946**	1.000
Coconut – Rambutan	1.000	0.609**	-0.609**
	0.609**	1.000	-1.000**
	-0.609**	-1.000**	1.000
Cocoa – Almond	1.000	0.531	-0.531
	0.531	1.000	-1.000**
	-0.531	-1.000**	1.000
Forest Area	1.000	0.620**	-0.620**
	0.620**	1.000	-1.000**
	-0.620**	-1.000**	1.000
** The correlation is significant at 0.001 level (bilateral)			

The analysis of Spearman's non-parametric correlation indicates that in the case of the trophic group and species variable there are high indexes of relationship with statistical trends among the citrus groups, Cocoa-Rambutan, and Forest area (R^2= 0.6; gl= 23; P= 0.001) in contrast to the cocoa almond agroecosystem. This is because the species have an affinity for the established area and it is a function of their feeding, space, quality of habitat, reproduction, and trophic guild, on the other hand, it is influenced by the degree of intervention in which the area is located. In this agroecosystem, the effect of fragmentation and discontinuity of the forests must be considered, which as one of the most outstanding effects has the reduction of biodiversity, distribution of flora and fauna (Kattan, 2002), however, it must also be analyzed that this effect reduces the presence of birds, insects, reptiles and terrestrial mammals as indispensable flyers for the well-being of the ecosystem (Martínez et al., 2019).

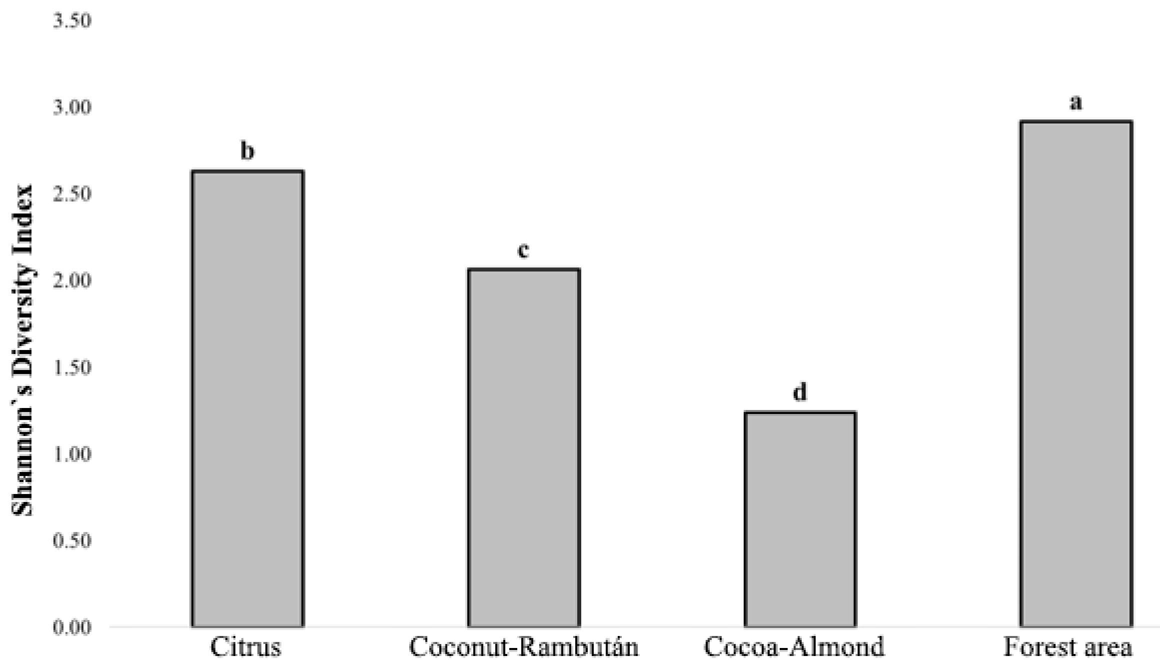

Figure 4. Biodiversity index of butterflies captured in CeTAF agroecosystems. Different letters (a-d) indicate a statistically significant difference (0.05) based on the Chi-square test (X^2).

In the case of the biodiversity of the evaluated agroecosystems, a clear difference was found between them in comparison with the forest concerning the others (F = 5.798, gl=2; X^2: 0.039) especially with the Cocoa-Almond association. This is since this agroecosystem particularly lacks the necessary conditions for a greater presence of species and individuals in it. This can be explained mainly by two reasons; the presence of the trees is dispersed which avoids the generation of a microclimate that provides adequate conditions for the refuge and reproduction of these individuals since they are directly affected by the weathering of the local climatic conditions; on the other hand, the feeding is also scarce due to the little fluorescence of these trees that besides being of specific temporary cycles it must be contemplated that the almond tree (*Dipteryx oleifera*) is a leguminous and the processing of the food becomes more difficult for the Lepidoptera due to the presence of basic oils.

The distribution of the species appears proportionally according to the conservation of the Habitats from more complex to less complex. The area of the forest without intervention hosts the largest number of species and individuals. This type of habitat with complex characteristics in the structure of the ecosystems provides greater ecosystem services for the subsistence of the wildlife and bat communities of the Caribbean in Nicaragua. Meanwhile, Figure 11 shows how the greatest number of species were sampled in the most highly conserved habitats and a significant reduction in the intervened forests. For this reason, the intervened forests have a close relationship with the non-intervened forest because many of the species established in the most degraded habitats move to the more conserved ones in search of food and shelter (Galindo, 2004).

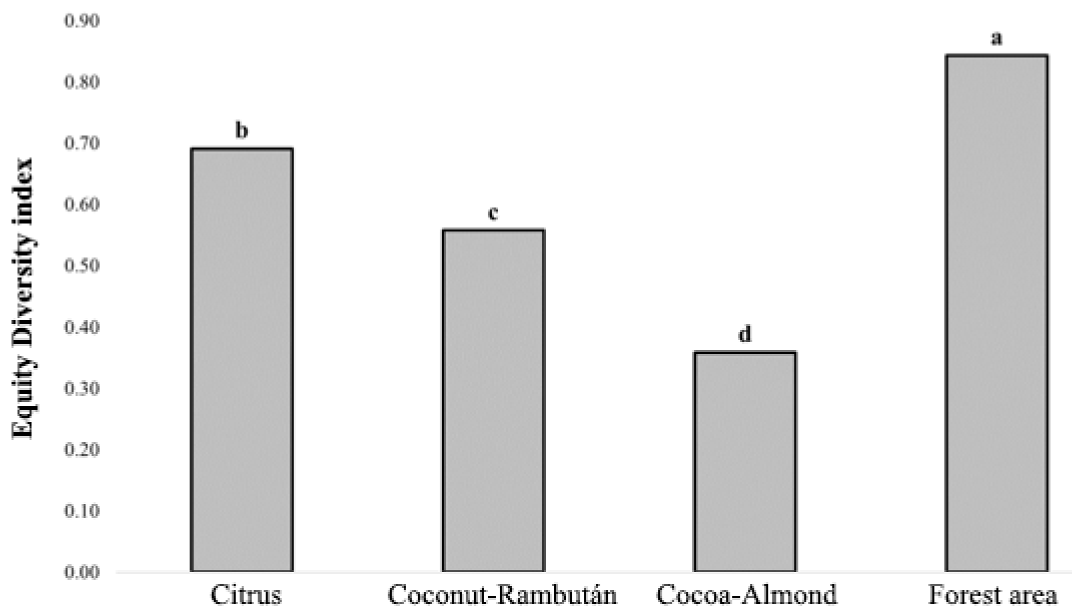

Figure 5. Equitable index of butterflies captured in CeTAF agroecosystems. Different letters (a-d) indicate a statistically significant difference (0.05) based on the Chi-square test (X^2).

To compare the different types of ecosystems, similarity indexes were calculated relating the habitat by the presence and absence of species (MacSwiney G, 2010; Moreno, 2001). Figure 9 complements the findings reflected in Figure 8, where again a statistical difference is identified (F= 1,028, gl=3; X^2: 0,049) between the forest agroecosystem area and the other associations understudy, mainly in the case of Cocoa-Almond. Coincidentally, as biodiversity and its distribution are affected by the lack of reproduction conditions, food, and hosts for the butterflies, the use and environmental burden are also affected. In the case of the Cocoa-Almond association, its use is unequal, which implies greater pressure on a limited resource since the individuals found in this agro-ecosystem compete more strongly for the same resources.

CONCLUSIONS

The total number of species found in all the samples represents 10% of the total number of species of fauna registered in our country. The family Nymphalidae was more dominant in the study, with a predominance of the species *Heliconius erato ssp.* (98 ssp) (Heliconinae). However, the subfamily Nymphalidae was more representative in terms of species diversity. The families that stood out the least were Coliadinae, Morphinae, Brassolinae, and Papilionidae. Also, the Prepona Dexamenus species stood out in this study because it was recently reported for the fauna of Nicaragua. The agroecosystems evaluated showed marked differences in composition, richness, and diversity. The forest area presented the greatest number of individuals and species; assuming that it is the result of the interaction between adjacent habitats; on the other hand, the decrease in richness and diversity in the Cocoa-Almond area may be related to the same changes that occur in this type of habitat, which generate microclimate parameters that affect the distribution of species.

The composition, richness, and diversity of butterflies showed both positive and negative correlations with different landscape characteristics, demonstrating with particular interest that more fragmented and complex landscapes can be richer and more diverse than those with less complex and homogeneous structural characteristics. The degree of disturbance and climatic factors such as seasonality plays an important role in the population changes of butterfly species. The study presented data of species that indicate the quality of habitats such as *Nessaea Aglaura, Pierella Helvetia, Opsiphanes Auiteria, and Prepona Dexamenus*.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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