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RESEARCH ARTICLE

Mountain cloud forest and grown-shade coffee plantations: A comparison of tree biodiversity in central Veracruz, Mexico

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Abstract

Aim of study: The objective of this work is to compare tree diversity and richness among one grown-shade coffee plantation (CAE) and two sites of montane cloud forests, one preserved (MCF1) and other perturbed (MCF2). We also develop an analysis of the importance of coffee plantations as a refuge of tree species, holding a potential role for conservation.

Area of study: Our study area is the coffee region of Coatepec-Xico, in the state of Veracruz, Mexico.

Material and Methods: We compiled a list of all tree species in each site to determine tree diversity and floristic similarity (dissimilarity). We used different similarity indices and a cluster analysis to show relations among sites.

Main results: 2721 individuals from 154 species were registered in the montane cloud forests as a whole. In the grown-shade coffee plantation we registered 2947 individuals from 64 species. The most similar sites were the perturbed montane cloud forest and the grown-shade coffee plantation and the least similar were the preserved montane cloud forest and the grown-shade coffee plantation. The high biodiversity found in all sites and the differences in tree composition between the two montane cloud forests supports evidence of the ecosystems richness in the region.

Research highlights: Diversity differences among sites determine that the grown-shade coffee plantation is not substitute for montane cloud forest. CAE's are developed under similar environmental conditions than the MCF; therefore, coexistence and recombination (replacement) of species make them particularly complementary. CAE's in Veracruz have a potential role as refuge for biodiversity.

Keywords: Agroforestry systems; floristic similarity; diversity; richness; biodiversity refuge.

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Introduction

In tropical regions, extensive conversion of forests and agricultural intensification are typically identified as the most prominent drivers of land-use change and biodiversity loss (Sala *et al*., 2000; Wright 2005). The mitigation of tropical deforestation and biodiversity protection must address livelihoods and needs of local communities (Bhagwat *et al*., 2008). In this sense, agroforestry is considered as a promising approach to reduce deforestation and improve rural livelihoods in the tropics (Current *et al*., 1995; Ashley *et al*., 2006). Agroforestry is a land-use management system where trees or shrubs develop around or among crops or pastureland, providing economic, social and environmental benefits (McNeely, 1995; Bhagwat *et al*., 2008).

Agroforestry systems are often very small in size and surrounded by open landscapes and resemble forest fragments. Species distinctiveness (presence of rare or endemic species) is frequently low, even though their species richness (total number of species) might be equal to, or higher than that of neighboring forests (O'Dea & Whittaker, 2007). Many agroforestry systems are important for protection of species and habitats outside protected areas, and agroforestry systems can be considered as refuges for biodiversity (Bhagwat *et al*., 2008; Manson *et al*., 2008; Nonato de Souza *et al*., 2012). These systems conserve biodiversity in remnant habitats and provide potential movement for species among these remnants (Bhagwat *et al*., 2008). These systems also provide environmental services such as carbon stock and sequestration (Albrecht & Kandji, 2003; Dávalos Sotelo *et al*., 2008; Thangata & Hildebrand, 2012), improvement of environmental quality (Tornquist *et al*., 1999; Geissert & Ibáñez, 2008), water harvesting, reducing water runoff, and increased recharge of aquifers, reduction of floods and droughts, among other services (Mejía *et al*., 2004).

Almost three quarters of the planet's surface and 67.3% of Mexico's surface are covered by ecosystems managed or modified by humans (Pimentel *et al*., 1992; McNeely, 1995; Palacio-Prieto *et al*., 2000; SAGARPA, 2007). Because of the dominance of these systems, their management changes can affect biodiversity conservation and ecosystem services (Tilman *et al*., 2002; MEA, 2005). For the montane cloud forest (MCF), despite its high strategic value for sustainable development, the key role it plays in the hydrological cycle, and being considered as reservoir of endemic biodiversity (Toledo-Aceves *et al*., 2011), in Mexico it is considered the most threatened terrestrial ecosystem because of land-use changes and the effects of global climate change. Currently, this ecosystem has been assigned as high priority for conservation and promotion of sustainable development (Aldrich *et al*., 1997; CONABIO, 2010; Toledo-Aceves *et al*., 2011; Calderon Aguilera *et al*., 2012).

Montane cloud forest (MCF) in Veracruz occupies ca. 1243.65 km^2 (1.73% of the total area; Ortega & Castillo, 1996; Ellis & Martinez, 2010; Castillo-Campos *et al*., 2011). In the central region of the state the MCF area was reduced gradually because of the expansion of the coffee cultivation. Since the late XIX century to 1960's, MCF's were replaced with coffee agro-ecosystems (Ruelas-Monjardín *et al*., 2014), and the forest fragmentation was accelerated because of the demographic pressure and territorial expansion (Williams-Linera *et al*., 2002), where the greatest impact on vegetation (transformation in species composition) was caused mostly by deforestation, fires, plantations establishment, and land-use conversion to pasture (Ellis & Martinez, 2010). As a result the development of several types of grown-shade coffee such as shade monoculture, simple polyculture, diverse or traditional polyculture, and rustic plantations in which the forest canopy is used as shade for coffee have taken place.

Currently, Veracruz is the second largest producer of coffee in Mexico with the 24.7% of the national coffee production, occupying an area of 1520 km^2, equivalent to 13.92% of total of vegetation present in the state (Olguín *et al*., 2011). Coffee agro-ecosystems (CAE) are developed at the lowest elevation of the MCF under similar environmental and climate conditions; therefore, coexistence and recombination (replacement) of species make them particularly complementary (Castillo-Campos *et al*., 2011). When coffee plantations are under shade, the system "CAE–MCF" maintains forest cover, although with less species diversity compared to the undisturbed MCF. However, because of its structure, species diversity, and environmental services provided, CAE's are of great importance for conservation (Ellis & Martinez, 2010; Olguín *et al*., 2011; Toledo-Aceves *et al*., 2011).

In this work, we compared tree diversity and richness among one grown-shade coffee plantations (CAE) and two sites of montane cloud forests (MCF), one preserved (MCF1) and other perturbed (MCF2), in the coffee region of Coatepec-Xico, Veracruz, Mexico. We also analyzed the importance of coffee plantations as a refuge of tree species, holding a potential role for conservation.

Material and methods

Study area and site selection

The coffee region of Coatepec-Xico is located in the central highlands of the state of Veracruz, Mexico (19° 29' 25''N, 97° 02' 30''W). In this region, the MCF is the dominant vegetation type. The area is located in the eastern slope of the Cofre de Perote, with altitudes from 1000 to 1350 m asl. Climate is temperate humid with an average annual temperature of 18 °C and annual precipitation between 1000 and 1500 mm (CONABIO, 2010; González-Espinosa *et al*., 2012). Dominated soil types are yellowish soils derived from volcanic rocks (Gómez-Pompa, 1978). The coffee region is located near the city of Coatepec in central Veracruz. Coatepec is the largest coffee producer of the state, with 24.59% of the total cultivated area in Veracruz (Landeros-Sánchez *et al*., 2011; Olguín *et al*., 2011).

We selected three sites. The first site (MCF1) corresponded to a preserved forest located at La Cortadura (19°29' 29''N, 97° 01' 58''W). The second site (MCF2, 19°26' 29''N, 97° 00' 02''W) was a perturbed forest, finding vegetation disturbance by anthropogenic causes with presence of *Citrus* spp. and some species of primary succession such as *Senecio arborescens* and *Myrsine coriacea.* The third site, a coffee agro-ecosystem (CAE) was located near to La Orduña (19° 29' 17''N, 97° 55' 32''W; Figure 1).

Data collection

For each MCFs site we sampled an area of 1500 m^2 with two perpendicular and two parallel transects. For the CAE site we also sampled an area of 1500 m^2 divided in ten traditional coffee areas dedicated only to

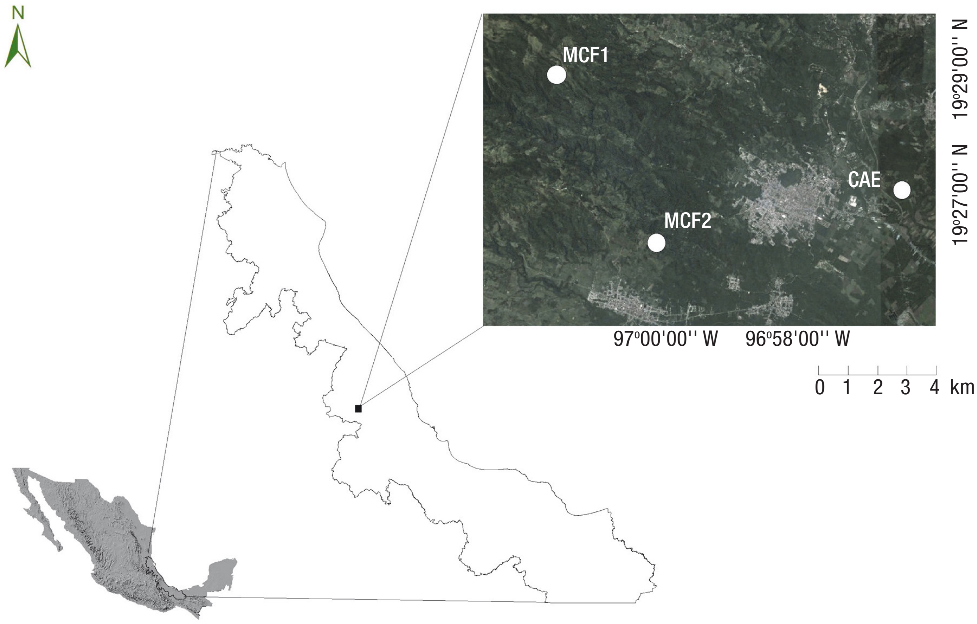

Figure 1. Study area and the study sites: undisturbed montane cloud forest (MCF1), perturbed montane cloud forest (MCF2), and coffee agro-ecosystem (CAE) within the coffee region of Coatepec-Xico located in the central highlands in the state of Veracruz, Mexico.

the grown-shaded coffee cultivation. We used the method of sample collection established by Mostacedo & Fredericksen (2000) and CONAFOR (2011). In the field, we determined the most dynamic areas of change and the more complex vegetative structures to be sampled and made transects of 15 x 100 m using GIS. This method was applied for the three sites. Sampling transects ended when new species were not found, and only repeated species were counted.

We counted all tree individuals within the sites, categorizing them *in situ* into two size classes: *i*) woody species with diameter at breast height (DBH) < 10 cm, and *ii*) woody species with DBH > 10 cm. All individuals counted at each site were identified to species level following the nomenclature of the Flora of Veracruz (Sosa & Gomez-Pompa, 1994) and the classifications of Cronquist (1988). Specimens that could not be identified in the field were collected and subsequently identified using taxonomic keys in the laboratory of Tropical Ecophysiology of the Institute of Ecology, Universidad Nacional Autónoma de México (UNAM).

Data analysis

All individuals found and counted were taken into account for the diversity estimation. The compiled list of all tree species was used to calculate species richness, diversity indices, and floristic similarity (dissimilarity) for all study sites. Diversity was determined considering the number of tree species per unit of sampled area. Species diversity of each site was determined using the indices of dominance and equity of Margalef (DMg) and Simpson (λ), equity of Menhinick (DMn), and Shannon-Wiener; this in order to obtain the diversity parameters of species and their quantification and representativeness (Mostacedo & Fredericksen, 2000; Moreno, 2001; Villarreal *et al*., 2004). To compare the number of species shared among sites, we estimated the floristic similarity using the similarity/dissimilarity indices and the coefficients of Jaccard (IJ), Sørensen (IS), Morisita-Horn (IM-H), and the similarity coefficient of Sørensen for quantitative data (Iscuant). All data were entered with the established formulas of diversity indices to a database where calculations were performed to determine the diversity in *Excel version 14.5.2.*

For a visual representation of the potential relationships among sites and to determine whether the degree of environmental disturbance of each site allowed a specific grouping we plotted a cluster dendrogram. In this case we used as measure the distance of Manhattan and the Average method. All statistical analyses were conducted using the statistical environment software R (RCoreTeam, 2014).

Results

The most representative/abundant species were: *i*) MCF1: *Parathesis melanosticta* and *Hedyosmum mexicanum*, *ii*) MCF2: *Beilschmiedia mexicana*, *Clethra macrophylla* and *Carpinus tropicalis,* and *iii*) CAE:

Citrus spp. and *Inga vera* (Table 1). For MCF1 the 14 most abundant species accounted only 15.26 %; whereas for MCF2 and CAE the 14 most abundant species accounted 70 and 77.5% respectively (Table 1). For MCF2 we found several species that evidenced the perturbation degree: *Citrus* spp., *Heliocarpus donnell-smithii, Lippia myriocephala, Myrsine coriácea, Solanum schlechtendalianum* and *Trema micrantha.*

2721 individuals from 154 tree species were registered in MCF1 and MCF2; 116 species in MCF1 and 38 in MCF2. In CAE we registered 64 tree species with 2947 individuals (Table 1). The highest and lowest species diversity corresponded to MCF1 and MCF2 respectively; this was reflected in the Margalef (DMg) and the Menhinick (DMn) indices (Table 2). The Shannon-Wiener (H) index also indicated that MCF1 had the greatest diversity of species, and the Simpson dominance (λ) index showed that CAE was the least diverse site, whereas MCF1 was the most diverse (Table 2).

Regarding floristic similarity, we found that MCF1 and MCF2 shared 15 species, with *Alchornea latifolia*, *Psychotria* sp. and *C. macrophylla* as the most represented (higher number of individuals; Table 3). The greatest similarity was found between sites MCF2 and CAE, sharing 16 species, of which the most frequent species were *C. tropicalis* and *Citrus* spp. (Table 3). This similarity between MCF2 and CAE was also observed in the cluster analysis (Figure 2). The sites sharing less number of species (12) were MCF1 and CAE (Table 3). The Jaccard (IJ) and the Sørensen (IS) similarity coefficients, and the Morisita-Horn (IM-H) and the Sørensen (Iscuant) indices also confirmed that sites with less similarity were MCF1 and CAE, and those having the highest similarity were MCF2 and CAE. Values obtained to calculate these indices were higher for both qualitative and quantitative data (Table 4).

Discussion

We confirmed similarity/dissimilarity among sites using different qualitative and quantitative methods. Measuring species' relative abundance and similarity among sites allowed us to identify those species whose low representation make them more sensitive or vulnerable to environmental perturbations: *B. mexicana*, *Miconia glaberrima* and *I. punctata*. It is important to note that the most similar sites were MCF2 and CAE, but only with 16 species, i.e. the 20% of species present in MCF2 and CAE as a whole. Low similarity among sites might be due to the low number of common species between pairs of comparisons, finding a high percentage of species exclusive of each site, which contributes to biodiversity conservation at regional scale. These findings highlight the CAE importance for conservation and the high tree biodiversity in the region, especially considering that the sites are not far apart geographically (Figure 1).

Another important finding is the high dissimilarity between MCF1 and MCF2, where the low number of species in MCF2 shows the shocking biodiversity loss in perturbed areas. Although ecosystems such as MCF2, are subject to influences determined by other species (e.g. predators, competitors, invaders), and temporal and spatial variations of environmental conditions, such as nutrient availability, temperature and precipitation (Chapin *et al*., 2000; Bellemare *et al*., 2002), human activities and perturbations have a great impact on them. Human perturbations can decrease local diversity or richness, as it was seen in MCF2; however, for CAE this is not necessarily true. Human perturbations can widely change floristic composition of ecosystems, but agroforestry can help to mitigate

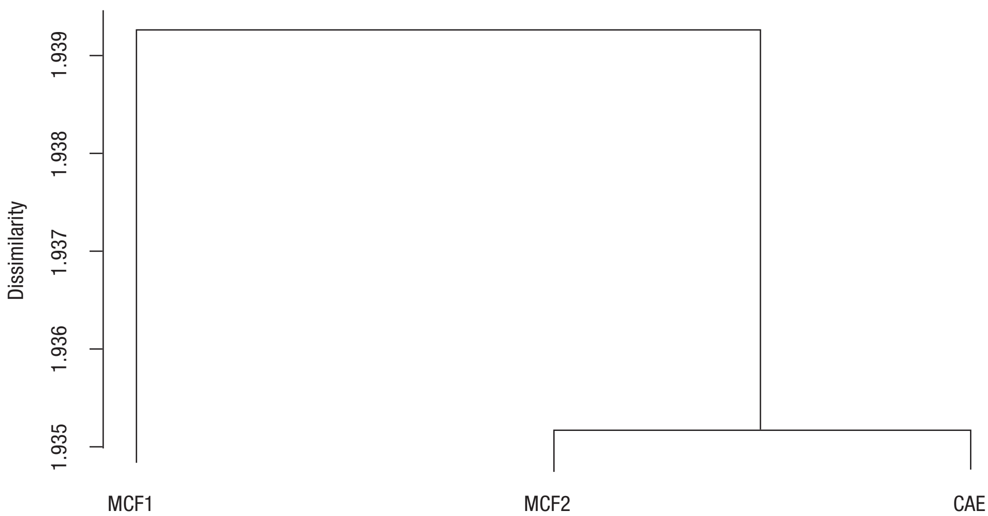

Figure 2. Cluster analysis showing the relationships among our study sites: undisturbed montane cloud forest (MCF1), perturbed montane cloud forest (MCF2), and coffee agro-ecosystem (CAE) within the coffee region of Coatepec-Xico located in the central highlands in the state of Veracruz, Mexico.

Table 1. Total number of individuals and percentage of the most abundant species of the three study sites from the coffee region of Coatepec-Xico, Veracruz, Mexico: *i*) undisturbed montane cloud forest (MCF1); *ii*) perturbed montane cloud forest (MCF2), and *iii*) coffee agro-ecosystem (CAE)

Species	Number of individuals	Percentage (%)
MCF1		
Zanthoxylum melanostictum Schltdl. & Cham	10	0.72
Phyllonoma laticuspis (Turcz.) Engl.	10	0.72
Arachnothryx bourgaei (Standl.) Borhid	10	0.72
Oreopanax xalapensis (Kunth) Decne. & Planch	12	0.86
Clethra macrophylla DC.	12	0.86
Turpinia occidentalis (Swartz) G. Don.	13	0.94
Calyptranthes schlechtendaliana O. Berg	13	0.94
*Miconia glaberrima (*Schltdl.) Naudin	16	1.15
Alchornea latifolia Sw.	17	1.22
Piper xanthostachyum C. DC.	17	1.22
Psychotria spp.	17	1.22
Miconia chrysoneura Triana	18	1.30
Hedyosmum mexicanum Cordem.	22	1.59
Parathesis melanosticta (Schltdl.) Hemsl.	25	1.80
Number of individuals with the highest frequency	212	15.27
Total number of individuals (N)	1388	-
MCF2		
Brunellia mexicana Standl.	38	2.85
Quercus xalapensis Bonpl.	38	2.85
Senecio arborescens Steetz	39	2.93
Quercus leiophylla A. DC.	44	3.30
Myrsine coriacea (Sw.) R. Br. ex Roem. & Schult.	46	3.45
Liquidambar styraciflua L.	47	3.53
Styrax glabrescens Benth.	47	3.53
Citrus spp.	51	3.83
Hampea integerrima Schltdl.	51	3.83
Quercus insignis M. Martens & Galeotti	60	4.50
Turpinia insignis (Kunth) Tul.	79	5.93
Beilschmiedia mexicana (Mez) Kosterm.	90	6.75
Clethra macrophylla DC.	90	6.75
Carpinus tropicalis Walter	214	16.05
Number of individuals with the highest frequency	934	70.07
Total number of individuals (N)	1333	-
CAE		
Inga punctata Willd.	42	1.43
Quercus sapotifolia Liebm.	42	1.43
Alchornea latifolia Sw.	46	1.56
Acrocarpus fraxinifolius Wright & Arn.	47	1.59
Erythrina poeppigiana (Walp.) Skeels.	47	1.59
Eriobotrya japonica Lindley	78	2.65
Enterolobium cyclocarpum (Jacq.) Griseb.	80	2.71
Heliocarpus donnell-smithii Rose	82	2.78
Mimosa scabrella Benth.	144	4.89
Trema micrantha (L.) Blume	145	4.92
I. jinicuil Schltr.	162	5.50
I. latibracteata Harms	163	5.53
Citrus spp.	225	7.63
I. vera Willd.	983	33.36
Number of individuals with the highest frequency	2286	77.57
Total number of individuals (N)	2947	-

Table 2. Diversity components, and indices of proportional abundance of dominance (λ and DS) and equity (Shannon-Wiener) of the three study sites from the coffee region of Coatepec-Xico, Veracruz, Mexico: *i*) undisturbed montane cloud forest (MCF1); *ii*) perturbed montane cloud forest (MCF2), and *iii*) coffee agro-ecosystem (CAE)

	MCF1	**MCF2**	**CAE**
Total number of individuals (N)	1388	1333	2947
Species number (S)	252	64	110
Margalef index DMg	34.69	8.756	13.64
Menhinick index DMn	6.764	1.753	2.026
Simpson index λ	0.0075	0.0532	0.1326
Diversity based on Gini–Simpson index (1−λ)	0.9925	0.9468	0.8674
Shannon-Wiener index	5.1521	3.4613	3.0364

the impacts of land-use change and preserve local biodiversity.

We found that vegetation in CAE included a wide variability of species, and richness increased probably for a species recombination with the MCF surrounding CAE (Villavicencio-Enriquez & Valdez-Hernández, 2003). We observed evidence of this recombination finding species similarities between CAE and the perturbed MFC2. High diversity might be due to a species shift with the MFC nearby (Williams-Linera, 2002). Also, the highest floristic similarity between MCF2 and CAE indicates that CAE is also a perturbed ecosystem. In CAE, the lower diversity in comparison with MFC1 is probably caused by the dominance of some species, partially *Citrus* spp. and *I. vera*.

The floristic composition in CAE is the result of the system's function directed to coffee cultivation. We found in CAE that 33.36% of the individuals were *I. vera*, which are promoted by farmers. Here, it is clear that diversity is influenced by local management, and not only by topography, precipitation or temperature. Trees provide numerous benefits such as building materials, food and firewood, generate family income, promote ecological conditions for wildlife habitats and ecological balance, and also protect against soil erosion (Salam *et al*., 2000). It has been shown that farmers in agroforestry systems select and eliminate certain tree species according to their preferences and beliefs (Salam *et al*., 2000; Russell & Franzel, 2004), and also to morphological characteristics (Schroth, 1995); therefore, species composition is conformed by ecological and biophysical variables, and management as well. Also, farmers are paid to modify their farming practice to provide environmental benefits (Salam *et al*., 2000; Kleijn & Sutherland, 2003). This management provides economic profit and income for local farmers, but it also contributes to improve social levels through the production of important goods, including export crops, fruits, raw material and firewood. Agroforestry systems success lies in the ecological productive capacity over the long term and also in economic benefits (Michon & de Foresta, 1995).

Maintaining biological diversity is essential for productive agriculture, and ecologically sustainable agriculture is in turn essential for maintaining biological diversity (Pimentel *et al*., 1992). This maintenance by CAE is reflected in the high number of different species compared to MCF2 and MCF1, which shows CAE's conservation potential, in spite of the presence of exotic (e.g. *Citrus* spp.) and secondary tree species (Table 1) that would be indicators of disturbance. Also, the high proportion of species registered in CAE can support evidence of the services that can provide this system, although we did not evaluate environmental services. Preservation of this agro-ecosystem might represent a possible solution to minimize local biodiversity loss and improve conservation in the central region of Veracruz, especially because the coffee cultivation is more beneficial to the environment than pasture and monocrops such as sugarcane (Esperón-Rodríguez *et al*., 2016), because coffee conserves tree cover and allows connectivity between open landscapes and forest fragments.

CAE's in Veracruz have a potential role as reservoirs of biodiversity maintaining the forest cover; their conservation as refuges must be considered a priority especially in areas where deforestation and land-use change are increasing. Conservation plans should be addressed to maintain local connection and species recombination between CAE and preserved forests. Knowing the local biodiversity can help local farmers to make better management decision, introducing agroforestry systems with consideration of the markets and products, and also the potential productivity gains and food crops. It must be noticed that although similar, CAE's are not substitute for natural forests; therefore, surrounding forest play an important role in conservation, especially for species that cannot thrive in human modified landscapes. Local management must prioritize the biodiversity preservation and conservation.

Table 3. Tree species diversity comparison among the study sites from the coffee region of Coatepec-Xico, Veracruz, Mexico: *i*) undisturbed montane cloud forest (MCF1); *ii*) perturbed montane cloud forest (MCF2), and *iii*) coffee agro-ecosystem (CAE)

Species	Number of individuals		Percentage (%)	
	MCF1	MCF2	MCF1	MCF2
Alchornea latifolia	17	2	0.1848	0.0054
Cinnamomum effusum	9	13	0.0978	0.0352
Clethra macrophylla	12	90	0.1304	0.2439
Cojoba arborea	1	4	0.0109	0.0108
Liquidambar styraciflua	1	47	0.0109	0.1274
Meliosma alba	2	16	0.0217	0.0434
Myrsine coriacea	2	46	0.0217	0.1247
Ocotea psychotrioides	6	2	0.0652	0.0054
Oreopanax xalapensis	12	4	0.1304	0.0108
Psychotria spp.	17	3	0.1848	0.0081
Quercus xalapensis	3	38	0.0326	0.1029
Styrax glabrescens	4	47	0.0435	0.1274
Symplocos coccinea	1	4	0.0109	0.0108
Trophis mexicana	4	2	0.0435	0.0054
Total number of individuals	92	369	-	-
	MCF2	**CAE**	**MCF2**	**CAE**
Alchornea latifolia	2	46	0.0047	0.0765
Carpinus tropicalis	214	1	0.50352	0.0017
Cinnamomum effusum	13	2	0.0306	0.0033
Citrus spp.	51	225	0.12	0.3744
Cojoba arborea	4	5	0.0094	0.0083
Erythrina americana	5	13	0.0118	0.0216
Heliocarpus donnell-smithii	5	82	0.0118	0.1364
Juglans pyriformis	3	2	0.0071	0.0033
Leucaena leucocephala	2	4	0.0047	0.0067
Lippia myriocephala	11	1	0.0259	0.0017
Myrsine coriacea	46	8	0.1082	0.0133
Quercus sartorii	21	37	0.0494	0.0616
Solanum schlechtendalianum	4	2	0.0094	0.0033
Tapirira mexicana	18	14	0.0424	0.0233
Trema micrantha	3	145	0.0071	0.2413
Unidentified	23	14	0.0541	0.0233
Total number of individuals	425	601	-	-
	MCF1	**CAE**	**MCF**	**CAE**
Alchornea latifolia	17	46	0.3269	0.1411
Cinnamomum effusum	9	2	0.1731	0.0061
Cojoba arborea	1	5	0.0192	0.0153
Dendropanax arboreus	2	9	0.0385	0.0276
Magnolia schiedeana	3	1	0.0577	0.0031
Myrsine coriacea	2	8	0.0385	0.0245
Oreopanax capitatus	1	2	0.0192	0.0061
Oreopanax liebmanni	6	13	0.1154	0.0399
Persea americana	4	7	0.0769	0.0215
Picramnia antidesma	1	7	0.0192	0.0215
Piper nudum	5	1	0.0962	0.0031
Total number of individuals	52	326	-	-

But, what causes this biodiversity in Veracruz? We registered high biodiversity in our study sites despite the size of the sampled area (1500 m^2). When we compared our results with previous studies from Veracruz, Mexico and South America (Table 5) we found a high biodiversity in Veracruz. Although differences may be due to several factors, precipitation is a factor that caught our attention because rainfall is a highly varying

Table 4. Floristic similarity (dissimilarity) components. Indices of similarity/dissimilarity with qualitative and quantitative data of the three study sites from the coffee region of Coatepec-Xico, Veracruz, Mexico: *i*) undisturbed montane cloud forest (MCF1); *ii*) perturbed montane cloud forest (MCF2), and *iii*) coffee agro-ecosystem (CAE)

	MCF1 & MCF2	MCF1 & CAE	MCF2 & CAE
Number of species shared between sites	15	12	16
Indices of similarity/dissimilarity with qualitative data			
Jaccard similarity coefficient IJ	0.0498	0.0343	0.1013
IJ %	4.9834	3.429	10.1266
Sørensen similarity coefficient of IS	0.0949	0.0663	0.1839
IS %	9.4937	6.629	18.3908
Indices of similarity/dissimilarity with quantitative data			
Morisita-Horn index IM-H	0.1796	0.0912	0.1897
IM-H %	17.959	9.115	18.971
Sørensen index (coefficiente of similarity-quantitative) Iscuant	0.0360	0.0179	0.0640
Iscuant %	3.602	1.799	6.402

Table 5. Biodiversity studies in montane cloud forests and coffee agro-ecosystems comparing mean annual precipitation (Pp), and species and individual numbers. In bold is indicated data from this work

Location	Pp (mm)	Species	Individuals	Reference
Montane cloud forest				
Teocelo, Veracruz	1500 - 2500	277	600	Luna *et al*. (1988)
Cofre de Perote, Cortadura, Veracruz	2500	258	Not reported	García *et al*. (2008)
El Cielo, Tamaulipas	2000	51	2322	Rivas *et al*. (2005)
Coatepec and Huatusco, Veracruz	1900 - 2000	62	775	López-Gómez *et al*. (2008)
Central region of Veracruz	1500-2000	83	1029	Williams-Linera (2007)
Central Cordillera of the Colombian Andes	2435	56	Not reported	Cavelier & Tobler (1998)
Western Andean, Peru	1750-2000	88	Not reported	Ledo *et al*. (2012)
Andean Slope of Bolivia	3500	73	Not reported	Kessler (1999)
Coatepec-Xico, Veracruz	**1000-1500**	**154**	**2721**	**-**
Coffee agro-ecosystem				
Central region of Veracruz	1500-2000	107	2863	López-Gómez *et al*. (2008)
Coatepec and Huatusco, Veracruz	1900 - 2000	150	Not reported	Travieso-Bello & Ros (2011)
Coatepec and Huatusco, Veracruz	1900 - 2000	107	2833	Williams-Linera & López-Gómez (2008)
Jitotol, Chiapas	1200 - 3000	50	Not reported	Peeters *et al*. (2003)
Coatepec-Xico, Veracruz	**1000-1500**	**64**	**2947**	**-**

parameter in Veracruz (Barradas *et al.*, 2010), and previous studies have shown the importance of water for the species development in the MCF of Veracruz (Esperón-Rodríguez & Barradas, 2015). We hypothesize that the high biodiversity found in our study might be because of a relatively low precipitation compared to other regions.

Regardless what is causing this high biodiversity, our results indicate that the central region of Veracruz is an important refuge for species, where CAE's plays an important role in the conservation of biodiversity.

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