STRUCTURE AND TREE DIVERSITY IN TRADITIONAL POPOLUCA COFFEE AGROECOSYSTEMS IN THE LOS TUXTLAS BIOSPHERE RESERVE, MEXICO

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SUMMARY

The structure and tree diversity of traditional coffee agroecosystems was studied in a Popoluca community within the Biological Reserve of Los Tuxtlas, Veracruz, Mexico, along an altitudinal gradient from 450 to 1000masl. The coffee agroecosystems were established in three physiognomic units: tropical semi-deciduous forest, tropical rain forest and deciduous forest. To understand the structure of the coffee agroecosystems, 30 plots of 400m² were established. Sixty-four tree species and 23 herbs from 44 families were recorded. The most numerous families were Mimosaceae, Asteraceae, Fabaceae and Myrtaceae. The coffee agroecosystems had four layers: herbs, shrubs, lower trees, and upper trees. The shrub layer was dominated by four varieties of Coffea arabica. *The species with the highest importance values were* Apeiba tibourbou, Cordia alliadora *and* Inga vera. *The species with the highest economic value were* Acosmium panamense, Calophyllum brasiliense, Terminalia amazonia, *and* Vochysia guatemalensis. *Coffee agroecosystems established in tropical semi-deciduous forest have higher diversity values, which has the lowest floristic similarity and the highest dissimilarity values. The complementarity index indicated a high rate of replacement and confirmed the fundamental role of peasant's knowledge and management in the selection of species and the structure of the agroecosystem, but also in increasing and in some cases improving diversity without reaching the original diversity of the vegetation.*

In Mexico, coffee is cultivated on the mountain slopes of the Sierra Madre Oriental facing the Gulf of Mexico, mainly in Hidalgo, Puebla, San Luis Potosí, Veracruz states and some districts in Tabasco; in the Pacific, it is cultivated in Chiapas, Colima, Jalisco, Nayarit and Oaxaca atates (Nolasco, 1985; Regalado-Ortiz, 2006) between 300 and 1,800masl. Coffee is grown on mountain slopes and in locations where northern, tropical and subtropical elements are found (Moguel and Toledo, 1999). According to Bartra (2003) 280,000 peasants produce coffee at smallholder scale in Mexico; 65% of the coffee peasants are indigenous, 183,000 of which own 2ha or less. In addition, there are 74,000 farms <5ha. Particularly in indigenous areas, 41% of the area occupied by coffee agroecosystems is present in tropical rain forests, 23% in pine and oak forest, 21% in low deciduous forest and 15% in deciduous forest. Traditional coffee agroecosystems are considered to help maintain diversity because they conserve different forest strata (Miranda and Hernández, 1963; Bartra, 2003). Moreover, the use of shade trees, such as 'solerillo' or 'xochicoahuitl' (*Cordia alliodora*) and different species of 'chalahuite' (*Inga* spp.), allows peasants to exploit several forest products and helps conserve orchids and other vascular epiphytes, along with birds and arthropods (Perfecto *et al.*, 1996; Moguel and Toledo, 1999; Villavicencio and Valdez, 2003; Cruz *et al.*, 2004; Hietz, 2005; Solís-Montero *et al.* 2005; Bandeira *et al.*, 2005;

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Soto-Pinto *et al.*, 2007). Similarly, within different coffee agroecosystems, environmental factors such as soil and water, together with shadow management, diversification of the tree canopy and use of cover legumes can improve coffee yields, while tree density can adversely affect coffee quality (Skovmand Bosselman *et al*., 2009). Also, as native trees are preserved, the role of natural regeneration could be important for the structure, floristic composition, richness and diversity of tree species (Godínez-Ibarra and López-Mata, 2002; Philpott *et al.*, 2008).

The state of Veracruz is second, after Chiapas, in coffee production in Mexico, by number of peasants and yield. Around 30% of the area dedicated to coffee is located between 300 and 800masl; these areas are considered marginal because they lie outside of the ideal agroecological zone for coffee production and yield, and quality are low (Moguel and Toledo, 1999). In the Sierra of Santa Marta, under the above mentioned conditions, management by the Popoluca peasants is similar to the diversified poly-culture structure (Franco, 2007; Hernández-Martínez, 2008; Williams-Linera and López-Gómez, 2008), which can increase β diversity. However, the prolonged coffee production crisis (Martínez, 1997) has forced these peasants to eliminate many coffee agroecosystems and replace them with cattle farms, which has had a negative impact on the soil, biological diversity, production and productivity, as well as having an impact on processes such as the water, carbon and nitrogen cycles (Sánchez *et al.*, 2003; Bandeira *et al.*, 2005). Due to its ecological importance, the tree structure and diversity in this type of agroecosystem must be studied in greater detail, as has been done for birds and insects (Gould and Guerrero-Rivera, 2006; López-Gómez *et al.*, 2007; Oijen *et al.*, 2010). This knowledge is essential to understand how the system operates to achieve a sustainable use of the natural resources associated with coffee production. This information is particularly relevant given the fast decline of natural resources at the local and global level, because these types of agroecosystems constitute important diversity reserves that have only recently been studied with the level of scientific rigour that they deserve (Vandermeer, 2011). The goal of this study was to analyse the tree structure and biological diversity of coffee agroecosystems established along an altitudinal gradient between 450 and 1,100masl within the buffer area of Los Tuxtlas Biosphere Reserve, Veracruz.

Materials and Methods

Study area

The study area is located in the Popoluca community of Ocotal Chico, Soteapan, Veracruz, at 18º18’31”N and 94º52’26”W, and covers 1361ha (Graciano, 2004). It is part of the buffer area of Los Tuxtlas Biosphere Reserve in the Sierra of Santa Marta (Siemens, 2004; Figure 1) and has a volcanic origin, with igneous rocks and andesitic or alkaline basaltic lava from the quaternary period. Its physiography includes five morpho-edaphological units that were formed by mountains with slopes covered by volcanic cones (Siemens, 2004). The area is located in the sub-basin of the Huazuntlan River, within the Coatzacoalcos river basin. The vegetation includes 1) tropical pine forest, which is dominated by *Pinus oocarpa* and five oak species; 2) tropical semideciduous forest (TSF) dominated by *Brosimum alicastrum*, *Cedrela odorata*, *Inga leptoloba* and *Luehea speciosa*, among others; 3) tropical rainforest (TRF) dominated by *Omphalea oleifera*, *Quercus* sp., *Terminalia amazonia* and *Calophyllum brasiliense*; and 4) deciduous forest (DF) dominated by *Alfaroa mexicana, Liquidambar styraciflua*, *Quercus* sp. and *Ulmus mexicana* (Castillo-Campos and Laborde, 2004).

Agroecosystem selection and measurements

Based on participatory workshops, a list of 69 peasants was compiled. Their agroecosystems were located in areas previously occupied by 1) TSF (TSF coffee) between 450 and 600masl, with warm humid climate, summer precipitation (García, 1988) and Acrisols; 2) TRF (TRF coffee) between 600 and 800masl, with warm humid climate, rainfall throughout the year and Acrisols; and 3) DF (DF coffee) between 800 and 1000masl, with semi-warm wet climate, rainfall throughout the year and Andosols. All soil types are highly susceptible to erosion (Mariano and García, 2010). All coffee agroecosystems studied are located

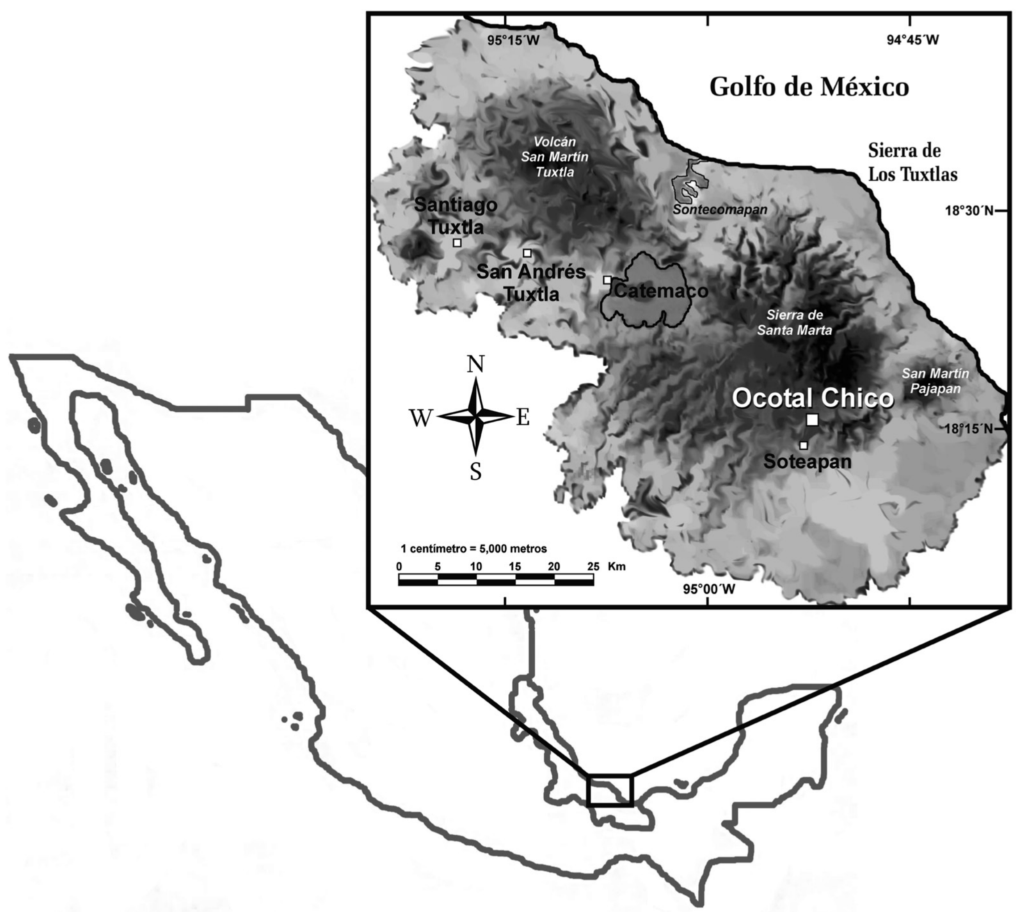

Figure 1. Location of the study area within the Los Tuxtlas Biosphere Reserve (after Siemens, 2004).

in slopes that vary between 15 and 60%, and within them some of the trees from the original vegetation were preserved. Using a random number table, 30 agroecosystems were chosen along the altitudinal gradient (Scheaffer and Ott, 1987), 10 from each section of the altitudinal gradient. Farm size varied based on the requests that each farmer made to the PROCEDE (Ejido and Community Right Program) of the National Agricultural Records. On each farm, a 400m^2 (20×20m) site was marked and divided into four 10×10m (100m^2) quadrats that, in turn, were subdivided into eight 5×10m (50m^2) quadrats. Four of these rectangles were randomly chosen and the height and cover of shrub and herbaceous strata were measured. For all the trees in the sampling area, the diameter at breast height (DBH) was measured at 1.3m above soil surface, and the total height and trunk height (up to the first branch) were measured using a Haga altimeter. Based on these data, basal area was calculated as $BA= (\pi \times D^2)/4$, where BA: basal area and D: DBH. The cover was quantified based on perpendicular measurements of the vertical projection of tree crowns, and the corresponding area was calculated as $CC= ((D_1+D_2/4)\ ^2)\pi$ (Müeller-Dombois and Ellenberg, 1974). The distance between trees was measured with a measuring tape in order to know the horizontal distribution of species. The vegetation structure was analysed based on the relative density values (RDVs), frequency (FR) and relative dominance (DOR) based upon DBH. All relative values were calculated by dividing the number, frequency and dominance of a species by the total number, frequency and dominance of all species. The importance value was calculated as the sum of the three values (IV= RDV+DOR+FR), and this value was divided by three to obtain the relative importance value (RIV) (Müller-Dombois and Ellenberg, 1974; Moreno, 2001). To quantify the floristic similarity, the Sørensen coefficient (Müeller-Dombois and Ellenberg, 1974) was calculated with the formula $IS= (2C/A+B)\times 100$, where A is the number of species in community A, B is the number of species in community B, and C is the number of species in both communities. Similarly, the complementarity index was calculated (Moreno, 2001). First, the total richness was calculated for all sites with the formula $S_{AB} = a+b-c$, where a: number of species in site A, b: number of species in site B and c: number of species common to both sites. Next, the number of species unique to each site was calculated as $U_{AB} = a+b-2c$. The complementarity index was calculated based on the values obtained above with the formula $C_{AB}= U_{AB}/S_{AB}$, where U_{AB} is the species unique to each site and S_{AB} is the total richness of all sites. The value of the index varies between 0 and 1, where 0 represents identical sites, and 1 indicates entirely different sites. By multiplying the value by 100, a percentage was obtained. Species richness and diversity was analysed with the Shannon-Wiener, Simpson and Fisher diversity indexes using the software Estimates 8.2.0 (Colwell, 2009).

Coffee agroecosystems structure

The vegetation structure was graphically represented with vertical and horizontal profile diagrams. To recognize the floristic composition, voucher specimens for all the plant species that were present on the coffee agroecosystems were collected. Species that were not at the sites but had flowers and/or fruit were also collected, although they were not included in the analysis. As the elevation increased, only plants that had not been previously observed were collected. Voucher specimens were deposited in the herbarium at the Instituto de Investigaciones Biológicas, Universidad Veracruzana in Xalapa, Veracruz, Mexico.

Results and Discussion

General structure and floristic composition of coffee agroecosystems

Coffee agroecosystems had four strata: herbaceous, shrub, low trees and tall trees, one layer less than those observed by Soto-Pinto *et al*. (2000). Due to peasant management the herbaceous layer had a low cover, which favoured the presence of some species with economic value and abundant leaf litter; additionally, weed control is carried out mainly by machete (66.6%), only 16.6% with herbicide, while another 16.6% use both (Franco, 2007). In this stratum, the dominant plants were shrub hot pepper (*Capsicum annuum* var. *annuum*), 'barbasco' (*Dioscorea composita*), cucumber (*Cucumis sativus), 'tomatillo' (Solanum pimpinellifolium*), bean (*Phaseolus* spp.), hot pepper fruits (*Capsicum annuum*), goosefoot (*Chenopodium* sp.), *Caladium bicolor*, *Colocasia* sp., *Ceratozamia* sp. and 'camedor' palm (*Chamaedorea* spp.), which was introduced through government programs and the Sierra de Santa Marta A. C. project.

In TSF coffee agroecosystems the shrub stratum was dominated by different varieties of *Coffea arabica*, including Mundo Novo (80.7%), Robusta (8.7%), Caturra (6.4%) and Criolla (4.1%). In TRF coffee plantation, Mundo Novo (79.8%), Caturra (7.5%), Robusta (6.8%) and Criolla (5.9%) were present. Finally, in DF coffee agroecosystems, Caturra (50%), Garnica (28.1%), Mondo Novo (10.7%) and Criolla (11.23%) dominate. Coffee plants were planted in 2.5×2.5m and 2.0×2.0m grids, for a density of 1600-2,500 shrubs/ha, similar to what was found by Soto-Pinto *et al*. (2000) and Peeters *et al*. (2003) in different places of Chiapas, Mexico. However, accordingly to Descroix and Wintgens (2004), density for coffee plantations under shade must be 1250-1600 plants/ha with distances of 2.8×2.8 to 3.0×3.0 for Robusta varieties, and 1100-1600 plants/ha for Arabica; that is to say, 3×3 to 2.5×2.5m. In this stratum, some species, such as Mexican pepper leaf (*Piper sanctum*) and 'platanillo' (*Heliconia curtispatha*) were not eliminated because their economic importance.

The floristic composition at the 30 study sites comprised 51 tree species. The most important were *I. vera* Willd (RIV= 26.42), *Cordia alliodora* (RIV= 10.59), *Cecropia obtusifolia* (7.40), *Heliocarpus appendiculatus* (6.85) and 23 herbaceous species. Forty-four families were identified (Table I); the most numerous were Mimosaceae (seven species), Asteraceae (six species), Fabaceae (six species) and Myrtaceae (four species). *I. vera* had the highest RIV along the altitudinal gradient because peasants consider it to be a tree with multiple uses: it does not lose its foliage in the dry season, produces firewood and provides more cover. Romero-Alvarado *et al*. (2002) found that the presence of *Inga* species does not improves the quality of coffee. Furthermore, using a parameterisation model, VanOijen *et al.* (2010) found that coffee yield tends to decrease with tree density in different coffee plantations in Central America, even in the presence of N-fixing trees, a similar phenomenon as was observed by Skovmand Bosselman *et al*. (2009) in Colombia. Importantly, although all species provide shade, the peasants conserve species like *Vochysia guatemalensis* (it has three different uses), *C. odorata* and *Swietenia macrophylla* because they sell the wood or use them for construction (they cover between 37-45% of the sites). Fruit trees cover 26-31% of the sites, outstanding among them *Annona reticulata*, *Inga jinicuil* and *Byrsonima crassifolia* (this one with three different uses). This Activity is similar to that observed by Rice (2011) in Peruvian and Guatemalan coffee plantations. It is noteworthy that, similar to Peruvian and Guatemalan peasants survival, Popoluca peasant survival depends not only on coffee agroecosystems (22%), but also other incomes such

TABLE I
FLORISTIC COMPOSITION OF THE COFFEE AGROECOSYSTEMS IN OCOTAL CHICO, SOTEAPAN, VER, MEXICO *

Family	Scientific name	Use	Life form	Original vegetation type
Anacardiaceae	*Astronium graveolens* Jacq.	Timber	Tree	DF
	Mangifera indica L.	Fruit	Tree	TRF
	Spondias mombin L.	Fruit	Tree	TRF-DF
Annonaceae	*Annona reticulata* L.	Fruit, medicinal *	Tree	DF
	Rollinia mucosa (Jacq.) Baill.	Not documented	Tree	TRF
Asteraceae	*Ageratella* sp.	Not documented	Herb	DF
	Baltimora recta L.	Not documented	Herb	DF
	Critonia daleoides (DC.)	Medicinal	Shrub	TRF
	Montanoa sp.	Medicinal	Herb	TRF
	Sinclairia discolor Hook. & Arn.	Not documented	Herb	TRF
	Vernonia patens Kunth	Not documented	Shrub	TRF
Bignoniaceae	*Spathodea campanulata* Beauv.	Shade	Tree**	TRF
Bombacaeae	*Pachira aquatica* Aubl.	Medicinal	Tree	TSF
Boraginaceae	*Cordia alliodora* (Ruiz & Pav.) Oken	Timber	Tree	TSF-TRF
Burseraceae	*Bursera simaruba* (L.) Sarg.	Hedge, shade	Tree	DF
Caricaeae	*Carica papaya* L.	Fruit	Tree	TSF
Cecropiaceae	*Cecropia obtusifolia* Bertol.	Shade	Tree	TSF-DF
Chrysobalanaceae	*Hirtella triandra* Sw	Medicinal	Tree	TRF-DF
Combretaceae	*Terminalia amazonia* (J. F. Gmel.) Exell	Timber	Tree	DF
Cucurbitaceae	*Sechium edule* (Jacq.) Sw.	Edible	Herb	TSF-TRF-DF
Euphorbiaceae	*Acalypha microstachya* Benth.	Medicinal	Tree	TRF
Fabaceae	*Acosmium panamense* (Benth.) Yakovlev	Timber	Tree	TSF
	Erythrina americana Mill.	Hedge, edible (flowers)	Tree	TSF-TRF
	Gliricidia sepium Stend.	Hedge, firewood	Tree	TSF
	Lonchocarpus guatemalensis Benth.	Shade	Tree	DF
	Tephrosia sp.	Temporal shade	Shrub**	TSF
	Willardia schiedeana (Schltdl.) F. J. Herm	Shade	Tree	TSF-TRF
Guttiferaceae	*Calophyllum brasiliense* Cambess.	Timber, construction	Tree	TRF
Haemodoraceae	*Xiphidium caeruleum* Aubl.	Not documented	Herb	TRF
Hamamelidaceae	*Liquidambar styraciflua* L.	Shade	Tree	DF
Heliconiaceae	*Heliconia curtispatha* Petersen	Not documented	Herb	TSF
Hypericaceae	*Vismia baccifera* (L.) Triana & Planch.	Medicinal	Tree	TSF
	Vismia camaguey Sparague & L. Riley	Not documented	Tree	DF
Lamiaceae	*Hyptis mutabilis* (L. Rich.) Briq.	Not documented	Herb	TRF
Lauraceae	*Ocotea verticillata* Rohwer	Shade	Tree	DF
Lasistemataceae	*Lacistema aggregatum* Rusby (P. J. Bergiev)	Not documented	Tree	DF
Malpighiaceae	*Byrsonima crassifolia* (L.) Kunth	Shade, fruit, medicinal	Tree	TSF
	Malpighia glabra L.	Not documented	Shrub	TSF
	Tetrapterys schiedeana Schltdl. & Cham.	Not documented	Woody vine	DF
Malvaceae	*Sida acuta* Burm. f.	Medicinal	Shrub	TSF
	Sida cordiflolia L.	Not documented	Shrub	TRF
	Sida rhombifolia L.	Medicinal	Shrub	TRF
Maranthaceae	*Stromanthe acrochlamys* (Woodson & Standley) H. A. Kenn. & Nicolson	Not documented	Herb	TSF
Melastomataceae	*Adelobotrys adscendens* (Sw.) Triana	Not documented	Vine	DF
	Miconia argentea (Sw.) DC.	Handles for tools, shade	Tree	TRF
Meliaceae	*Cedrela odorata* L.	Timber, shade	Tree	TSF-DF
	Swietenia macrophylla G. King	Timber, shade	Tree	TRF
	Trichilia havanensis Jacq.	Timber, handles for tools	Tree	TSF
Mimosaceae	*Zapoteca* sp.	Medicinal	Tree	TSF
	Cojoba arborea (L.) Britton & Rose	Timber, shade	Tree	TSF
	Inga jinicuil Schltdl. & Cham.	Shade, fruit	Tree	TSF-TRF-DF
	Inga punctata Willd.	Shade, firewood	Tree	TSF-TRF
	Inga marginata Willd.	Shade, firewood	Tree	TSF-TRF
	Inga vera Willd.	Shade, firewood	Tree	TSF-TRF-DF
	Leucaena leucocephala (Rose) S. Zárate	Shade, fruit	Tree	TRF
Myrtaceae	*Calyptranthes lindeniana* O. Berg.	Shade	Tree	DF
	Eugenia acapulcensis Steud.	Shade, fruit, medicinal	Tree	TSF
	Eugenia capuli (Schltdl. & Cham.) O. Berg.	Fruit, shade	Tree	TSF
	Pimenta dioica (L.) Merr.	Spice, shade	Tree	TSF-TRF-DF
Orchidaceae	*Catasetum integerrimum* Hook.	Ornamental	Epiphyte	DF
	Sacoila lanceolata A. Rich	Ornamental	Herb	TSF
	Vanilla planifolia G. Andrews	Ornamental	Epiphyte	TRF
Palmae	*Astrocaryum mexicanun* Liebm ex Mart.	Edible	Tree	DF

(It continues in following page)

Continuation Table 1

Family	Scientific name	Use	Life form	Original vegetation type
Primulacaceae	*Rapanea* sp.	Not documented	Tree	DF
Polygonaceae	*Coccoloba uvifera* L.	Medicinal	Tree	TRF
Rubiaceae	*Alibertia edulis* (L. Rich) A. Rich. ex. DC.	Medicinal	Tree	TSF
	Chiococca alba (L.) Hitchc.	Not documented	Tree	TSF
Rutaceae	*Citrus aurantifolia* Swingle	Fruit, Shade	Tree	TRF
	Citrus sinensis (L) Osbeck	Fruit, Shade	Tree	TSF-TRF
	Zanthoxylum caribaeum Lam.	Shade	Tree	TSF
Salicaceae	*Zuelania guidonia* (Sw.) Britton & Millsp.	Not documented	Tree	DF
Sapindaceae	*Allophylus cominia* (L.) Sw.	Medicinal	Tree	DF
	Cupania glabra Sw.	Firewood	Tree	TSF
Solanaceae	*Capsicum annum Var. glabriusculum* (Dunal) Heiser & Pickersgill	Edible	Herb	TSF-TRF
	Solanum pimpinellifolium L.	Edible	Herb	TSF
Sapotaceae	*Chrysophyllum cainito* L.	Fruit	Tree	TSF
	Chrysophyllum mexicanum Brandegee & Standl.	Fruit, handles for tools	Tree	TSF
Surianaceae	*Suriana maritima* L.	Not documented	Shrub	TRF
Thelypteridaceae	*Thelypteris blanda* C. F. Reed	Not documented	Herb	DF
Tiliaceae	*Apeiba tibourbou* Aubl.	Medicinal	Tree	TRF
	Heliocarpus appendiculatus Turcz.	Not documented	Tree	TSF-DF
	Luehea speciosa Wild.	Timber, shade	Tree	TRF
Ulmaceae	*Trema micrantha* (L.) Blume	Bird feed	Tree	TSF-TRF-DF
Verbenaceae	*Tectona grandis* L. f.	Timber	Tree**	DF
Vochysiaceae	*Vochysia guatemalensis* Donn. Sm.	Construction, timber, shade	Tree	TRF-DF

* Medicinal uses were documented based upon Leonti (2002). ** Introduced.

as government programs (52%), off-farm labor (17%) and livestock sales (9%) (Franco, 2007). In San Fernando, near the study area, socioeconomic variables influence ecological ones and modernization might have a negative effect in traditional coffee agroecosystems diversity (Potvin *et al*., 2005).

The structure: floristic composition, vertical strata, spatial distribution and diversity of the coffee agroecosystems studied followed similar patterns to those observed by Perfecto *et al.* (1996) and Soto-Pinto *et al*. (2000) in Chiapas; Bandeira *et al.* (2005) in the Chinantec region, Oaxaca; and Hernández-Martínez (2008) in Coatepec, Veracruz. Moreover, local management and knowledge of agroecosystems play a fundamental role in the selection of the species that will be part of these systems because each peasant follows a different strategy to structure the coffee agroecosystem, altogether with a vast knowledge of local environmental conditions. We found 51 different tree species (345 individuals) in the studied sites, 60 to 85% fewer than reported in similar agroecosystems and vegetation types studies in Veracruz (Sánchez *et al.*, 2003; Villavicencio and Valdez, 2003; Williams-Linera *et al*., 2005; López-Gómez *et al.*, 2007). We collected 44 different families of plants in the whole study area, representing 84 different plant species, of which 64 are trees. That is, twice the plant families and 28% more trees than reported by Peeters *et al*. (2003) in Paredón, Chiapas. Additionally, the coffee agroecosystems studied conserved 25% more species, or at least the same number of species, as compared with some TSFs in Puerto Rico (Bandeira *et al.*, 2005; Gould and Guerrero-Rivera, 2006).

The horizontal structure of all the coffee agroecosystems studied was similar; 80% of the tree species displayed a random distribution, and only 20% displayed a uniform one (Figure 2). Height ranges 5-35m, and it can be deduced that the more or less complex tree structure of the agroecosystems can help as a refuge for a diversity of birds, insects, and microorganisms (Philpott and Bichier, 2012; Jacinto, 2012; Retama *et al*., 2014). It is also important that the age of coffee plantations is 16-40 years old, the older being located at higher elevations, while coffee agroecosystems closer to villages are the younger ones, generally with a better management.

For TSF coffee agroecosystems (Table II), height was 0.6-26.0m. The tallest species were *Acosmium panamense* ('guayacan', 12m), *Cecropia obtusifolia* (trumpet tree, 26m), *Cedrela odorata* (cedar, 19m), *Cordia alliodora* ('solerillo', 20m), *Gliricidia sepium* (13m), *Heliocarpus appendiculatus* ('jonote', 15m), *Inga jinicuil* (22m), *I. vera* ('chalahuite', 26m) and *Trema micrantha* ('mupi' or 'ixpepe', 26m). Seventeen tree species (97 individuals) were identified on these coffee agroecosystems. The species with the highest RIVs were *A. panamense, C. obtusifolia*, *C. odorata*, *Cojoba arborea* ('cañamazo'), *C. alliodora*, *H. appendiculatus*, *I. vera*, *Pimenta dioica* (allspice) and *T. micrantha*. The importance value for *I. vera* was twice as large as the importance value of *C. alliodora*. The species with the lowest RIVs were *Citrus sinensis*, *Chrysophyllum cainito, Carica papaya, Pachira aquatica* and *Tephrosia* sp. (introduced). The species with the highest cover were *I. jinicuil,* with 80.3m^2, greater than that of *I. vera* (69.3m^2) despite having a lower density, *B. crassifolia* (68.7m^2)*,* *C. alliodora* (64.5), *G. sepium* (63.4) and *A. panamense* (45.6m^2). A total of 37 species were identified from the different strata.

In the TRF coffee agroecosystems (Table III), 18 tree species (115 individuals) were identified. The maximum height was 35m, and the minimum 4.5m. The tallest species were *Apeiba tibourbou* (18m), *Calophyllum brasiliense* (35m), *C. alliodora* (32m), *Hirtella triandra* (26), *I. jinicuil* (25m), *I. vera* (26, *Luehea speciosa* (17)*,* *Pimenta dioica* (20) and *V. guatemalensis* (18). The species with the highest RIVs were *Apeiba tibourbou* ('palo gusano' or 'papachote'), *Citrus sinensis* (sour orange), *C. alliodora*, *Inga jinicuil* (pod), *I. vera*, *P. dioica*, *T. micrantha* and *Vochysia guatemalensis* ('corpo'). The species with the lowest importance values were *Coccoloba uvifera* (sea grape), *Citrus aurantifolia* (lime) and *Swietenia macrophylla*

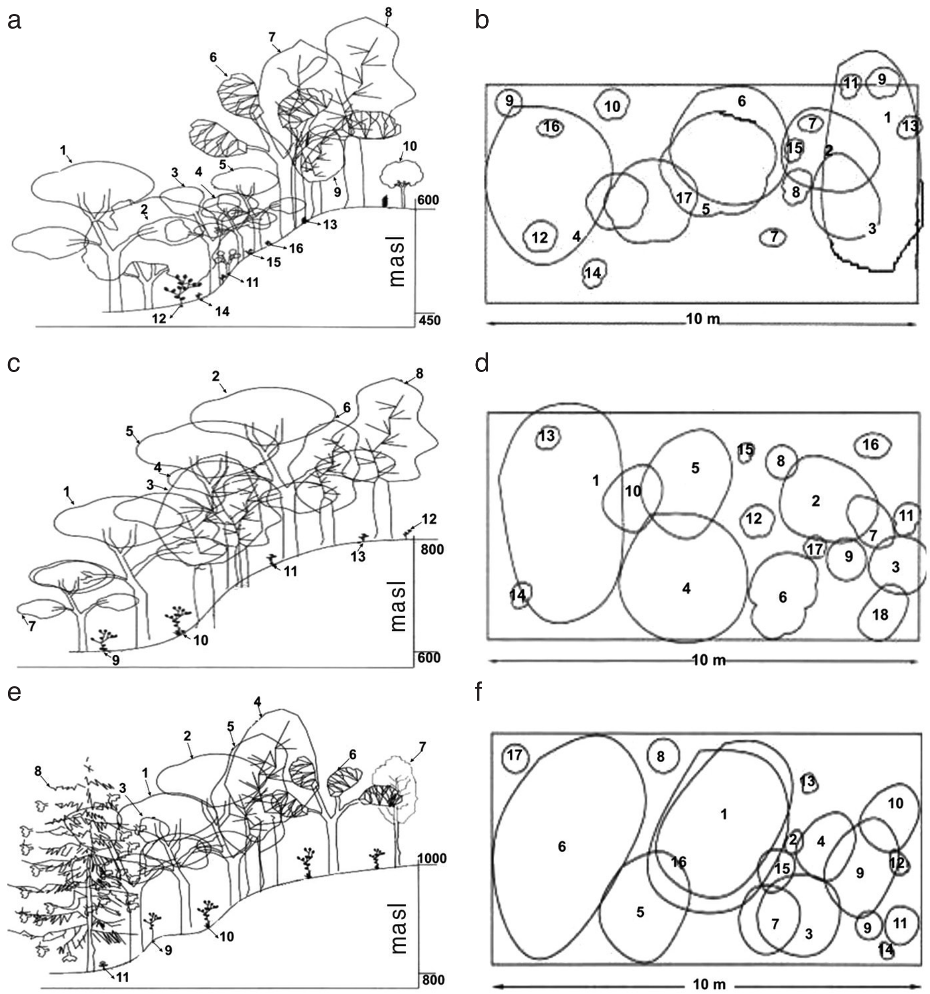

Figure 2. Vertical (a, c and e) and horizontal (b, d and f) profiles of coffee agroecosystems in Ocotal Chico. In a and b the species with greater importance values and highest covers in TSF coffee were, in tree stratum, 1: *Inga vera*, 2: *Acosmium panamense*, 3: *Trema micrantha*, 4: *I. jinicuil*, 5: *Pimenta dioica*, 6: *Cecropia obtusifolia*, 7: *Cedrela odorata*, 8: *Cordia alliodora*, 9: *Heliocarpus appendiculatus*, 10: *Citrus sinensis*, and 11: *Carica papaya*; in shrub stratum, 12: C*offea arabica* v. Robusta, and 13: *arabica* v. Mundo Novo; in herbaceous stratum, 14: *Dioscorea composita*, 15: *Phaseolus* spp., and 16: *Chenopodium* sp. In b these species were 1: *I. jinicuil*, 2: *Gliricidia sepium*, 3: *C. alliadora*, 4: *I. vera*, 5: *Byrsonima crassifolia*, and 6: *A. panamense*. In c and d the species with greater importance values and highest cover in TRF coffee were, in tree stratum, 1: *I. vera*, 2: *I. jinicuil*, 3: *Apeiba tibourbou*, 4: *T. micrantha*, 4: *P. dioica*, 5: *Vochysia guatemalensis*, 7: *C. sinensis*, and 8: *C. alliadora*; in shrub stratum, 9: C. *arabica* v. Caturra and 10: C. *arabica* v. Mundo Novo; in herbaceous stratum, 11: *Capsicum annum*, 12: *Dioscorea composita* and 13: *Chenopodium* sp. In d these species were 1: *A. tibourbou*, 2: *Luehea speciosa*, 3: *Hirtella triandra*, 4: *Callophyllum brasiliense*, and 5: *I. jinicuil*. In e and f greater importance values and highest cover in DF coffee were, in tree stratum, 1: *I. vera*, 2: *I. jinicuil*, 3: *T. micrantha*, 4: *Terminalia amazonia*, 5: *V. guatemalensis*, 6: *C. obtusifolia*, 7: *Ocotea verticillata*, and 8: *Liquidambar styraciflua*; in shrub stratum, 9: C. *arabica* v. Garnica and 10: C. *arabica* v. Caturra; in herbaceous stratum: 1: *Tetrapterys schiedeana*. In f these species were 1: *I. vera*, 2: *I. jinicuil*, 3: *V. guatemalensis*, 4: *T. amazonia*, and 5: *T. micrantha*.

(mahogany). The species with the greatest cover were *A. tibourbou* (151.66m^2), *C. brasiliense* (103.86)*, C. alliodora* (51.54)*, Hirtella triandra* (55.41), *I. jinicuil* (59.20) and *L. speciosa* (77.47m^2). These coffee agroecosystems had a total of 36 species.

In the areas with DF coffee agroecosystems (Table IV) 16 tree species (133 individuals) were observed, with a minimum height of 4.2 and a maximum of 32m. The tallest trees were *A. reticulata* (20m), *Cecropia obtusifolia* (18), *H. appendiculatus* (18), *H. triandra* Sw (14), *I. jinicuil* (30), *I. vera* (32), *T. amazonia* (31), *T. micrantha* (18) and *V. guatemalensis* (18). The species with the highest RIVs were *I. vera*, *T. micrantha*, *T. amazonia*, *I. jinicuil*, *C. obtusifolia*, *V. guatemalensis*, *C. odorata* and *L. guatemalensis*. The species with the lowest RIVs were *Bursera simaruba* (copper wood)*, L. guatemalensis* ('gusanillo' or 'palo blanco'), *Spondias mombin* (yellow mombin) and *Tectona grandis* (introduced). The species with the greatest cover were *A. reticulata* L. (93.3m^2), *T. amazonia* (75.9), *T. micrantha* (55.4) and *I. vera* (50.7m^2). On these coffee agroecosystems, 31 species were collected from the different strata.

Structurally, the species with the highest importance value along the altitudinal gradient were *I. vera*, *A. tibourbou*, *C. alliadora* and *T. micrantha*. The first two species also dominate coffee agroecosystems in the Chinantec region in Oaxaca (Bandeira *et al.*, 2005). The type II structural pattern of these species suggests the existence of disturbed areas in an advanced phase of tree gap planting (Martínez-Ramos and Álvarez-Buylla, 1995). As observed in the study by López-Gómez and Williams-Linera (2006) on the coffee agroecosystems of Ocotal Chico, no important structural differences existed because the peasants were interested in species composition, not in increasing the height or basal area of the trees. In addition to *I. vera*, other species that were highlighted in López-Gómez and Williams-Linera (2006) are *Citrus* spp., *Mangifera indica*, *Psidium guajava* and *Persea schiedeana*. The first three were found in the present study. However, *B. crassifolia*, *C. alliadora*, *I. jinicuil*, *L. speciosa* and *T. micrantha* displayed greater cover and lower density.

Population structure

Based on the diameter class distribution of species with a higher importance value, some structural patterns (*sensu* Martínez-Ramos and Álvarez-Buylla, 1995) were distinguished. For TSF coffee agroecosystems, *I. vera* and *C. alliodora* displayed a type II pattern, which is characterised by a higher frequency of intermediate size individuals and a lower frequency of older individuals. *T. micrantha* follows a type III pattern, with small, intermediate and large individuals. *C. obtusifolia* and *A. panamense* did not display any defined structural patterns (Figure 3). In TRF coffee agroecosystems, *I. vera* and *C. alliadora* followed a type II pattern, but *V. guatemalensis* was characterised by a type III pattern, with small, intermediate and large individuals. *I. jinicuil* and *A. tibourbou* did not show a defined structural pattern (Figure 4). In DF coffee agroecosystems, *I. vera, T. micrantha* and *I. jinicuil* displayed a type II pattern, and *T. amazonia*, and *C. obtusifolia* did not have a defined structural pattern (Figure 5). The horizontal tree distribution was heterogeneous along the gradient as a result of the topological arrangement and

TABLE II
TREE STRUCTURE OF COFFEE AGROECOSYSTEMS LOCATED IN THE TROPICAL SEMIDECIDUOUS RAINFOREST (450-600M) IN OCOTAL CHICO*

Species	Number of individuals	Cover (m^2)	Height (m)	Basal area (m^2)	Absolute frequency	Relative density	Relative frequency	Relative dominance	IV.	RIV
Acosmium panamense	3	45.6	10.6	218.16	0.3 (30%)	0.03	0.06	0.08	0.18	6.12
Byrsonima crassifolia	1	68.6	15	283.52	0.1 (10%)	0.01	0.02	0.11	0.14	4.76
Carica papaya	1	6.61	3	19.63	0.1 (10%)	0.01	0.02	0.00	0.04	1.35
Cojoba arborea	2	0.1	0.7	0.12	0.3 (30%)	0.02	0.06	0.00	0.08	2.96
Cecropia obtusifolia	5	23.93	14.1	263.59	0.3 (30%)	0.05	0.06	0.10	0.22	7.40
Cedrela odorata	3	17.7	16.2	245.13	0.2 (20%)	0.03	0.04	0.09	0.17	5.71
Citrus sinensis	3	4.4	4.9	84.94	0.1 (10%)	0.03	0.02	0.03	0.08	2.88
Cordia alliodora	11	64.5	17.3	234.32	0.5 (50%)	0.11	0.11	0.09	0.31	10.59
Chrysophyllum cainito	1	2.14	3	50.26	0.1 (10%)	0.01	0.02	0.02	0.05	1.75
Gliricidia sepium	2	63.4	12.5	188.69	0.2 (20%)	0.02	0.04	0.07	0.13	4.64
Heliocarpus appendiculatus	3	23.9	8.6	333.29	0.2 (20%)	0.03	0.04	0.12	0.20	6.85
Inga vera	45	69.3	16.4	261.74	1 (100%)	0.46	0.22	0.10	0.79	26.42
Inga jinicuil	4	80.4	13.3	176.71	0.2 (20%)	0.04	0.04	0.06	0.15	5.17
Pachira aquatica	1	2.0	2.5	7.06	0.1 (10%)	0.01	0.02	0.003	0.03	1.19
Pimenta dioica	4	11.4	7.1	44.76	0.3 (30%)	0.04	0.06	0.017	0.12	4.22
Tephrosia sp.	1	0.33	2	7.06	0.1 (10%)	0.01	0.02	0.003	0.03	1.19
Trema micrantha	7	30.8	8.7	157.73	0.3 (30%)	0.07	0.06	0.06	0.20	6.71
n=17	97			2576.80	4.4	1.00	1.00	1.00	3.00	100.00

* Reference area 4,000m^2 (10 sampling sites of 400m^2).

TABLE III
TREE STRUCTURE IN COFFEE AGROECOSYSTEMS LOCATED IN THE TROPICAL RAINFOREST (600-800M) IN OCOTAL CHICO

Species	Number of individuals	Cover (m^2)	Height (m)	Basal area (m^2)	Absolute frequency	Relative density	Relative frequency	Relative dominance	IV	RIV
Apeiba tibourbou	2	151.6	18	15614.54	0.1 (10%)	0.02	0.02	0.72	0.76	25.33
Calophyllum brasiliense	1	103.9	35	855.30	0.1 (10%)	0.01	0.02	0.04	0.07	2.33
Citrus aurantifolia	2	12.3	4.5	63.61	0.1 (10%)	0.02	0.03	0.00	0.05	1.78
Citrus sinensis	3	7.7	7.8	263.98	0.3 (30%)	0.03	0.07	0.01	0.11	3.67
Coccoloba uvifera	1	12.3	26	176.71	0.1 (10%)	0.01	0.02	0.01	0.04	1.33
Cordia alliodora	15	51.5	23.9	776.01	0.4 (40%)	0.13	0.09	0.04	0.26	8.67
Hirtella triandra	1	55.4	6	1017.87	0.1 (10%)	0.01	0.02	0.05	0.08	2.67
Inga jinicuil	5	59.2	15.6	589.64	0.4 (40%)	0.04	0.09	0.03	0.16	5.33
Inga vera	59	42.3	14.4	376.10	1 (100%)	0.51	0.23	0.02	0.76	25.33
Leucaena leucocephala	3	6.8	6.2	34.90	0.1 (10%)	0.03	0.02	0.00	0.05	1.73
Luehea speciosa	3	77.5	12.6	732.21	0.2 (20%)	0.03	0.05	0.03	0.11	3.67
Mangifera indica	1	17.3	7.5	295.59	0.1 (10%)	0.01	0.02	0.01	0.04	1.33
Pimenta dioica	4	42.3	10.5	226.98	0.3 (30%)	0.03	0.07	0.01	0.11	3.67
Spathodea campanulata	1	3.9	5	95.03	0.1 (10%)	0.01	0.02	0.00	0.03	1.00
Spondias mombin	2	6.0	5	78.54	0.2 (20%)	0.02	0.05	0.00	0.07	2.34
Swietenia macrophylla	2	11.2	6	116.89	0.1 (10%)	0.02	0.02	0.01	0.05	1.70
Trema micrantha	3	41.6	8.2	143.13	0.3 (30%)	0.03	0.07	0.01	0.11	3.58
Vochysia guatemalensis	7	18.7	9.6	173.36	0.4 (40%)	0.06	0.09	0.01	0.16	5.33
n=18	115			21630.47	4.4	1	1.01	1.00	3.02	100.80

* Reference area 4,000m^2 (10 sampling sites of 400m^2).

management conducted by peasants (Figure 2). The population structure of *C. alliadora* and *V. guatemalensis* is due because their use is centered on diameter classes for home construction and planks, respectively.

Floristic similarity

According to the Sørensen index, the coffee agroecosystems that were established in TSF and DF had 21% similarity and shared seven species: *C. obtusifolia*, *C. odorata*, *H. appendiculatus*, *I. jinicuil*, *I. vera*, *P. dioica* and *T. micrantha.* The agroecosystems that were located in TRF and DF were 21% similar and had seven species in common: *H. triandra*, *I. jinicuil*, *I. vera*, *P. dioica*, *S. mombin*, *T.*

TABLE IV
VEGETATION STRUCTURE OF COFFEE AGROECOSYSTEMS LOCATED IN THE DECIDUOUS FORESTS (800-1000M) IN OCOTAL CHICO*

Species	Number of individuals	Cover (m^2)	Height (m)	Basal area (m^2)	Absolute frequency	Relative density	Relative frequency	Relative dominance	IV	RIV
Annona reticulata	1	93.3	20	764.53	0.1 (10%)	0.01	0.03	0.12	0.13	4.33
Astrocarium mexicanun	1	13.5	5	314.16	0.1 (10%)	0.01	0.03	0.05	0.09	3.00
Bursera simaruba	2	1.7	2.8	8.81	0.1 (10%)	0.02	0.03	0.02	0.07	2.33
Cecropia obtusifolia	3	51.6	14.6	481.75	0.2 (20%)	0.02	0.06	0.06	0.14	4.67
Cedrela odorata	4	3.1	4.2	46.86	0.2 (20%)	0.03	0.06	0.02	0.11	3.67
Heliocarpus appendiculatus	2	17.7	6.9	95.03	0.2 (20%)	0.02	0.06	0.03	0.08	2.67
Hirtella triandra	3	48.7	4.5	838.10	0.1 (10%)	0.02	0.03	0.13	0.18	6.00
Inga jinicuil	6	45.4	13.5	373.25	0.2 (20%)	0.05	0.06	0.05	0.16	5.33
Inga vera	86	50.8	11.8	351.52	1 (100%)	0.65	0.28	0.07	1.00	33.33
Lonchocarpus guatemalensis	3	0.3	12	73.39	0.1 (10%)	0.02	0.03	0.02	0.07	2.33
Pimenta dioica	2	7.6	6	94.17	0.2 (20%)	0.02	0.06	0.02	0.10	3.33
Spondias mombin	1	4.5	5.8	314.16	0.1 (10%)	0.01	0.03	0.03	0.07	2.33
Tectona grandis	1	49.1	6	415.47	0.1 (10%)	0.01	0.03	0.06	0.11	3.67
Terminalia amazonia	2	75.9	31	1541.34	0.1 (10%)	0.02	0.03	0.23	0.28	9.33
Trema micrantha	11	55.4	12.4	341.87	0.6 (60%)	0.08	0.17	0.04	0.29	9.67
Vochysia guatemalensis	5	20.9	14.3	264.75	0.2 (20%)	0.04	0.06	0.03	0.13	4.33
n=16	133			6319.22	3.6	1	1	0.98	3.01	100.33

* Reference area $4000m^2$ (10 sampling sites of $400m^2$).

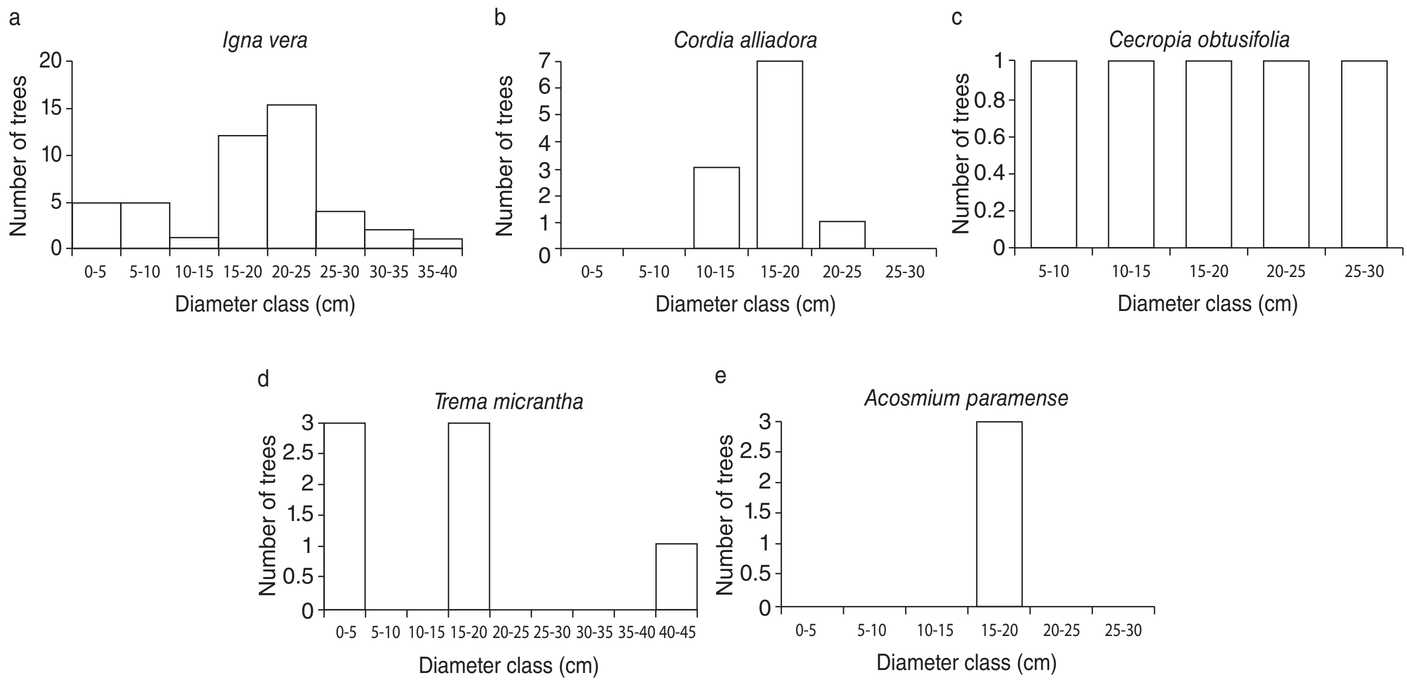

Figure 3. Population structure patterns, based on diameter classes, for species with greater importance values for coffee agroecosystems established in the tropical semideciduous forest. a: *I. vera* and b: *C. alliadora* display a type II pattern; c: *C. obtusifolia* and e: *A. panamense* do not have a defined structural pattern; and d: *T. micrantha* displays a type III pattern.

micrantha and *V. guatemalensis*. Coffee agroecosystems located in TSF and TRF displayed 30% similarity and had 11 common species: *C. annum* var. *glabriusculum*, *C. sinensis*, *C. alliodora*, *Erythrina americana*, *I. jinicuil*, *Inga punctata*, *Inga marginata*, *I. vera, P. dioica*, *T. micrantha* and *Willardia schiedeana*. The indexes of floristic similarity were low; that is to say, the different coffee agroecosystems have high replacement rates due to the decisions peasants made about plants they used in each section of the altitudinal gradient, a phenomenon also reported by Williams-Linera and López-Gómez (2008) and by Rice (2011) for fruit species. This observation is remarkable for the case of TSFs, which are located closest to dwellings. In other areas of Veracruz, the values were even lower (Williams-Linera and López-Gómez, 2008). The mean floristic similarity was 12%, more than twice that found by Guiracocha *et al.* (2001) in cacao agroforestry systems in Costa Rica. Likewise, Godínez-Ibarra and López-Mata (2002) reported an intermediate similarity, with a low number of shared species, for three TSF samples.

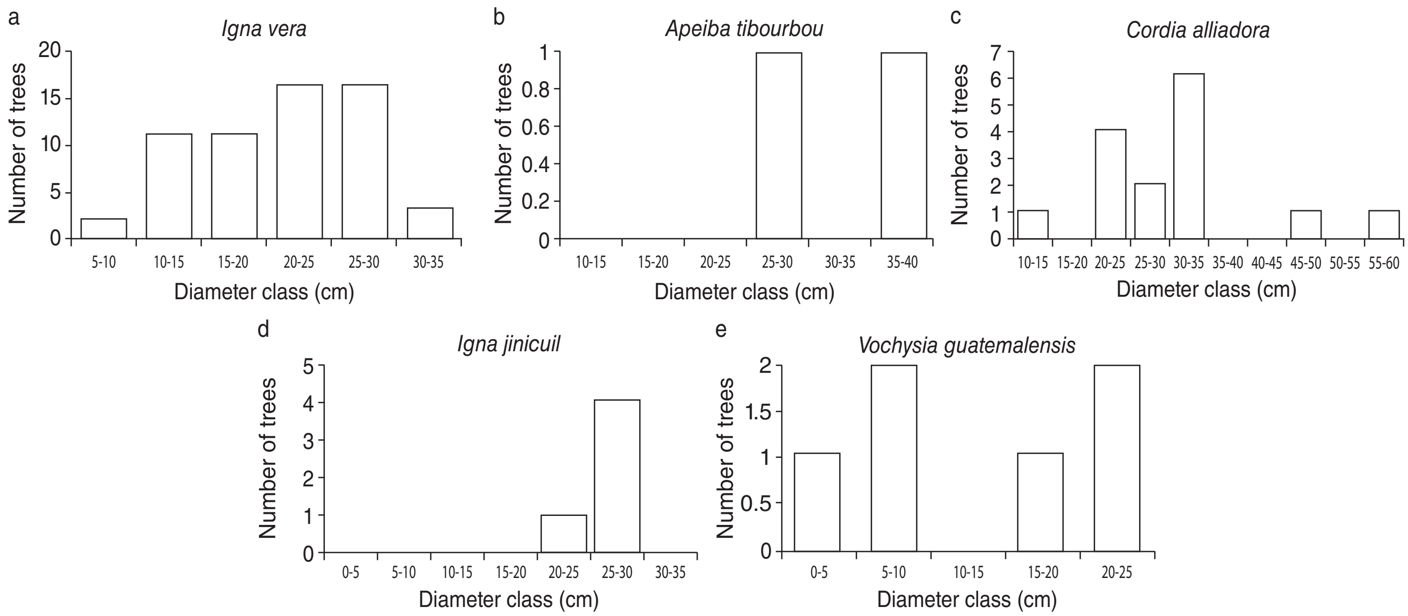

Figure 4. Population structure patterns, based on diameter classes, for species with greater importance values for coffee agroecosystems established in tropical rainforests. a: *I. vera* and c: *C. alliadora* display a type II pattern; b: *A. tibourbou* and d: *I. jinicuil* do not have defined structural patterns; and e: *V. guatemalensis* displays a type III pattern.

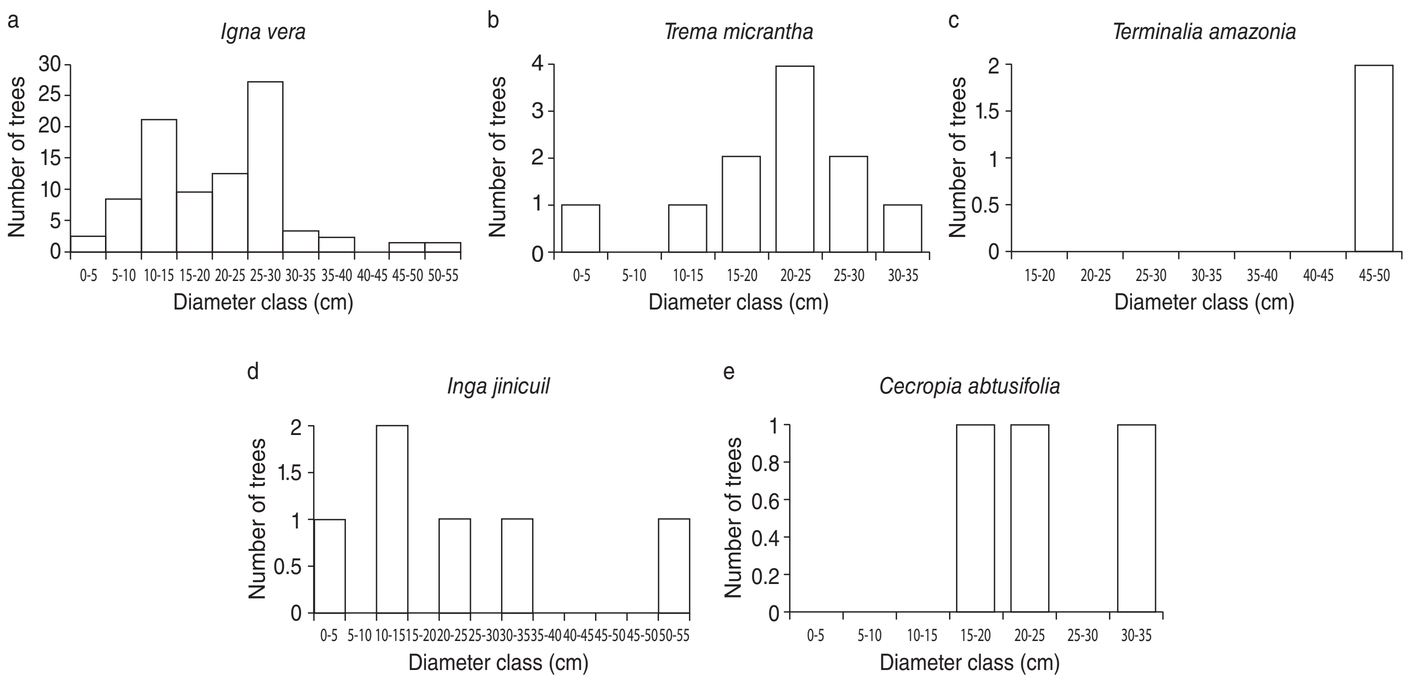

Figure 5. Population structure patterns, based on diameter classes, for species with greater importance values in coffee agroecosystems established in deciduous forest. a: *I. vera,* b: *T. micrantha* and d: *I. jinicuil* display a type II pattern, characterised by higher frequency of medium-sized individuals and lower frequency of older individuals; c: *T. amazonia* and e: *C. obtusifolia* do not have defined structural patterns.

Species richness, diversity and complementarity index

Along the altitudinal gradient, 345 individuals were recorded (60 tree and 23 herbaceous species) within 12000m^2. The greatest tree richness (44.5%) occurred on coffee agroecosystems that were located in TSFs. For these agroecosystems, the Shannon-Wiener diversity index varied between 3.39 and 1.89, the Simpson index ranged between 61.95 and 31.1 and Fisher's alpha varied between 57.8 and 27.35. The coffee agroecosystems that presents higher diversity values are those located near dwellings. These values confirm the greater biological diversity of these systems (Table V).

The complementarity in species composition for the coffee agroecosystems that were located in TSFs and DFs

TABLE V
BIOLOGICAL DIVERSITY INDEX FOR COFFEE AGROECOSYSTEMS IN OCOTAL, CHICO

Site	Type of agroecosystem	Fisher's alpha	Shannon's index	Simpson's index
1	TSF coffee	43.4	1.89	1
2	TSF coffee	57.8	2.42	61.95
3	TSF coffee	44	2.73	42.71
4	TSF coffee	40	2.9	37.13
5	TSF coffee	39.35	3.04	34.95
6	TSF coffee	37.72	3.15	33.62
7	TSF coffee	37	3.23	32.65
8	TSF coffee	34.83	3.28	31.42
9	TSF coffee	34.71	3.35	31.45
10	TSF coffee	34.17	3.39	31.15
11	TRF coffee	34.12	3.44	31.14
12	TRF coffee	33.19	3.47	30.75
13	TRF coffee	33.02	3.51	30.85
14	TRF coffee	32.7	3.53	30.77
15	TRF coffee	32.4	3.56	30.62
16	TRF coffee	31.9	3.58	30.51
17	TRF coffee	31.83	3.6	30.57
18	TRF coffee	30.48	3.62	30.58
19	TRF coffee	30.61	3.63	30.36
20	TRF coffee	30.3	3.64	30.3
21	DF coffee	29.67	3.65	30.38
22	DF coffee	29.32	3.66	30.35
23	DF coffee	29	3.67	30.23
24	DF coffee	28.54	3.68	30.35
25	DF coffee	28.26	3.69	30.28
26	DF coffee	28.07	3.7	30.22
27	DF coffee	27.91	3.7	30.11
28	DF coffee	27.78	3.71	30.21
29	DF coffee	27.65	3.72	30.25
30	DF coffee	27.35	3.73	30.21

TSF coffee: tropical semi deciduous forest coffee agroecosystems, TRF coffee: tropical rain forest coffee agroecosystems, DF coffee: deciduous forest coffee agroecosystems. Calculation made with Estimates Version 8.2.0 (http://viceroy.eeb.uconn.edu/estimates)

was 88%; those located in TRFs and DFs had the same value. For agroecosystems located in TSFs and TRFs, complementarity was 82%, similar to those obtained by Williams-Linera *et al*. (2005) and López-Gómez *et al*. (2007) in deciduous forest and coffee agroecosystems of central Veracruz. Similarly, Villavicencio and Valdez (2003) found a 58% floristic similarity and 42% different species for coffee agroecosystems established in TSFs and TRFs in San Miguel, near Cordoba, Veracruz. In this same area, these authors observed greater evenness in the tree structure of rustic coffee agroecosystems established in TSF. Our results indicate a high replacement rate and, therefore, a high β diversity, which confirms that moderate disturbances resulting from human management, may have increased the species richness, although the original vegetation diversity was not reached (Williams-Linera *et al*., 2005; Philpott *et al*., 2008a).

Furthermore, the exclusive species found in each coffee agroecosystem studied herein also indicate a high diversity (Table VI) and confirm the influential role of traditional peasants in preserving and even increasing diversity. Their management practices seem to be fundamental for conservation of natural resources in the area. It should be noted that, contrary to what was found by Philpott *et al*. (2008b) in Sumatra, Popoluca peasants conserve more native species along the altitudinal gradient (of those mandatory to be certified by programs like the Smithsonian Migratory Bird Center or 'Bird Friendly'). This diversity could be the basis for local programs aimed to conserve trees, but also birds, insects, microorganisms, biogeochemical cycles and give more resilience to the agricultural matrix (*sensu* Perfecto and Vandermeer, 2008). For instance, tree species such as *A. panamense*, *C. brasiliense*, *T. amazonia*, *T. micrantha* and *V. guatemalensis* in the lower and upper tree strata can diversify the productivity of coffee agroecosystems, giving emphasis to the use of evergreen species. This diversity contributes to soil structural stability because of the high susceptibility to erosion (Juárez, 2008; Cruz, 2009). In the lower tree stratum, *C. alliodora*, *B. crassifolia*, *C. papaya, C. sinensis*, *C. cainito*, *I. jinicuil*, *P. dioica* and *S. mombin* are important species. In the herbaceous stratum, some species, such *C. annuum var. annuum, Chenopodium* sp., *C. sativus and S. pimpinellifolium*, could be used as garden produce, and species such as *Colocasia bicolor*, *Colocasia* sp., *Chamaedorea* sp. and *Ceratozamia* sp. could be used as ornamentals.

TABLE VI
EXCLUSIVE SPECIES FOUND IN THE DIFFERENT COFFEE AGROECOSYSTEMS, ACCORDINGLY WITH ORIGINAL VEGETATION TYPE, IN OCOTAL CHICO, SOTEAPAN, VERACRUZ

TSF coffee (23)	TRF coffee (23)	DF coffee (21)
Acosmium panamense	*Acalypha microstachya*	
Alibertia edulis	*Apeiba tibourbou*	*Adelobotrys adscendens*
Byrsonima crassifolia	*Calophyllum brasiliense*	*Agerantia* sp.
Calathea macrochlamys	*Citrus aurantifolia*	*Allophylus cominia*
Carica papaya	*Coccoloba uvifera*	*Annona reticulata*
Chiococca Alba	*Eupatorium daleoides*	*Astrocarium mexicanum*
Chrysophyllum cainito	*Hyptis mutabilis*	*Astronium graveolens*
Chrysophyllum mexicanum	*Leucaena leucocephala*	*Baltimore recta*
Cojoba arborea	*Luehea speciosa*	*Bursera simaruba*
Cupania glabra	*Mangifera indica***	*Calyptranthes lindeniana*
Eugenia acapulcensis	*Miconia argentea*	*Catasetum integerrimum*
Eugenia capulli	*Montana* sp.	*Lacistema aggregatum*
Gliricidia sepium	*Rollinia mucosa*	*Liquidambar styraciflua*
Heliconia curtispatha	*Sida cordiflolia*	*Lonchocarpus guatemalensis*
Malpighia glabra	*Sida rhombifolia*	*Ocotea verticillata*
Sacoila lanceolata	*Sinclaria discolor*	*Rapanea* sp.
Sida acuta	*Spathodea campanulata***	*Tectona grandis***
Pachira aquatica	*Suriana maritima*	*Terminalia amazonia*
Tephrosia sp.**	*Swietenia macrophylla*	*Tetrapterys schiedeana*
Trichilia havanensis	*Vanilla planifolia*	*Thelypteris blanda*
Vismia camaguey	*Vernonia patens*	*Vismia baccifera*
Zanthoxylum caribaeum	*Vochysia guatemalensis*	*Zuelania guidonia*
Zapoteca sp.	*Xiphidium caeruleum*	

TSF coffee: tropical semi deciduous forest coffee agroecosystems, TRF coffee: tropical rain forest coffee agroecosystems, DF coffee: deciduous forest coffee agroecosystems. ** Introduced.

Conclusions

Four strata were found in the 30 coffee agroecosystems studied. *Inga vera* had the highest importance value; however, we found 84 different plants, 64 of which are trees. Of those whose uses could be documented, we found one to three different uses, timber, fruits and medicinal being remarkable. Coffee agroecosystems located near dwellings (TSD coffee) have higher diversity values; however, its tree density is lower (97 individuals) than in TRF coffee (115 individuals) and in DF coffee (133 individuals). Tree height ranges 5-35m. Results show high diversity indices, even higher than in other areas of Chiapas, which is confirmed by the few species that all the coffee agroecosystems share, by the high replacement rate, and by the great number of exclusive species found at each coffee agroecosystem. All these confirm the fundamental role of peasant's knowledge and management in the selection of species and the structure of the agroecosystem, but also in increasing and in some cases improving diversity. Popoluca peasants conserve native species instead of exotics, of which only three species were found. With the information obtained, diversification and restoration programs could be organized based upon native tree richness and the participation of the Popoluca people. This will allow to structure agroecological matrices to improve production and productivity of agroecosystems, but also conserve birds, mammals, insects, microorganisms and the essential biogeochemical cycles.

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ESTRUCTURA Y DIVERSIDAD DE ÁRBOLES EN AGROSISTEMAS CAFETALEROS POPOLUCA, RESERVA DE BIOFERA DE LAS TUXLAS, MÉXICO

Guadalupe Castillo Capitán, Carlos H. Ávila-Bello, Lauro López-Mata y Fernando de León González

RESUMEN

La estructura y diversidad arbórea de agroecosistemas cafetaleros tradicionales fue estudiada en una comunidad popoluca dentro de la Reserva de la Biosfera de Los Tuxtlas, Veracruz, México, a lo largo de un gradiente altitudinal entre los 450 y 1000msnm. Los agroecosistemas cafetaleros se encuentran establecidos en tres unidades fisonómicas: selva mediana subperennifolia, selva alta perennifolia y bosque caducifolio. Para entender la estructura de estos agroecosistemas se establecieron 30 parcelas de 400m². Se registraron 64 especies de árboles y 23 hierbas pertenecientes a 44 familias. Las familias más numerosas fueron Mimosaceae, Asteraceae, Fabaceae y Myrtaceae. Los agroecosistemas cafetaleros presentan cuatro estratos: herbáceo, arbustivo, arbóreo inferior y arbóreo superior. El estrato arbustivo está dominado por cuatro variedades de Coffea arabica. *Las especies con los mayores valores de importancia fueron* Apeiba tibourbou, Cordia alliadora *e* Inga vera, *y las especies con mayor valor económico son* Acosmium panamense, Calophyllum brasiliense, Terminalia amazonia *y* Vochysia guatemalensis. *Los agroecosistemas cafetaleros establecidos en selva mediana subperennifolia tienen valores más altos de diversidad, similitud florística más baja y los valores más altos de disimilitud. El índice de complementariedad indica una alta tasa de reemplazo y confirma el papel fundamental del conocimiento y manejo de los campesinos en la selección de especies y la estructura del agroecosistema, así como en el aumento y en algunos casos la mejora de la diversidad, sin alcanzar los valores originales de la vegetación.*

ESTRUTURA E DIVERSIDADE DE ÁRVORES EM AGROECOSSISTEMAS CAFEEIROS POPOLUCA NA RESERVA DE BIOFERA DAS TUXLAS, MÉXICO

Guadalupe Castillo Capitán, Carlos H. Ávila-Bello, Lauro López-Mata e Fernando de León González

RESUMO

A estrutura e diversidade arbóreas de agroecossistemas cafeeiros tradicionais foi estudada em uma comunidade Popoluca dentro da Reserva da Biosfera de "Los Tuxtlas", *Veracruz, México, ao longo de gradiente altitudinal entre os 450 e 1.000 msnm. Os agroecossistemas cafeeiros se encontram estabelecidos em três unidades fisionômicas: selva mediana subperenifólia, selva alta perenifólia e bosque caducifólio. Para entender a estrutura de estes agroecossistemas se estabeleceram 30 lotes de 400m². Registraram-se 64 espécies de árvores e 23 ervas pertencentes a 44 famílias. As famílias mais numerosas foram Mimosaceae, Asteraceae, Fabaceae e Myrtaceae. Os agroecossistemas cafeeiros apresentam quatro extratos: herbáceo, arbustivo, arbóreo inferior e arbóreo superior. O extrato arbustivo está dominado por quatro variedades de* Coffea arábica. *As espécies com os maiores valores de importância foram* Apeiba tibourbou, Cordia alliadora e Inga vera*, e as espécies com maior valor econômico são Acosmium panamense,* Calophyllum brasiliense, Terminalia amazonia *e* Vochysia guatemalensis. *Os agroecossistemas cafeeiros estabelecidos em selva mediana subperenifólia têm valores mais altos de diversidade, similitude florística mais baixa e os valores mais altos de dissimilitude. O índice de complementariedade indica uma alta taxa de substituição e reforça o papel fundamental dos camponeses no conhecimento e manejo da seleção de espécies e a estrutura do agroecossistema, assim como no aumento e em alguns casos na melhora da diversidade, sem alcançar os valores originais da vegetação.*