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Woody plant diversity and structure of shade-grown-coffee plantations in Northern Chiapas, Mexico

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Abstract: Shade-grown coffee is an agricultural system that contains some forest-like characteristics. However, structure and diversity are poorly known in shade coffee systems. In 61 coffee-growers' plots of Chiapas, Mexico, structural variables of shade vegetation and coffee yields were measured, recording species and their use. Coffee stands had five vegetation strata. Seventy seven woody species mostly used as wood were found (mean density 371.4 trees per hectare). Ninety percent were native species (40 % of the local flora), the remaining were introduced species, mainly fruit trees/shrubs. Diametric distribution resembles that of a secondary forest. Principal Coordinates Analysis grouped plots in four classes by the presence of *Inga*, however the majority of plots are diverse. There was no difference in equitability among groups or coffee yields. Coffee yield was 835 g clean coffee per shrub, or ca. 1 668 kg ha^{-1}. There is a significant role of shade-grown coffee as diversity refuge for woody plants and presumably associated fauna, as well as an opportunity for shade-coffee growers to participate in the new biodiversity-friendly-coffee market.

Key words: Diversity, shade-grown coffee, *Coffea arabica*, vegetation structure, woody plants, agroecosystems.

Diversity loss concerns researchers and development agents who are studying the causes of diversity loss and trying to propose alternative solutions. In some countries researchers survey existing diversity, but many of these resources are accelerately being lost, it is estimated that around 150 species go extinct daily (Reid and Miller in Pimentel *et al.* 1992).

The loss of diversity has occurred mainly due to agricultural, industrial, and urban expansion that has penetrated the agricultural frontier, in addition to other factors such as use of pesticides, introduction of exotic species and forest fragmentation (Pimentel *et al.* 1992, Brown and Lugo 1994, Lugo 1995).

Some agricultural partially resemble to the natural environment; shaded coffee plantations, maintain soil, climatic and biological conditions similar to surrounding natural forests (Jiménez-Avila and Martínez 1979, Perfecto *et al.*1996, Moguel and Toledo 1999, Zúñiga and Calvo unpublished). However, in many countries, coffee growers have used single genus combinations for shade. In other cases, they have cultivated only one species, and in the most extreme cases, they have used unshaded coffee. As a result, this simplification process has caused diversity loss and other problems associated with it, such as erosion, pest attacks, diseases and loss of resource availability in the coffee stand (specially for subsistence producers) (Jiménez-Avila and Martínez 1979, Moguel and Toledo 1999).

Recent studies have shown the significance of managed forests for bio-diversity conservation (Hansen *et al.* 1991), diverse shade-grown coffee plantations can be considered managed forests. It has been reported that shade-grown coffee is very important as habitat for birds (Aguilar-Ortiz 1982, Greenberg *et al.* 1997, 1997a), mammals (Estrada *et al.* 1993, Gallina *et al.* 1996), reptiles (Seib, cited by Perfecto *et al.*1996), insects (Torres 1984, Perfecto *et al.* 1997), arachnids (Ibarra-Núñez 1990), woody plants (Purata and Meave 1993) and orchids (Nir 1988), which find refuge within coffee stands. Additionally, shade-grown coffee plantations can be considered as corridors for fauna and flora, since they are part of the scarcely vegetated areas within fragmented zones (Moguel and Toledo 1999). However, there are few studies that describe structural characteristics and woody plant species diversity in coffee stands that make possible to define criteria for shade-grown coffee plantations. Such studies have acquired importance due to the recent developing biodiversity friendly coffee markets in the United States and Europe. This market gives producers the opportunity to increase their income by selling "ecological friendly coffee"; additionally, it benefits consumers who prefer specialty coffee, and helps to maintain environmental health.

The present study describes and analyzes coffee stand structure and woody plant diversity in shade-grown coffee systems in Northern Chiapas, Mexico.

MATERIALS AND METHODS

Study area and selection of sampling sites: This study was carried out in two areas of Northern Chiapas. One in the municipality of Chilon and the other in the municipality of Jitotol. Both zones are located in the coffee belt of Northern Chiapas, Mexico, within the subtropical zone characterized by a warm and humid climate (A)C(m) (García 1988). The area presents a gradient between 800 to 1 200 m above sea level, having an annual rainfall of 1 200 to 1 500 mm in the higher altitudes; and 2 000 mm at the lower altitudes. Average annual temperature is 22 °C. Soils are recent, thin, and stony. Typical vegetation in the highest areas is the montane rain forest (bosque mesófilo de montaña), and in the middle and lowest zones semi-evergreen seasonal forest (bosque tropical subperennifolio (Rzedoswki 1978, Breedlove 1981).

The population of the Jitotol area belongs to the Tzotzil ethnic group and in Chilon they are Tzeltales. Both of them are Mayan descendants whose main activity is agricultural production of corn, beans, squash and coffee along with some cattle raising.

A characterization of main environmental and technical conditions in which coffee is grown was carried out. A questionnaire was given to 102 producers from Chilon and Jitotol to identify the main variants in regional coffee systems. Sixty-one sampling sites were chosen, controlling for coffee plant age, variety, and type of shade and management (organic vs. chemical). In each of the 61 plots a permanent sampling area of 10 m x 10 m was selected, where measurements of the studied variables were conducted. The square size was defined in order to relate community structure and canopy cover (Anderson 1966) based on the assumption that resulting image from hemispherical photographs gives an almost 180 degree view in all directions, with the zenith at the center and the horizon at the edges of the photograph (Roxburgh and Kelly 1995).

Measurements of coffee stand structure and diversity: Coffee density, slope and plot aspect were measured. In each plot a forest inventory with the following variables was carried out: number of individuals of each shade species, separated into nine diametric classes (1-10 cm, 10.1-20 cm, 20.1-30 cm, 30.1-40 cm, 40.1-50 cm, 50.1-60 cm, 60.1-70 cm, 70.1-80 cm, and > 80 cm in breast height diameter (breast height being 1.3 m);

life forms (tree, shrub, palm and tall herbs). The number of strata in coffee stand as well as height, use of the species and qualitative presence of woody plant seedlings were recorded. With the above-mentioned information the following variables were estimated: density, frequency, abundance, species richness, diversity index and importance value (Mueller-Dumbois 1974, Whittaker 1975). All trees and shrubs in the plots were mapped in order to define number of strata. Light density class, crown form, and number of dead trees were also recorded (Hutchinson 1988). Illumination classes considered by the position of tree crown with respect to the canopy were the following: 1) emergent, 2) full overhead light, 3) some overhead light, 4) mainly oblique light, and 5) indirect light. Crown form classes included: 1) complete circle, 2) irregular circle, 3) half circle, 4) less than half circle, 5) few branches, 6) mainly sprouts, 7) alive without crown. Voucher specimens were collected for identification and deposited in the ECOSUR's herbarium (El Colegio de la Frontera Sur) and at the National Herbarium of Universidad Nacional Autónoma de México (MEXU).

Hemispherical photos were taken in each plot (for methodology see Soto-Pinto 2000). Hemiphot (a computer program) was used to calculate canopy cover and photon flux density below the canopy (Steege 1996).

A Principal Coordinates Analysis (Everitt and Dunn 1991) based on the Jaccard's Similarity Index (Sneath and Sokal 1973) was carried out in order to identify groups of plots by floristic composition though the computational program NTSYS. Unidentified species were not included in the analysis. For each group, plot equitability was estimated through the following formula:

$$E = BA/R$$

Where:
E = plot equitability
BA = average basal area
R = species richness in 100 m^2

RESULTS

Coffee producers are indigenous people, which possess in general less than 5 ha in total; about one fifth of this land is devoted to coffee production. Shade-grown coffee is managed as a low-input system. In Jitotol there are organically-grown coffee, chemical-grown-coffee and natural-grown coffee (no inputs), while in Chilon the natural-coffee prevails. Producers do not control any pest or disease besides the berry borer, what is controlled by cultural methods. Weeds are handling removed twice a year. Cultural practices, except for harvesting are based upon family labor.

Coffee stands present a mixture of varieties Bourbon, Caturra, Mundonovo and Typica in an average density of 1 500 shrubs per hectare. Shade trees are densely non-uniformly distributed in the plots, since producers tolerate seedlings growing naturally in the coffee plantation.

Shade vegetation structure in coffee stands showed a complex vertical profile. There were five strata of shade vegetation: one herbaceous stratum, two shrubby strata and two tree strata. The average profile showed 26.4 % of emergent trees in the canopy; 21.5 % of individuals with full overhead light, 18.9 % of individuals with some overhead or oblique light; and 34.2 % with trees or shrubs with indirect light (not including coffee shrubs). Different species were represented in each stratum. The species: *Inga pavoniana*, *I. punctata, Belotia mexicana, Heliocarpus appendiculatus* and *I. sapindioides* were mainly emergent trees with full overhead light, while *H. appendiculatus*, *Citrus sinensis*, *Musa sapientum* and *Croton draco* mainly had some overhead or oblique light. Additionally, the species *Oecopetalum mexicanum, Piper auritum, Astrocharium mexicanum, Chamaedorea cataractarum, Musa sapientum and Neurolaena lobata* represented the stratum receiving indirect light. Frequency of species by illumination classes is presented in Table 1. Canopy cover ranged between 23 and 80 %.

TABLE 1

Species frequency by illumination classes for 61 producers' plot in Chilón and Jitotol, Chiapas, México

Species	Illumination classes (%)				
	Emergent trees	Full overhead light	Some overhead light	Mainly oblique light	Indirect light
Inga pavoniana	24.7	27.9	10.0	2.9	0
Inga punctata	9.9	13.2	3.3	2.9	1.5
Belotia mexicana	9.9	10.3	3.3	0	2.9
Heliocarpus appendiculatus	6.2	2.9	11.7	8.8	1.5
Inga sapindioides	6.2	2.9	3.3	2.9	1.5
Citrus sinensis	0	0	8.3	2.9	4.4
Other species	43.1	57.2	60.1	79.6	88.2

The average tree density was 371.4 trees ha^{-1}, varying between 100 and 800 trees ha^{-1}. Of all shade trees or shrubs, 76 % was woody trees. Average species richness was 3.2 species per 100 m^2, varying between one and eight species per 100 m^2.

Tree height varies between 1 and 29 m, diameters vary between 1 and 109 cm. Most of shade components were in the range of < 20 cm diameter. Diametric distribution resembles that of the secondary forest. *Inga* contributes significantly to diameters between 30 and 80 cm (Fig.1).

Tree crowns presented different forms: 49 % were a complete circle; 14 % an irregular circle; 21 % a half circle; and the remaining 16 % showed less than a half circle, few branches or mainly sprouts. There were no alive without-crown trees or shrubs registered.

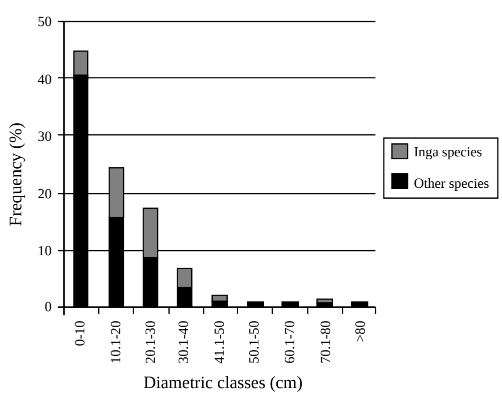

Fig. 1. Diametric distributions of shade trees and shrubs in rustic coffee plantations, Northern Chiapas, Mexico.

Seventy-seven woody species were registered in the sampling plots (Table 2). Of the total number of species, 90 % were native ones, the remaining were introduced species, mainly fruit trees. Most shade species of coffee stands belong to tropical forests. The remaining belongs to montane forests or are present in both vegetation types.

Of the total of shade species, 61.5 % are trees, 29.5 % shrubs, 6.4 % palms, and 2.6 % tall herbs. Thirty-three families and 56 genera were identified. The most numerous families are Fabaceae (legumes), followed by the Tiliaceae, Asteraceae, Arecaceae, Euphorbiaceae and Rutaceae. Most of the species of these families (55 %) were infrequent, occurred in only one plot. Other group of species (35.9 %) is more frequent (10 % of the total the plots). A smaller group (7.7 %) is the most frequent species (10-12 % of the total the plots) (Fig. 2). The most frequent-species were: *I. pavoniana*, *I. punctata*, *H. appendiculatus*, *N. lobata*, *B. mexicana*, *I. sapindioides*, and *Croton draco*. Although coffee shade is diverse in woody species, 38 % of the plots presented high importance values for any of the *Inga* species. The rest of the plots were dominated by other 26 species.

TABLE 2

Shade species, families, life forms, origin, vegetation type and relative frequency in 61 plots of shade-grown-coffee plantations in Northern Chiapas, Mexico

Family	Species	Local name	Life form	Origin	Vegetation type	Relative frequency (%)
Anacardiaceae	*Mangifera indica* L.	Mango	T	I	—-	1.6
Araliaceae	*Dendropanax arboreus* (L.) Dacne and Planchon	Ya can chamel	S	N	TF	1.6
Arecaceae	*Astrocharium mexicanum* Liebm.*	Chapay	P	N	TF	3.2
	Chamaedorea cataractarum Liebm.*	Chi'b	P	N	TF	4.8
	Chamaedorea tepejilote Liebm.*	Joma	P	N	TF	3.2
	Desmoncus schippii Burr.*	Baas	P	N	TF	1.6
Asteraceae	*Clibadium arboreum* Donn. Sm.	Jaal'te	T	N	TF	1.6
	Eupatorium chiapensis Rob.	Yash'ajal'te	S	N	TF	3.2
	Montanoa sp.*	Malacate	T	N	CF	1.6
	Neurolaena lobata (L.) R. Br.	Pom'te	S	N	BT	12.9
	Tithonia rotundifolia (Miller) Blake*	Sun	S	N	TF	1.6
	Vernonia deppeana Less.*	Sitit	S	N	TF	1.6
	Vernonia patens H.B.K.*_	Sitit	S	N	TF	1.6
Bignoniaceae	*Amphitecna macrophylla* (Seem.) Miers.	Mistel	T	N	TF	1.6
Burseraceae	*Bursera simaruba* (L.) S.	Chacaj	T	N	TF	3.2
Caricaceae	*Carica pennata* Heilb.	Papaya	T	N	TF	1.6
Elaeocarpaceae	*Muntingia calabura**	Capulin	T	N	CF	3.2
Euphorbiaceae	*Bernardia* aff. *interrupta* (Schel.) Muell-Arg.	Sac juluchay	T	N	TF	3.2
	Croton billbergianus Mull Arg.	Tumin'te	T	N	TF	1.6
	Croton draco Schlecht.*	Chi'ch bat	T	N	TF	11.3
	Sapium sp.	Juun	S	N	TF	1.6
Fabaceae	*Calliandra* sp.*	Shashim	S	N	CF	1.6
	Erythrina sp.*	Mot'e	T	N	TF	3.2
	Inga pavoniana Donn.*	Coquil'te	T	N	TF	41.9
	Inga punctata Willd.*	Tzelel	T	N	TF	24.2
	Inga sapindioides Willd.	Cok	T	N	CF	12.9
	Lonchocarpus sp.*	Shin'te	S	N	TF	4.8
	Senna multijuga (L. C. Rich.) I. and B. var *doylei*	Xaxib'te	T	N	TF	1.6
	Senna papilosa (B. and R.) I. and B.*	Cantelal tzi	T	N	TF	1.6

Table 2…Continued

Family	Species	Local name	Life form	Origin	Vegetation type	Relative frequency (%)
Fagaceae	*Quercus* sp.	Tziz'te	T	N	CF	1.6
Hamamelidaceae	*Liquidambar styraciflua* L.	Tzost'e	T	N	TF	1.6
Icacinaceae	*Oecopetalum mexicanum* Gr. and Th.	Cacaté	T	N	TF	3.2
Lauraceae	*Nectandra globosa* (Aublet) Mez.*	On'te	T	N	TF	1.6
	Persea schiedeana Nees*	Chinino	T	N	TF	3.2
Marantaceae	*Calathea macrochlamys* Woodson and Standl.*	Pimil	H	N	TF	6.5
Melastomataceae	*Conostegia xalapensis* (Bonpl.) D.Don	Pem chitom	S	N	CF	1.6
	Miconia aff. *ibaguensis* (Bonpl.)Triana*	Chac'taj'mut	T	N	TF	1.6
Meliaceae	*Cedrela mexicana* Roe	Cedro	T	N	TF	3.2
Moraceae	*Castilla elastica* Cerv.	Hule	T	N	TF	3.2
	Cecropia obtusifolia Bert*	Guarón	T	N	BT	3.2
Musaceae	*Musa sapientum* L.	Plátano roatan	T	I	—-	9.7
Myricaceae	*Myrica cerifera* L.	Atsam'te	T	N	BT	1.6
Myrsinaceae	*Myrsine myricoides* (Schlecht.) Lundell	Atsam'te	T	N	BT	3.2
Myrtaceae	*Casearia corymbosa* Kunth	Tanchit	T	N	TF	1.6
	Sysingium jambos L.*	Pomarrosa	T	I	—-	6.5
	Psidium guajava L.*	Guayaba	T	N	TF	4.8
Piperaceae	*Piper auritum* Kunth*	Momun	H	N	TF	1.6
	Piper patulum Bertol.	Momun chitom	S	N	CF	1.6
Rhamnaceae	*Rhamnus capraefolia* Shclecht.	K'anol'te	T	N	TF	1.6
Rubiaceae	*Blepharidium mexicanum* Standl.	Xacaxte	S	N	TF	1.6
Rutaceae	*Citrus aurantifolia* Osb.	Limón	S	I	—-	1.6
	Citrus reticulata Lour.	Mandarina	S	I	—-	1.6
	Citrus sinensis Osb.	Naranja	S	I	—-	8.1
	Zanthoxylum aff. *microcarpum* Griseb*	Pajul'te	T	N	TF	3.2
	Zanthoxylum aff. *kellermanii* P. Wilson*	Ichil'te	T	N	BT	1.6
Sapindaceae	*Cupania dentata* D.C.	Toj'pos'te	T	N	TF	1.6
Sapotaceae	*Pouteria zapota* Merr.	Zapote	T	N	TF	1.6
	Chrysophyllum caimito L.	Caimito	P	N	CF	1.6
	Chrysophyllum mexicanum (Brand) Standl.*	Chii't	T	N	BT	9.7
Solanaceae	*Solanum aphyodendron* Knapp*	Ashin'te	S	N	TF	1.6

Table 2…Continued

Family	Species	Local name	Life form	Origin	Vegetation type	Relative frequency (%)
Sterculiaceae	*Theobroma cacao* L.	Cacao	S	N	TF	4.8
Tiliaceae	*Belotia mexicana* Shum.*	Ik'bat	T	N	TF	12.9
	Heliocarpus appendiculatus Turcz.*	Saquil Bat	T	N	BT	16.1
	Heliocarpus donnell-smithii Rose*	Jono 'ha	T	N	TF	3.2
	Heliocarpus mexicanus (Turcz) Sprague*	Sajal Bat	T	N	TF	1.6
	Heliocarpus reticulatus Nash*	Xoch'bat	T	N	TF	1.6
Urticaceae	*Myriocarpa longipes* Liebm.	Bac'te	T	N	CF	3.2
Verbenaceae	*Lippia myriocephala* Schlech. and Cham.*	Sac Mumus	T	N	TF	1.6
Violaceae	*Orthion subssesile* (Standl.) Steyerm. and Stadl.	Weel	T	N	TF	1.6
	Non identified	Jitit'ul	T	-	TF	1.6
	Non identified	Netam'te	T	-	CF	4.8
	Non identified	Pisisnich	S	-	CF	1.6
	Non identified	Suchalanal	S	-	CF	3.2
	Non identified	Tzajal tzit	S	-	CF	1.6
	Non identified	Tzerey	T	-	CF	4.8
	Non identified	Ujchum	S	-	TF	1.6
	Non identified	Yax'te	S	-	CF	1.6
	Non identified	Zon	S	-	CF	1.6

* Seedlings of these species were presented in the plots
Origin key: N = native, I = introduced; vegetation type: TF = tropical forest, CF = cloud forest, BT = both types; life form: H = herb, S = shrub, T = tree

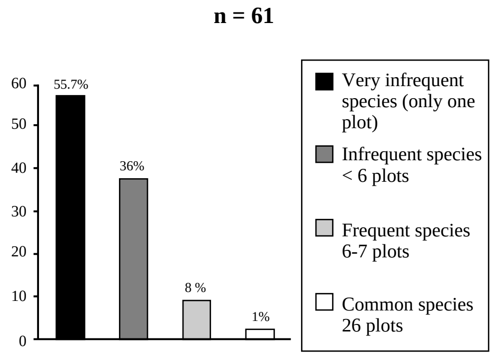

Fig. 2. Species frequency presented in shade-grown coffee plantations in northern Chiapas, Mexico.

In most plots (83.3 %), seedlings of woody species growing from the natural vegetation were registered. These seedlings are tolerated by coffee growers due to their function as useful or protection (shade) plants. Seedlings of 34 useful species were registered. Most salients were *Nectandra globosa*, *Chrysophyllum mexicanum*, *Chamaedorea cataractarum*, and *Inga pavoniana* (Table 2).

Ninety percent of the species present in the coffee stands are of some use to the producers. One hundred and twenty-three products or services were registered, most of them being represented by firewood (27.6 %), followed by food (23.6 %) and construction materials (9.8 %). The remaining are represented by plants recognized as good shade for coffee (16 %), poles used for living fences (5 %), prime material for handcrafts and labor instruments (3.3 %), home remedies (3.3 %), fibers (1 %), gums (1 %), fodder (1 %) and other domestic uses (8.4 %). Of food species, 29 different products were registered: fruits, stems and edible flowers, with fruits the most frequent. Other organisms observed in the coffee stands are mushrooms, and plant species of the families Orchidaceae, Bromeliaceae, Cicadaceae and Araceae. Three percent of the total individuals are dead trees or shrubs.

Average yield in sampling plots is 835 g of clean coffee per bush or approximately 1 668 kg ha^{-1}.

The Principal Coordinate Analyses shows four groups of plots: the first group includes plots (57.6 % of the total of plots) with diverse composition of species; the following group comprises plots (24.5 % of the total of the plots) with diverse species and *I. pavoniana*; the third group contain plots (9.8 % of the total the plots) with *I. punctata* and other diverse species; and finally, the last group comprises plots (8.1 % of the plots) including *I. punctata, I. pavoniana* and other diverse species (Fig. 3). Equitability and yields were not significantly different among groups ($p < 0.05$).

DISCUSSION

Most of the coffee shade species are native species and correspond to 40 % of the species reported for the coffee belt in northern Chiapas (Miranda 1953, Breedlove 1986, Del Amo *et al.* 1992). This highlights the salient role of shade-grown coffee system in the conservation of woody flora, as has been pointed out by Purata and Meave (1993). Shade-grown coffee systems play an important role for

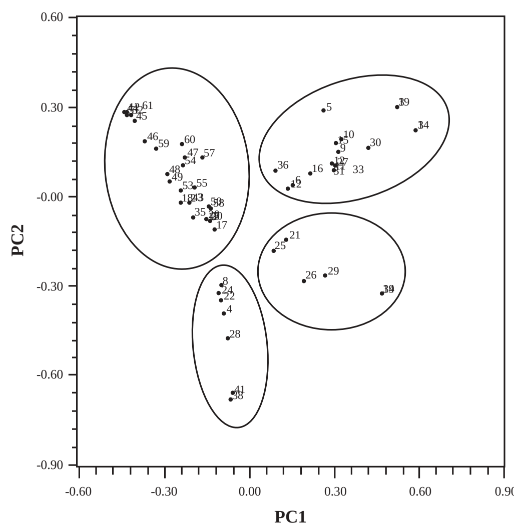

Fig. 3. Plot space projection of the first and second principal coordinates resulting from the Principal Coordinate Analyses based on a Jaccard index similarity matrix.

conservation, specially for species with narrowed distribution, as in the case of species restricted to montane forests or tropical forest as the majority of species in this study are. Even when the results showed four groups of coffee stands in relation to their woody species composition, there was no difference in equitability among groups. Each coffee stand is practically unique in plant composition, except for the presence of *Inga* species, whose dominance was corroborated in 38 % of plots. However, the majority of plots were diverse.

The dominance of *Inga* species could be due to the intervention of INMECAFE (Instituto Mexicano del Café), a government institution with wide impact on coffee activities in Mexico. This institute promoted a technological package that included the use of improved coffee varieties, use of inorganic fertilizers, pesticides and the use of species of *Inga* as shade trees. Actually, producers of several zones in Mexico still maintain the idea that *Inga* is the best choice for shade, and although the INMECAFE's dissemination programs have finished, producers still are interested in shifting diversified shade by shade dominated by one or two species of *Inga*. Producers tolerate seedlings of *Inga* species, one of the most notable species in secondary regeneration, and even, in some places they grow seeds for sowing. The fact that plots were grouped in four classes, depending on the presence of *Inga*, responds to this technological innovation occurred in last three decades. However, Romero-Alvarado (pers. comm. 2000) and Peeters (pers. comm. 2000) could not find significant differences in yields comparing *Inga*-dominated plantations versus rustic plantations. This mosaic diversity acquires importance for conservation of associated flora and fauna (Aguilar-Ortiz 1982, Torres 1984, Brash 1987, Nir 1988, Pimentel *et al.* 1992, Purata and Meave 1993, Perfecto and Vandermeer 1994, Perfecto and Snelling 1995, Greenberg *et al.* 1997a, b, and others summarized by Perfecto *et al.* (1996). The heterogeneity of vegetation can play an important role in habitat selection for associated fauna, *e.g.* bird species (Greenberg *et al.* 1997a). This heterogeneity is maintained by the following factors: the different crown forms, mainly complete and irregular circles, the presence of several vegetation strata, an irregular (non-systematic) disposition of shade trees, a high number of different taxa, the presence of dead trees, epiphytes, mushrooms and herbs. This species mosaic probably contributes to biological diversity. Unfortunately, the unavailability of studies in natural forest in this life zone do not permit to compare ecological and structural features between these and coffee plantations.

Although we did not quantify secondary regeneration, the presence of seedlings of many of the woody species reported was found in the plots. Consequently, since growing of diverse woody native species is promoted through the tolerance of seedlings, the role of producer in bio-diversity conservation is significant.

The majority of species have some useful value. Most notables are those that offer products that can not be substituted and are of primary necessity such as firewood, food and materials for construction. Other uses are less generalized, such as the use of *Heliocarpus donnell-smithii* (bark inhabits the larva of an edible butterfly), *B. mexicana* (bark is used to make rope) and *Calathea macroclamys* (leaves used to wrap "tamales", a traditional Mexican dish made of corn and wrapped in natural leaves). In this sense, it is very important to note the important role of producer's knowledge in adding ecological and socioeconomic benefits to local and global scopes.

Although producers maintain a high tree density in their plots which provides the aforementioned products or services, this density does not avoid the maintenance of coffee yields even above the Mexican average. According to Soto *et al.* (2000), coffee yield behaves in a quadratic form in relation to the percentage of shade cover, with the highest yields nearer to 50 % cover, with an average of 463 shade trees. In addition, Romero-Alvarado (pers. comm. 2000) also reported that shade tree density had no effect on crop yields.

These results lead us to think that coffee growers working on shade-grown coffee plantations have the opportunity to have a place in the bio-diversity friendly coffee production and in the specialty coffee market without a reduction in yields. Some estimations suggest that shade-grown coffee represents roughly one to two percent of the specialty coffee market, with total sales estimated at US $ to $60 million per year (Commision for the Environmental Cooperation Web Page, 2000. http: //www.cec.org). At the same time, shade-grown coffee can contribute to the preservation of natural resources and wildlife habitats in Mexico.

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RESUMEN

El café bajo sombra es un sistema agrícola que contiene algunas características de los bosques. Sin embargo, las características estructurales y de diversidad de la sombra del café son poco conocidas. En 61 parcelas de productores del norte de Chiapas, Mexico, se midieron variables estructurales de la vegetación de sombra y los rendimientos de café, registrando las especies y sus usos. Los cafetales presentaron cinco estratos de vegetación. Se encontraron 77 especies leñosas, la mayoría de uso maderable (densidad promedio de 371.4 árboles por hectárea). Noventa por ciento fueron especies nativas (40 % de la flora local), el porcentaje restante fueron especies introducidas, principalmente árboles o arbustos frutales. La distribución diamétrica se asemeja a la distribución típica de bosques secundarios. El Análisis de Coordenadas Principales distinguió cuatro grupos de parcelas por la presencia de *Inga*, sin embargo las parcelas son diversas. No hubo diferencias en equitabilidad entre grupos y tampoco en rendimientos de café. Los rendimientos fueron de 835 g de café pergamino por arbusto o aproximadamente 1668 kg por ha. Se discute el importante papel del café de sombra como refugio de plantas leñosas y como hábitats para fauna asociada así como la oportunidad de los productores de participar en el nuevo mercado de café amable con la biodiversidad.

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