Field-Testing Ecological and Economic Benefits of Coffee Certification Programs

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Abstract: *Coffee agroecosystems are critical to the success of conservation efforts in Latin America because of their ecological and economic importance. Coffee certification programs may offer one way to protect biodiversity and maintain farmer livelihoods. Established coffee certification programs fall into three distinct, but not mutually exclusive categories: organic, fair trade, and shade. The results of previous studies demonstrate that shade certification can benefit biodiversity, but it remains unclear whether a farmer's participation in any certification program can provide both ecological and economic benefits. To assess the value of coffee certification for conservation efforts in the region, we examined economic and ecological aspects of coffee production for eight coffee cooperatives in Chiapas, Mexico, that were certified organic, certified organic and fair trade, or uncertified. We compared vegetation and ant and bird diversity in coffee farms and forests, and interviewed farmers to determine coffee yield, gross revenue from coffee production, and area in coffee production. Although there are no shade-certified farms in the study region, we used vegetation data to determine whether cooperatives would qualify for shade certification. We found no differences in vegetation characteristics, ant or bird species richness, or fraction of forest fauna in farms based on certification. Farmers with organic and organic and fair-trade certification had more land under cultivation and in some cases higher revenue than uncertified farmers. Coffee production area did not vary among farm types. No cooperative passed shade-coffee certification standards because the plantations lacked vertical stratification, yet vegetation variables for shade certification significantly correlated with ant and bird diversity. Although farmers in the Chiapas highlands with organic and/or fair-trade certification may reap some economic benefits from their certification status, their farms may not protect as much biodiversity as shade-certified farms. Working toward triple certification (organic, fair trade, and shade) at the farm level may enhance biodiversity protection, increase benefits to farmers, and lead to more successful conservation strategies in coffee-growing regions.*

Keywords: ants, birds, Chiapas, fair trade, Mexico, organic coffee, price premium, shade coffee

Pruebas en Campo de los Beneficios Ecológicos y Económicos de los Programas de Certificación de Café

Resumen: *Los agroecosistemas de café son críticos para el éxito de esfuerzos de conservación en América Latina debido a su importancia ecológica y económica. Los programas de certificación de café pueden ofrecer una manera de proteger la biodiversidad y mantener el sustento de los campesinos. Los programas de certificación de café caen en tres categorías distintas, pero no mutuamente excluyentes: orgánico, comercio justo y de sombra. Los resultados de estudios previos demuestran que la certificación de sombra puede beneficiar a la biodiversidad, pero no es claro si la participación de un campesino en cualquier programa de certificación puede proporcionar beneficios tanto ecológicos como económicos. Para estimar el valor de la certificación de café para los esfuerzos de conservación en la región, examinamos aspectos económicos y ecológicos de la producción de café en ocho cooperativas en Chiapas, México, que tenían certificado orgánico, certificado orgánico y comercio justo o no certificado. Comparamos la vegetación y la diversidad de aves y hormigas en las fincas cafetaleras y bosques, y entrevistamos a campesinos para determinar la producción de café,*

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la ganancia bruta por la producción de café y la superficie con producción de café. Aunque no hay fincas con certificación de sombra en la región de estudio, utilizamos datos de la vegetación para determinar si las cooperativas pudieran calificar para certificación de sombra. Con base en la certificación, no encontramos diferencias en las características de la vegetación, riqueza de especies de aves y hormigas o la fracción de fauna de bosque en las fincas. Los campesinos con certificación orgánica y orgánica y comercio justo tuvieron más tierra bajo cultivo y, en algunos casos, mayores ganancias que los campesinos no certificados. La superficie de producción de café no varió entre tipos de finca. Ninguna cooperativa alcanzó los estándares de certificación de sombra porque sus plantaciones carecían de estratificación vertical, aunque las variables de la vegetación para la certificación de sombra se correlacionaron significativamente con la diversidad de aves y hormigas. Aunque los campesinos del altiplano de Chiapas con certificación orgánica y/o de comercio justo pueden obtener algunos beneficios económicos de su estatus de certificación, sus fincas no protegen tanta biodiversidad como las fincas con certificación de sombra. Trabajar hacia la triple certificación (orgánica, comercio justo y sombra) a nivel de fincas puede reforzar la protección de biodiversidad, incrementar beneficios a los campesinos y llevar hacia estrategias de conservación más exitosas en regiones productoras de café.

Palabras Clave: aves, café orgánico, Chiapas, comercio justo, hormigas, México, precios

Introduction

Coffee production areas overlap with biodiversity hotspots (Hardner & Rice 2002), and in much of northern Latin America, coffee grows in areas with little remaining forest. For example, in northern Chiapas, forest patches cover <20% of land area (DeJong et al. 1999; Ochoa-Gaona 2001), but about 90% of coffee is shade-grown (Moguel & Toledo 1999). In El Salvador, <10% of the original forest remains, but 92% of the coffee is grown under shade and accounts for 80% of the country's tree cover (Rice & Ward 1996; Panayotou et al. 1997). Coffee managed under a floristically and structurally diverse canopy provides important habitat for biodiversity, but removing shade trees, limiting shade cover, and using agrochemicals generally results in losses of biodiversity for epiphytes, arthropods, birds, and mammals (e.g., Perfecto et al. 1996; Moguel & Toledo 1999; Perfecto et al. 2007). For Central American countries and Mexico coffee accounts for between 5% and 25% of exports, which makes coffee production very important to local economies (Gresser & Trickell 2002). In addition, coffee provides livelihoods for millions in the region, but market fluctuations have encouraged farmers to abandon coffee production temporarily or to turn to agricultural systems such as pasture or coca production with fewer ecological benefits (Gresser & Trickell 2002; Philpott & Dietsch 2003; Bacon 2005). Thus the importance to conservation of finding ways to make coffee production economically viable cannot be overstated.

Certification of coffee farms as organic, fair trade, and/or shade grown offers one way to protect biodiversity and to promote living wages for farmers. Certification is a process whereby producers solicit inspections to independently verify they meet criteria relating to, for example, farm management, processing, and working conditions. If criteria are met the certification agency authorizes a seal of approval on packaging, thereby assuring consumers that specific criteria are met on the farm where products are grown. Criteria and cost for each coffee certification (organic, fair trade, and shade) differs. Organic certification works to eliminate agrochemical use and to promote management practices that maintain soil fertility (Vandermeer 1995). All organic certification agencies must comply with standards maintained by the International Federation of Organic Agriculture Movements. Although certification costs present a barrier for some farmers, national certification initiatives such as Certimex in Mexico have helped reduce costs (Gobbi 2000; Calo & Wise 2005). Fair-trade certification focuses on providing smallholder cooperatives minimum prices for coffee and producer financing. Cooperatives receive US$2.78/kg (US$3.11/kg for fair trade and organic) and are guaranteed at least US$0.11/kg above market prices with the expectation that this premium will be used to further infrastructural or social goals. Since 2004 farmer cooperatives pay for initial certification and for renewal (http://www.fairtrade.net). Fair Trade Labeling Organizations International (FLO) regulates certification, but national initiatives market fair-trade coffee in importer countries. Shade coffee is certified under two programs: Smithsonian Bird-Friendly (BF) and Rainforest Alliance Certified. Shade certification is based on research that structurally complex and diverse shade canopies protect biodiversity. The BF charges a per-year certification fee and farms must also be organic. Rainforest Alliance charges a per-hectare fee. In addition, programs require paying travel and per-diem expenses for inspectors but try to minimize costs by employing local certification agencies.

The positive effect of shade coffee on biodiversity is well established and is summarized in recent reviews (Moguel & Toledo 1999; Philpott & Armbrecht 2006; Perfecto et al. 2007), but little attention has been given to outlining how shade certification works or studying impacts

Table 1. Farm vegetation characteristics compared with criteria for shade-coffee certification to determine ability to obtain certification.[a]

	Certification program[b]		*Organic farms*			*Organic and fair-trade farms*			*Uncertified farms*	
Criteria	*Bird-Friendly*	*Rainforest Alliance*	*CW*	*TZ*	*UR*	*OPTC*	*TB*	*TT*	*DM*	*NM*
No. of tree species	>10	na	63	72	49	47	50	61	44	64
No. of tree species/ha	na	>12	30	46	17	19	18	33	20	35
Mean no. of trees/ha	na	>70	316.7	299.5	171.2	136.8	283.3	260.3	107.0	151.7
Cover (%)	>40	>40	51.4	62.3	49.4	56.8	51.5	56.5	52.6	65.8
Shade strata (leaf volume [%])										
emergent layer (<15 m)	20	20	3.1	0.9	3.7	0.3	0.2	2.4	0.6	7.0
backbone layer (12–15 m)	60	na	44.7	47.2	23.5	35.1	12.7	49.7	31.2	42.2
understory (<12 m)	20	na	52.1	52.0	72.9	64.6	87.1	47.9	68.3	50.9
no. of shade strata	3	2	3	3	3	3	3	3	3	3
epiphytes	present	na	yes	yes	yes	yes	yes	yes	yes	yes
no. of species representing >1% of individuals	10	na	18	22	12	19	9	20	16	21
individuals of *Inga* spp. (% of total)	<60	na	39.4	14.8	33.1	62.6	62.9	28.2	62.4	19.9
no. of Bird-Friendly certified (total 7)	na	na	6	6	6	6	5	6	6	6
no. of Rainforest Alliance certified (total 5)	na	na	4	4	4	4	4	4	4	4

[a] *Coffee cooperatives are: CW, Cafetaleros de la Cañada de Cacwilja; TZ, Tzajalchen; UR, Ureafa; OPTC, Organizacion de Productores Tzeltales de Café; TB, Tzijib Babi; TT, Tzotzilotic Tzobolotic; DM, Despertar Maya; NM, Nuevo Milenio.*

[b] *An na indicates that no criteria are necessary for that factor.*

of shade certification on biodiversity. BF and Rainforest Alliance certification programs include shade criteria for tree species richness and composition, tree height, number of strata in the canopy, and percent canopy cover. The Rainforest Alliance also includes tree density, and the BF program includes presence of epiphytes (Table 1). During farm visits, BF inspectors establish a series of 25-m-radius plots in which they determine tree species richness, estimate tree height of the principal canopy layer, note presence of emergent trees, and measure canopy cover with concave spherical densiometers. Inspectors must sample two points per hectare on small farms (≤5 ha), one point per hectare on medium farms (5–10 ha), and one point per every 2 ha on large farms (≥10 ha) for up to roughly 10 points per farm or until general farm characteristics have been assessed adequately. Certification for cooperatives differs slightly from that of large farms because members may be dispersed among communities that differ significantly in shade management. In these cases the cooperative evaluates its members' shade characteristics and separates those growers with adequate shade from those without. Farms with adequate shade are then the ones inspected. If the cooperative wants all communities to be certified, inspectors randomly choose which farms to visit and the entire cooperative either passes or fails certification. For Rainforest Alliance inspection auditors rely heavily on data provided from farm managers and make farm visits to confirm information provided. During visits inspectors estimate canopy cover, count the number of trees per hectare, and estimate tree species richness per hectare in small plots, which they then extrapolate to species richness per hectare (Komar 2006).

To our knowledge examination of coffee farms for both faunal biodiversity and shade-certification status (based on BF shade-certification criteria) has been conducted in only four studies, all from the same farms in the Soconusco region of Chiapas (Andresen 2003; Mas & Dietsch 2003; Perfecto et al. 2003; Mas & Dietsch 2004). Although other farms included in the studies could have passed Rainforest Alliance criteria at the time studies were conducted, those criteria have since changed. Butterflies and birds were sampled in two forest fragments, one BF farm, and three farms that could not have passed BF certification (non-BF); both arboreal and ground-foraging ants were sampled in these and one additional non-BF farm.

With information provided by authors of the studies in Soconusco, we examined the species overlap between the BF and non-BF farms and the nearest forest fragment. We calculated numbers and percentages of forest species maintained in farms and species similarity (Bray–Curtis similarity index). For all taxa except for butterflies, BF farms supported a higher number and proportion of forest species and had higher species similarity to forests than did non-BF farms. Butterfly species richness was higher in the BF farm, but numbers of forest species in BF farms (4, 28.57%) and non-BF farms (3.75, 27.50%) did not differ (Mas & Dietsch 2003). Furthermore, butterfly similarity between the BF farm and forest was 0.21, and between non-BF farms and forest it was 0.23 ± 0.04 (±SE). In contrast, 20 (58.82%) species of forest birds occurred in the

BF farm and only 9.75 (38.52%) species occurred in non-BF farms, and similarity between the BF farm and forests (0.59) was greater than similarity between non-BF farms and forest (0.25 ± 0.03). For ground-foraging ants, there were 13 (56.52%) forest species in the BF farm and only 8.4 (30.72%) in non-BF farms. Similarity to forests was also greater in BF than in non-BF farms (0.58 vs. 0.47 ± 0.08). Finally, more forest arboreal ants were seen in the BF farm (8 or 40.00%) than in non-BF farms (4.6 or 26.19%), and similarity to forest was also greater (0.21 vs. 0.13 ± 0.01) in BF than in non-BF farms. These results strongly support the argument that shade certification benefits biodiversity generally and for forest species in particular. Whether or not organic and fair-trade certification have similar ecological benefits is less clear.

Given that each certification program has different goals, uncertainty surrounds how each contributes to ecological and economic sustainability at the farm level (Ponte 2004). Organic certifiers such as Certimex in Mexico encourage planting diverse plant species for shade, but do not define minimum criteria, and their technical assistants reportedly advise farmers to cut or prune trees to improve yields. Information on FLO's Web site states that 80% of producers grow coffee in the shade, yet it is unclear if this shade is of a level adequate to protect biodiversity. Some have found that organic and fair-trade certification provide at least some financial benefit to farmers (Bacon 2005; Calo & Wise 2005). Although shade certification may attract price premiums for producers, this is not an inherent part of shade certification (Ponte 2004) and no one has convincingly demonstrated economic benefits to farmers. Much double-certified coffee (organic and fair trade or organic and BF) exists, but some argue that a coordinated effort of triple certification incorporating all three might better meet overall sustainability goals (Philpott & Dietsch 2003; Ponte 2004) and thus better contribute to conservation efforts. Yet, it is unknown whether there are farms that meet criteria for all three programs or whether the ecological and economic goals of these programs could overlap. In addition, the relative benefits of economic and ecological factors have not been examined in certified and uncertified farms. Understanding these factors may be important for achieving sustainable agricultural systems that contribute to both farmer livelihoods and conservation.

The landscape of highland Chiapas is dominated by coffee agriculture, and there are more than 70 smallholder cooperatives in this area, the majority of which have some type of coffee certification. In fact, Mexico is one of the top producers of both organic and fair-trade coffees (Calo & Wise 2005). At the time our research was conducted, there were no shade-certified cooperatives in the same areas where fair-trade and organic cooperatives were prevalent. We compared vegetation characteristics and ant and bird diversity in coffee farms with and without organic and fair-trade certification and in nearby forests. We also investigated farmer-reported yields, gross revenue from coffee production, and use of alternative crops to examine relationships between these economic factors, certification, and biodiversity. Specifically, we pursued answers to the following questions: How does vegetative complexity (floristic diversity and structure) of organic and fair-trade farms and uncertified farms compare with shade certification criteria and with nearby forests? How do the numbers of species, percentage of forest species, and similarity of species assemblages of trees, ants, and birds in certified and uncertified coffee and forest habitats compare? Do coffee yields, revenues, or use of alternative products differ according to certification? In an attempt to guide certification efforts toward incorporating both ecological and economic goals, we investigated how organic and fair-trade coffee certification programs compare in terms of economic attributes and how each compares ecologically with shade-certification guidelines.

Methods

In the highlands of Chiapas, Mexico, around San Cristobal de las Casas, there are more than 70 smallholder coffee cooperatives—approximately 50 have organic certification and 20 (all of which are also organic) are listed in the fair-trade register, but none have shade certification. On the basis of this availability we compared cooperatives with organic certification, organic and fair-trade certification, or no certification. To select cooperatives we presented projects to >20 groups and independently verified their certification status. We verified fair-trade certification with the 2005 FLO Fair Trade Register and organic certification with the FLO Fair Trade Register (includes information on international organic certification) and Certimex producer lists (national organic certification). We then selected eight cooperatives from those that accepted our project. We conducted field studies in eight sites distributed in three regions of Chiapas (Los Altos, Zona Norte, and Norte Selva). Technical assistants of each cooperative selected the specific communities we visited on the basis of our minimum site requirements (>30-ha coffee production, 800–1400-m elevation, and nearby forest habitat). Each site had members belonging to one cooperative (three organic cooperatives, three organic and fair trade, and two uncertified) (Table 2). Farmer plots in each community were managed by individual families, rather than collectively by the cooperative. In each site we established 30 plots in coffee agroecosystems and 10 plots in nearby forest. Each plot was a 25-m-radius circle at least 100 m from any other plot. We sampled vegetation and ant and bird diversity in these plots in October–November 2004 and in June–July 2005.

To quantify vegetation characteristics, we counted the number of shade trees, coffee plants, and epiphytes and recorded the species and height of each tree in a plot. At

Table 2. Location and certification of coffee cooperatives sampled in the Chiapas highlands.[a]

Region	*Cooperative*	*Certification held*	*Municipio*	*Community*	*No. of households*	*Household landholding (ha)*[b]	*Mean elevation (m)*
Los Altos	OPTC	organic, fair trade	Tenejapa	Majosik, Pacteton, Jomenachim	125	2.05	1358
	TZ	organic	Oxchuc	Tzajalchen	45	2.12	1548
	DM	uncertified	San Juan Cancuc	Tzuluwitz	28	0.68	1464
Zona Norte	TT	organic, fair trade	El Bosque	San Miguel, Sabinotic, El Virgel	250	2.94	1233
	UR	organic	Simojovel	Plan Paredon	341	1.66	971
	NM	uncertified	Jitotol	Altamirano	58	1.3	1464
Norte Selva	TB	organic, fair trade	Tumbala	Yevalchen	1074	1.38	1237
	CW	organic	Chilon	Cacwilja, Centro Cacwilja	17	1.65	1223

[a] *Coffee cooperatives are: CW, Cafetaleros de la Cañada de Cacwilja; TZ, Tzajalchen; UR, Ureafa; OPTC, Organización de Productores; Tzeltales de Café; TB, Tzijib Babi; TT, Tzotzilotic Tzobolotic; DM, Despertar Maya; NM, Nuevo Milenio.*

[b] *Mean size based on landholdings in surveyed communities, not cooperative-wide data.*

five points per plot (at the circle center and 10 m to north, south, east, and west), we measured canopy cover with a concave spherical densitometer and estimated height of the low and high points of vegetation overhead to calculate average canopy depth. We sampled vegetation >18 m tall with a range finder. When possible, tree identifications were made in the field. Unknown trees were given a unique morphospecies number and later identified on the basis of comparisons of collected leaves and/or reproductive material with specimens in the collection at the Universidad de Ciencias y Arte de Chiapas herbarium in Tuxtla Gutierrez.

Using vegetation data, we created a management index (MI) to summarize farm management strategy (Mas & Dietsch 2003). Raw values for each variable (per plot) were converted to numbers on a scale from 0 (least intensive) to 1 (most intensive). To convert most variables (number of trees, number of tree species, vegetation depth, average tree height, percent shade cover, number of epiphytes, and percent emergent trees [>15 m]) to the scale, we divided each measurement by the highest recorded value and subtracted this from 1. For coffee density, which is proportional to management intensity, we divided each measurement by the highest recorded value. We summed values for each variable for a possible total of 8 per plot and divided this value by the total number of variables to obtain a value between 0 and 1. We used multivariate analysis of variance (MANOVA) to test for differences in vegetation variables, analysis of variance (ANOVA) to test for differences in MI, and Tukey's post hoc tests to distinguish between habitat type and certification. Data for vegetation depth, epiphytes, tree individuals, and average tree height were log transformed and percent emergent trees were square-root transformed to meet conditions of normality.

Because no farms in this region were certified by the BF program or by the Rainforest Alliance, we used the vegetation variables measured in each community to determine whether each cooperative qualified for either shade certification program. We randomly selected five farm plots per site (equaling roughly 1 ha) to determine tree density per hectare. For all other variables we calculated mean numbers per plot. Certification criteria for shade strata differed slightly from our field measurements, so we used height data to separate trees into strata (<12, 12–15, and >15 m) and weighted tree densities to estimate total leaf volume (<12 m $=$ density $\times$ 1; 12–15 m $=$ density $\times$ 2; >15 $=$ density $\times$ 3). We then compared vegetation variable values from the sites with certification criteria.

We sampled ants in two ways. First, we used mini-Winkler leaf litter traps to sample a 1-m^2 area of leaf litter randomly taken from inside the circular plots following standard protocol for sampling leaf-litter ants (Agosti & Alonso 2000). We chopped and sifted leaf litter for 5 minutes per sample, placed sifted litter (including arthropods) into mini-Winkler traps affixed with alcohol-filled cups for 48 hours. We also visually sampled ants and conducted nest searches on the coffee plants. In each plot we observed ants on four haphazardly selected coffee plants (or understory plants in forest plots) that were first shaken to disturb workers. We broke off all dry twigs on coffee or understory plants and examined them for ants. All ants were collected for later identification. All ants were identified by S.M.P., who was assisted by myrmecologists at Harvard University and the Smithsonian Institution. Voucher specimens of ants were deposited in the National Museum of Natural History (Washington, D.C.).

We surveyed birds by sight and sound with 10-minute point counts in each of the plots (Hutto et al. 1986; Petit et al. 1994). We sampled plots in Mexico once during the dry season when neotropical migrants are present, and once during the wet season when only resident birds are expected to be seen or heard.

To compare tree, ant, and bird richness in coffee and forest sites in each geographic region, we generated sample-based rarefaction curves (MaoTao estimates) with EstimateS (version 7.5) (Colwell & Coddington 1994; http://www/viceroy/eeb/uconn/.edu/estimates). To compare richness between sites, we rescaled sample-based rarefaction curves to the number of individuals (or occurrences for ants) (Gotelli & Colwell 2001; Longino et al. 2002). Statistical comparisons of richness are possible with MaoTao estimates and corresponding 95% confidence intervals produced with analytical formulas.

We compared species similarity between coffee and forest plots with similarity indices calculated with EstimateS and by examining raw numbers of shared species in each habitat type. For all taxa (trees, ants, and birds) we compared the composition of coffee plots in each community with forest plots within that geographical area for a total of eight comparisons. For each comparison all species in coffee plots comprised one sample, and all species in forest plots comprised the second sample. As a baseline reference we also compared species similarity among forest plots in each area (three comparisons total). We used the Bray–Curtis and Jaccard Similarity indices (Marrugan 1988) and the Chao–Jaccard raw abundance and Chao–Jaccard estimated abundance indices (CJEAI; Chao et al. 2005) as measures of similarity. The latter two indices are based on the probability that two individuals, chosen at random from two samples, belong to a species shared by both but not necessarily the same species. The CJEAI includes a bias correction for those species that may occur in a site even though they were not encountered in sampling. Both estimators can significantly reduce sample-size bias. Because we made several comparisons between coffee and forest plots in each area, we were able to statistically compare the calculated index values for each habitat and area with ANOVA, and we used Tukey's post hoc tests to determine whether coffee plots with a certain certification preserved a higher proportion of forest species.

We used linear regressions in SPSS (v. 10.0, SPSS, Chicago, Illinois) to investigate whether individual vegetation characteristics of coffee farms or overall coffee MI predicted ant or bird species richness. For separate vegetation variables we used stepwise multiple linear regression with backward selection when vegetation variables (percent canopy cover; vegetation depth; number of epiphytes, trees, tree species; mean tree height; percent emergent trees, and number of coffee plants) were the independent variables and ant or bird richness were dependent variables. Data for vegetation depth, epiphytes, tree individuals, and average tree height were log transformed and percent of emergent trees was square-root transformed to meet conditions of normality. For the MI we used simple linear regressions in which the MI value was the independent variable and ant or bird species richness was the dependent variable.

Local workers interviewed farmers in Tzotzil, Tzeltal, and Spanish (depending on community visited) in July 2005. To directly compare farmers with different certifications, we questioned farmers about area in coffee production, coffee yields, and coffee prices for the most recent (2004) and previous (2003) harvests. We asked farmers about the number and types of alternative products grown, costs and use of agrochemicals, and off-farm incomes (city jobs, remittances). We interviewed 10 farmers per community for a total of 80 farmers. To examine for differences in coffee landholding, coffee yields, coffee price, and gross revenue per hectare over the 2-year period, we used repeated-measures ANOVA with year as the repeated factor and certification and area, yield, or gross revenue from coffee as between-subject factors. We compared the average number of alternative products among certification types with ANOVA.

Results

Ecological Surveys

Overall, the intensity of coffee management of the farms did not depend on coffee certification (Table 3). Generally, forest fragments had higher floristic diversity and structure than the coffee farms. Farms with organic, organic and fair trade, or without certification were not distinguishable from one another. Nevertheless, farms with different certifications differed for some individual vegetation variables (Table 3). Organic and organic and fair-trade farms had higher coffee densities than uncertified farms. Organic farms had between 1.2 and 1.4 times more tree species than the other farms and had twice as many individuals as the uncertified farms. Uncertified farms had higher mean tree height than organic farms and thicker canopies than the organic or organic and fair-trade farms. None of the farms met BF or Rainforest Alliance shade criteria (Table 1). For seven of the eight cooperatives, only one criterion for each program was not met—vertical stratification (percent of leaf volume belonging to the understory, backbone, and emergent tree layers). The remaining cooperative additionally had too few species, comprising at least 1% of the individuals sampled.

According to species accumulation curves and 95% confidence intervals, there were significantly more species of trees, ants, and birds in forests than in any of the coffee types (Fig. 1). Furthermore, there were significantly more tree species in the organic farms than in the organic fair-trade or uncertified farms, but numbers of ants and birds did not differ with certification (Fig. 1). The organic farms shared a higher number of tree, ant, and bird species with forests than did organic and fair-trade farms or uncertified farms, and a higher percentage of forest species occurred in organic farms (Table 4) than in other coffee farms. According to patterns in species-similarity indices, the ant and bird assemblages in

Table 3. Vegetation variables and elevation measured in coffee farms with different sustainable certifications and nearby forest fragments.*

	Forest	*OFT*	*ORG*	*UC*
Elevation (m)	1293 ± 24	1265 ± 12	1243 ± 25	1308 ± 20
Cover (%)	77.40 ± 1.60a	55.00 ± 1.40b	54.40 ± 1.50b	59.30 ± 1.90b
Vegetation depth (m)	7.13 ± 0.52a	2.33 ± 0.14c	2.84 ± 0.19b,c	3.57 ± 0.25b
No. of epiphytes	34.06 ± 8.49a	8.28 ± 1.53b	26.77 ± 4.83b	8.15 ± 2.02b
No. of tree individuals	47.38 ± 4.20b	50.11 ± 3.25a,b	52.49 ± 2.92a	26.80 ± 1.13c
No. of tree species	10.91 ± 0.55b	10.14 ± 0.46b	12.89 ± 0.49a	9.33 ± 0.47b
Mean tree height (m)	8.49 ± 0.39a,b	7.43 ± 0.18b	7.83 ± 0.17a,b	8.39 ± 0.19a
Emergent trees (%)	8.70 ± 1.50a	0.80 ± 0.40c	1.90 ± 0.40b,c	2.80 ± 0.50b
No. of coffee plants	0 ± 0c	207.78 ± 3.05a	212.10 ± 4.10a	184.17 ± 4.52b
Management index	0.58 ± 0.01b	0.74 ± 0.01a	0.72 ± 0.01a	0.73 ± 0.01a

**Numbers show mean ± standard error and letters indicate significant differences (p < 0.05) within a variable for each certification type (OFT, organic, fair trade; ORG, organic; UC, uncertified). The management index is proportional to management intensity.*

forests and on coffee farms were more similar than were tree assemblages in these two habitat types (Table 4). Yet none of the similarity indices showed trees, ants, or birds in coffee farms from one certification to be more similar to forests than other certification types (ANOVA, $p > 0.05$). The number of ant and bird species significantly decreased with increases in management intensity (ants: $y = -107.23x + 88.688$, $r^2 = 0.8005$, $p = 0.003$; birds: $y = -64.854x + 56.454$, $r^2 = 0.7651$, $p = 0.004$). For individual vegetation variables the final model predicting ant richness included number of coffee plants ($t = -1.755$, $p = 0.082$), tree richness ($t = 4.849$, $p < 0.001$), number of trees ($t = 2.73$, $p = 0.007$), tree height ($t = 2.354$, $p = 0.02$), and percentage of emergent trees ($t = -1.841$, $p = 0.068$) as the best predictors of ant richness (final model, $r^2 = 0.386$). The regression model predicting bird richness included number of coffee plants ($t = -2.482$, $p = 0.014$), tree richness ($t = 2.8$, $p = 0.006$), and canopy depth ($t = 2.579$, $p = 0.011$) as the best predictors of bird richness (final model, $r^2 = 0.218$).

Farmer Interviews

Production area, yield, gross revenue from coffee, and coffee price varied with certification and year, but there were no significant changes in coffee landholding over time. According to farmer interview data, coffee yields were greater in 2003 than in 2004 ($F_{1,77} = 25.318$, $p < 0.001$), but there was no difference in yield due to certification ($F_{2,77} = 2.636$, $p = 0.078$) or interaction between year and certification ($F_{2,77} = 0.188$, $p = 0.829$) (Fig. 2). The price paid to farmers for coffee increased from 2003 to 2004 ($F_{1,77} = 314.07$, $p < 0.001$) (Fig. 2). Certified farmers did not receive consistently higher prices for their coffee than uncertified farmers ($F_{2,77} = 0.632$, $p = 0.534$); nevertheless, different groups of farmers were paid more in different years ($F_{2,77} = 8.155$, $p = 0.001$). In 2003 all farmers were paid a similar amount per kilogram, whereas in 2004 uncertified farmers were paid slightly more than others (Fig. 2). Gross revenue from coffee production also increased from 2003 to 2004 ($F_{1,77} = 3.589$,

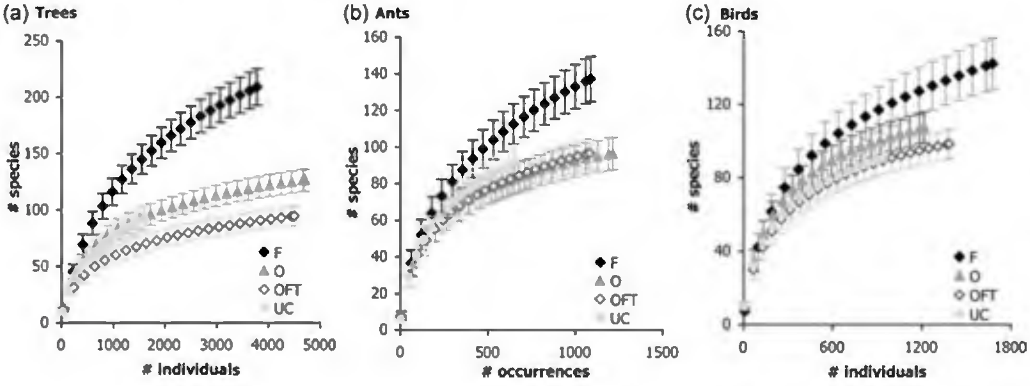

Figure 1. Species accumulation curves for (a) trees, (b) ants, and (c) birds found in forests (F) and coffee agroecosystems based on coffee certification type (O, organic; OFT, organic and fair trade; UC, uncertified). Accumulation curves were created with EstimateS and show MaoTao estimates. Error bars show 95% CI, and nonoverlapping bars show statistical differences.

Table 4. Species richness, shared species, and similarity indices for forest and coffee farms (uncertified, organic, and organic/ fair trade) in Chiapas, Mexico.*

Taxa and plot type	*No. species*	*No. individuals*	*No. shared species*	*Forest species maintained (%)*	*Bray-Curtis*	*Jaccard*	*Chao-Jaccard estimated*
Trees							
forest	208	3790	na	na	0.18 ± 0.02	0.24 ± 0.02	0.30 ± 0.03
uncertified	92	1608	62	29.01	0.18 ± 0.09	0.24 ± 0.06	0.33 ± 0.13
organic	126	4724	91	43.75	0.22 ± 0.08	0.32 ± 0.06	0.46 ± 0.07
organic + fair trade	94	4510	68	32.69	0.18 ± 0.06	0.26 ± 0.04	0.37 ± 0.09
Ants							
forest	137	1099	na	na	0.60 ± 0.01	0.41 ± 0.01	0.85 ±0.04
uncertified	91	661	78	56.93	0.61 ± 0.02	0.46 ± 0.01	0.88 ± 0.01
organic	96	1220	84	61.30	0.59 ± 0.10	0.42 ± 0.10	0.80 ± 0.12
organic + fair trade	96	1085	79	57.66	0.63 ± 0.02	0.46 ± 0.01	0.87 ± 0.04
Birds							
forest	142	1693	na	na	0.55 ± 0.04	0.47 ± 0.04	0.70 ± 0.05
uncertified	90	951	80	56.33	0.55 ± 0.06	0.53 ± 0.02	0.80 ± 0.02
organic	107	1229	94	66.19	0.47 ± 0.05	0.45 ± 0.06	0.67 ± 0.06
organic + fair trade	98	1399	88	61.97	0.52 ± 0.02	0.52 ± 0.02	0.78 ± 0.03

**Total species per forest and farm type, no. of individuals (or ant occurrences) per habitat. For farms, we also show number of species shared with forest, and percentage of forest species in each coffee habitat. Similarity indices (Bray-Curtis, Jaccard, and Chao-Jaccard estimated) show mean (±SE) between forests in different regions (forest) or for forests and coffee farm types in the same region. See text for explanation of calculations.*

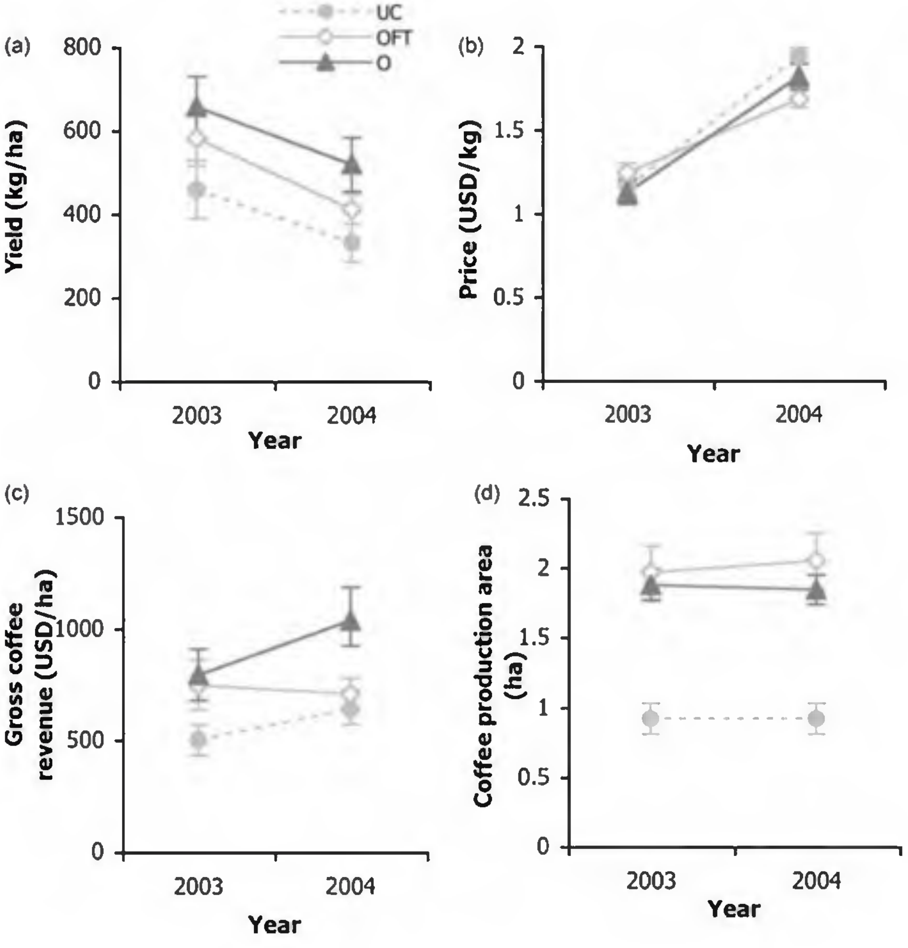

Figure 2. (a) Farmer yields, (b) prices paid per kilogram of coffee (USD, U.S. dollars), (c) total gross revenue from coffee per hectare, and (d) total area in coffee production reported in farmer interviews in Chiapas, Mexico. Farms were either certified organic (O), organic and fair trade (OFT), or uncertified (UC).

$p = 0.032$), but did not depend on certification ($F_{2,77} = 2.541, p = 0.085$) (Fig. 2). There was, however, a significant interaction between year and certification. Organic and organic fair-trade farmers earned more than uncertified farmers in 2003, but in 2004 only organic farmers earned a higher amount than uncertified farmers ($F_{2,77} = 5.989, p = 0.017$) (Fig. 2). Organic and organic fair-trade farmers had on average 1.8–2.3 times larger coffee landholdings than uncertified farmers ($F_{2,77} = 12.809$, $p < 0.001$), but there was no change in land area in coffee production between 2003 and 2004 ($F_{1,77} = 0.548, p = 0.461$) or a change in total land area in coffee production for any group over time ($F_{2,77} = 2.733$, $p = 0.071$) (Fig. 2).

Coffee farmers in all groups also had several other potential sources of income. Of the 80 farmers interviewed, 79 grew alternative products with their coffee, and numbers of farmers growing alternative crops did not differ by type of certification ($\chi^2, p = 0.980$). Nevertheless, the average number of alternative products grown differed with certification ($F_{2,72} = 3.147$, $p = 0.049$). Organic farmers grew 6.06 ± 0.49 alternative products in coffee farms, significantly more than uncertified farmers (4.40 ± 0.28) ($p = 0.037$), but numbers of products grown by organic fair-trade farmers (5.43 ± 0.44) did not differ from organic or uncertified farms. Uncertified farmers grew nearly twice as many products per hectare (6.17 ± 0.76) than organic (3.53 ± 0.33; $p = 0.002$) or organic fair-trade farmers (3.67 ± 0.47; $p = 0.003$) ($F_{2,77} = 3.147$, $p = 0.001$). Seven of 80 farmers received income from off-farm labor such as carpentry, playing music, selling soda, or running a store. Only one of 80 farmers received remittances from relatives in Sonora. Seventeen farmers also raised cattle, which they often sold to cover the costs of production. Because of the survey design, we could not calculate the income farmers gained from alternative products, but all off-farm income sources accounted for only 7.92 ± 2.13% of their income when including total revenue from coffee and other sources. None of the farmers spent money on agrochemicals and none reported using chemical control of weeds or pests on their plot within the past year.

Discussion

In general, forests had higher tree, ant, and bird species richness and vegetation complexity than coffee farms, and there were no significant differences between farms participating in organic and/or fair-trade certification programs and uncertified farms in terms of shade management or species richness of ants and birds. Decreases in management intensity and coffee plant density and increases in tree richness all correlated with increases in ant and bird species richness. Ant richness was negatively correlated with percentage of emergent trees but increased with average tree height, and bird richness increased with increases in canopy depth. Each vegetation variable measured roughly corresponded to one or more shade-certification criteria, and none of the farms studied qualified for either shade-certification program because they lacked the necessary vertical stratification. Average tree height and canopy depth, two of the variables important for predicting ant and bird richness, respectively, corresponded to the vertical aspect of the shade canopy. It is unknown why ant richness responded positively to tree height and negatively to percentage of emergent trees. One explanation may be that we sampled leaf-litter and lower-strata arboreal ants and did not find ants that would inhabit trees in the emergent layer. In general, one may assume that with increases in canopy depth and average tree height and with overall decreases in management intensity that more diverse ant and bird communities would occur on these coffee farms. From a strictly ecological standpoint, were farmers to meet all shade criteria they would likely protect more species and a higher fraction of forest biodiversity.

Another way to examine whether meeting shade criteria increases ant and bird richness would be to directly compare data from our study with ant and bird data from BF-certified farms in Soconusco. Mas and Dietsch (2004) found nearly 60% of forest birds in a BF farm but only around 40% in non-BF farms. In cooperative farms we found 55–66% of bird species found in nearby forests. For ants, Perfecto et al. (2003) and Andresen (2003) found between 40% and 56% of forest ants in a BF farm, but only 26–30% in non-BF farms compared with 55–62% of forest ants in cooperative samples in the highlands. It appears that the organic, organic and fair-trade, and uncertified farms we sampled captured an equal or greater percentage of the forest fauna than BF-certified farms. Nevertheless, such a comparison should only be done for data collected with similar methods and under similar landscape conditions. There are several differences between the methods (time of year sampled, number of samples, number of farms, distance between farms, elevation range of sites, sampling technique) used and landscape conditions (relatively homogenous landscape in the Soconusco and highly heterogeneous in the highlands) of Soconusco and the Chiapas highlands that make direct comparisons of these two data sets highly problematic. We suggest that comparing certified and uncertified farms in the same regions and using shade certification as a baseline where shade-certified farms do not exist is a more valid way to evaluate the relative ecological impact of certification on biodiversity.

From an economic perspective there were some differences between farmers with and without certification, but the financial gains may not be enough to outweigh costs. Organic farmers had higher gross revenues from coffee than uncertified farmers. Organic farmers also had more alternative products; nevertheless, uncertified farmers had more alternative products on a per hectare basis. In Peru and Costa Rica alternative products provide a substantial portion (from 5% to 63%) of household incomes in coffee growing areas (Somarriba et al. 2004). We could not infer the direct revenue from alternative products, but most farmers reported that they consumed rather than sold most of their products. Thus cooperative members surveyed likely had reduced dependence on outside products and increased food sovereignty, but they may also have benefited from sales of alternative products. Although organic fair-trade farmers did not receive higher gross revenue from coffee, fair-trade cooperatives rather than farmers are paid by coffee importers. During the time of the study two of the three fair-trade–certified cooperatives were building processing plants in producer communities, and one was involved in a vermiculture project. These cooperative-funded projects provided financial benefits to their members, whereas those cooperatives with only organic or without certification were not involved in similar activities. Such financial benefits for certified farmers at the cooperative and farm level are also reported from Nicaragua and Oaxaca (Bacon 2005; Calo & Wise 2005) and form the principal reason for which farmers participate in certification programs (Bray et al. 2002). But the modest increases certified farmers and cooperatives receive may be insufficient. For example, when market prices were low, farmers in an organic and fair-trade cooperative in Oaxaca received substantially higher prices for coffee than did their uncertified counterparts (Calo & Wise 2005). Nevertheless, these higher prices were not high enough to meet farmer production costs, and farmers relied on government subsidies to pay their bills.

From 2003 to 2004, coffee prices for uncertified farmers (based on market price) nearly doubled. With increases in market prices for coffee, organic premiums increase, but the premiums for fair-trade coffee are minimized (Ponte 2004). This may mean, as we observed, that the relative increases for organic and fair-trade farmers are lower than the increases for those with organic or no certification. This also may mean that certified farmers are enticed to sell to intermediaries who pay upfront rather than selling to the cooperative, thus undermining the certification itself. Cooperatives in Chiapas with organic and/or fair-trade certification have generally higher revenues from coffee production or otherwise benefit economically from cooperative participation, and they may have added economic stability, but the amount and the way in which price premiums are distributed must be examined carefully.

There has also been active debate regarding the influences of price premiums and more generally the impacts of market fluctuations on forest destruction or other landscape changes. For the case of Mexico it appears that both high and low prices may play some role in large-scale changes to landscape (Nestel 1995). From 1970 to 1982, when coffee prices were relatively high, extension agents from the Instituto Mexicano del Café encouraged coffee farmers to transform their diverse shaded farms to shade monocultures to increase yields and thus capture more of the market share for coffee (Nestel 1995). Yet in the following years many farmers transformed their coffee to more environmentally destructive crops as a result of low coffee prices (Renard 1992). Blackman et al. (2003) found that low coffee prices during the late 1990s increased deforestation in many areas of Oaxaca, but that farmers receiving higher prices (via membership in cooperatives) were much less likely to clear forests because of their price advantages and income from shade canopy crops. Land conversion to crops with fewer ecological benefits as a result of this same coffee glut has been reported in Colombia, Nicaragua, and Costa Rica (Philpott & Dietsch 2003; Bacon 2005). Some argue that high price premiums paid to farmers for shade coffee result in extension agents encouraging farmers to plant coffee in the understory of native forests (Rappole et al. 2003). Thus the impacts of shade and other certifications on biodiversity may not only include ecological relationships between habitat characteristics and biodiversity, but may also strongly depend on farmers' income and larger market forces.

There are some overlapping goals between certification types, but whether they can independently and simultaneously promote ecological and economic sustainability is questionable. Farmers with organic and/or fair-trade certification may reap marginal economic or social benefits. Their farms, however, do not meet the scientific standards for shade coffee certification known to correlate with increased biodiversity. In highland Chiapas, shade used by most farmers is diverse and dense enough to meet most shade certification criteria, but does not have the vertical stratification necessary to be certified. In Soconusco (Andresen 2003; Mas & Dietsch 2003; Perfecto et al. 2003; Mas & Dietsch 2004) farms that meet BF criteria have more forest biodiversity and higher species similarity than other farms, leading to the logical hypothesis that, were farms in the highlands to meet shade certification criteria, they would subsequently protect a larger fraction of forest fauna. In sum, existing data on shade, organic, and fair-trade certification show that each carries certain benefits. For a more comprehensive conservation plan incorporating both ecological and economic goals, the relative benefits of each of these certification programs need to be carefully considered and combined where appropriate.

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