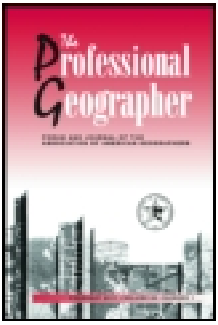

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Agrobiodiversity and Shade Coffee Smallholder Livelihoods: A Review and Synthesis of Ten Years of Research in Central America

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Agrobiodiversity and Shade Coffee Smallholder Livelihoods: A Review and Synthesis of Ten Years of Research in Central America*

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We used households as the primary unit of analysis to synthesize agrobiodiversity research in small-scale coffee farms and cooperatives of Nicaragua and El Salvador. Surveys, focus groups, and plant inventories were used to analyze agrobiodiversity and its contribution to livelihoods. Households managed high levels of agrobiodiversity, including 100 shade tree and epiphyte species, food crops, and medicinals. Small farms contained higher levels of agrobiodiversity than larger, collectively managed cooperatives. Households benefited from agrobiodiversity through consumption and sales. To better support agrobiodiversity conservation, our analysis calls for a hybrid approach integrating bottom-up initiatives with the resources from top-down projects. **Key Words: agroecology, biodiversity conservation, farmer cooperatives, participatory action research.**

我们利用家庭作为分析的基本单位，对尼加拉瓜和萨尔瓦多的小规模咖啡农场和合作社进行了综合性的农业生物多样性研究。统计调查、重点小组和作物库存被用来分析农业生物多样性及其对日常生计的影响。家庭管理着高层次的农业生物多样性，包括 100 种遮荫树和附生植物，粮食作物和药材作物。小型农场比大的、集体管理的合作社具有更高水平的农业生物多样性。通过消费和销售，农户受益于农业生物多样性。为了更好地支持农业生物多样性的保护，我们的分析提出了一种混合型的方案，以结合自下而上的主动性和自上而下的项目资源。**关键词：农业生态学，生物多样性保护，农民合作社，参与行动研究。**

Utilizamos los hogares como unidad básica de análisis para sintetizar la investigación sobre agrobiodiversidad en fincas pequeñas y cooperativas cafeteras de Nicaragua y El Salvador. Se utilizaron estudios de campo, grupos focales e inventario de plantas para analizar la agrobiodiversidad y su contribución al medio de vida de la gente. Los hogares manejan niveles altos de agrobiodiversidad, lo cual incluye 100 especies de árboles de sombrío y epífitas, cultivos alimentarios y plantas medicinales. Las fincas pequeñas contienen niveles más

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altos de agrobiodiversidad que las cooperativas, más grandes y de manejo colectivo. Las unidades familiares se benefician de la agrobiodiversidad por consumo y ventas. Para apoyar de mejor manera la conservación de la agrobiodiversidad, nuestro análisis es partidario de un enfoque híbrido que integre iniciativas de abajo hacia arriba con los recursos de proyectos que operan de arriba abajo. **Palabras clave: agroecología, conservación de la biodiversidad, cooperativas de agricultores, investigación de acción participativa.**

The last two decades have seen a proliferation of studies on the biodiversity conservation potential of shade coffee agroecosystems (Perfecto et al. 1996; Perfecto and Vandermeer 2008). The evidence shows that coffee plantations with a diversified shade tree canopy have higher biodiversity conservation potential than plantations under full sun or simplified shade (Perfecto et al. 1996; Moguel and Toledo 1999; Somarriba et al. 2004; Philpott et al. 2008). Most of this research has focused on the coffee plantation and does not take into account other agricultural plots that are managed by coffee farmers (Somarriba et al. 2004; Philpott et al. 2008).

Although the notion of agrobiodiversity is implicit in most of the ecological research on shade coffee, no studies have explicitly used the concept to analyze these agroecosystems. Previous studies have focused on what Vandermeer and Perfecto (1995) define as *associated biodiversity*, which refers to plants and animals that colonize an agroecosystem without direct intervention from farmers. This perspective stems from an interest in shade coffee plantations to act as extended habitat for wild biodiversity, such as birds (Komar 2006), insects (Armbrecht, Perfecto, and Silverman 2006; Perfecto et al. 1997), mammals (Gallina, Mandujano, and Gonzalez-Romero 1996), and orchids (Solis-Montero, Flores-Palacios, and Cruz-Angon 2005), among others. This leaves an information gap regarding *planned biodiversity*, which refers to organisms directly incorporated into agroecosystems by farmers (Altieri 1999; Vandermeer and Perfecto 1995). The lines between associated and planned agrobiodiversity can be unclear (Phillips and Stolton 2008), and both are ultimately affected by farmer management. Both types of biodiversity have an effect on ecosystem function and dynamics (Vandermeer et al. 2002) and on the products and benefits that growers obtain (Méndez 2008). We focused on the useful plant agrobiodiversity of smallholder farmers and their cooperatives, who tend to manage coffee plantations with diversified shade canopies, and low-input management (Moguel and Toledo 1999; Gliessman 2008).

Agrobiodiversity has been defined in different ways (Qualset, McGuire, and Warburton 1995; Wood and Lenne 1997; Love and Spaner 2007) and can be synonymous with the terms *agricultural biodiversity* and *agrodiversity* (Brookfield and Padoch 1994). We consider agrobiodiversity to encompass the diversity of plants, practices, and knowledge that farmers manage and use within their farms and in the broader landscape (Food and Agriculture Organization [FAO] 1999; Brookfield and Padoch 2007).

Household Agrobiodiversity Management at Multiple Scales

To fully account for the agrobiodiversity managed by coffee farmers, it is necessary to step outside of the coffee plantation and observe the additional plots where they maintain plants. These include parcels for annual crops, trees, live fences, and homegardens surrounding households (Coelli and Fleming 2004; Ponette-Gonzalez 2007). We propose that to examine the entirety of agrobiodiversity present, it is necessary to use the household as the unit of analysis, rather than the coffee plantation. This allows us to capture the agrobiodiversity managed by a household unit, which might include plots separate from the coffee plantation, often cared for by different family members.

Although agrobiodiversity is mostly managed at the plot and farm scales, ecological and social factors at the landscape scale influence its composition and diversity (Brookfield and Padoch 2007; Phillips and Stolton 2008). These can include the distance a farmer walks to reach a field; seed sources; plant arrangements within fields, farms, or landscapes; and different types of support networks (e.g., technical, financial, etc.; Méndez, Lok, and Somarriba 2001; Bacon 2005a; Méndez 2008). There is also a growing interest in assessing agrobiodiversity at the landscape scale and its potential role in ecosystem services conservation

(Brookfield and Padoch 2007; Jackson, Pascual, and Hodgkin 2007).

A focus on coffee smallholder agrobiodiversity management is timely because they are facing globally driven challenges, such as unstable international coffee prices and threats to food security[1] (FAO 2008; Petchers and Harris 2008). We use the livelihoods concept to analyze the contributions of agrobiodiversity to farm households. A livelihood "comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living" (Chambers and Conway 1992, 6). Understanding the linkages between agrobiodiversity and household livelihoods can provide insight on how these resources can be used to support both conservation and livelihood strategies (Bacon, Méndez, and Fox 2008).

Initiatives to Support Biodiversity Conservation in Central American Shade Coffee

Many studies have highlighted the importance of agrobiodiversity, for both livelihood and conservation, yet farmers have received minimal support for on-farm conservation (Jackson, Pascual, and Hodgkin 2007; Jarvis, Padoch, and Cooper 2007; Amend et al. 2008).

In Central America, several initiatives have attempted to assist shade coffee farmers to conserve biodiversity. We discuss four initiatives that have directly or indirectly reached the rural communities we have collaborated with for this article. The first initiative is Rainforest Alliance certification (Gobbi 2000; Perfecto et al. 2005; Philpott et al. 2007), which pays a premium to coffee farms that meet biodiversity-friendly and social criteria (e.g., number of shade trees, limited agrochemical use and dignified housing for workers; Mas and Dietsch 2004). This certification was initiated through the Coffee and Biodiversity Project, implemented in El Salvador between 1997 and 2001. Working with the Rainforest Alliance, this project developed the criteria for the ECO-OK label, which later became Rainforest Alliance (Herrador and Dimas 2000; Perfecto and Ambrecht 2003).

Second, we focus on payment or compensation for ecosystem services (PES or CES), which argues for rewarding land owners who manage their properties in a way that will conserve ecosystem services. Ecosystem services can be defined as the benefits that humans obtain from ecosystems (Costanza et al. 1997; Daily et al. 1997; Wunder 2007). There is growing interest in utilizing PES to conserve ecosystem services in agricultural landscapes (Pagiola et al. 2004; Robertson and Swinton 2005). If managed adequately, shade coffee has the potential to conserve several ecosystem services (Blackman, Avalos-Sartorio, and Chow 2007), including biodiversity, soil and water conservation, and carbon sequestration (Ataroff and Monasterio 1997; Montagnini and Nair 2004; Dossa et al. 2008; Philpott et al. 2008; Méndez, Shapiro, and Gilbert 2009). The explicit value of agrobiodiversity to ecosystem services conservation has recently begun to be recognized (Hajjar, Jarvis, and Gemmill-Herren 2008).

Agroecotourism is the third initiative we addressed. It is well established in coffee plantations of Central America and has proven successful mostly for medium to large plantation owners (Méndez 2005). Agroecotourism uses the beauty of the coffee landscape, the cultural heritage associated with coffee production and processing, and the planned (e.g., shade trees) and associated (e.g., birds) agrobiodiversity as attractions for visitors (Méndez, 2005).

Finally, we assessed participatory action research (PAR), an approach that brings together researchers and other stakeholders in a process that integrates research and action objectives (Fals-Borda and Rahman 1991; Selener 1997). In agriculture and natural resources management, PAR will ideally yield interesting research products (e.g., publications) and also support the livelihoods, natural resources management capacities, and conservation efforts of community partners (for farmers, this could mean implementing sustainable agriculture practices, or accessing better markets; Castellanet and Jordan 2002; Fortmann 2008).

This article synthesizes ten years of agrobiodiversity-related research in coffee communities of Nicaragua and El Salvador. We focused on the interactions between agrobiodiversity and household livelihoods and on the challenges and opportunities to support on-farm conservation. The specific objectives of our analysis were to (1) assess the types and levels of plant agrobiodiversity managed by smallholder coffee households; (2) examine how agrobiodiversity contributed to household livelihoods; and (3) discuss challenges and opportunities of selected initiatives to support agrobiodiversity conservation in small-scale coffee farms and cooperatives of Central America.

Study Sites

The landscapes we studied contained a protected area surrounded by an agricultural matrix (Perfecto and Vandermeer, 2002) composed of larger patches of shade coffee and smaller areas of annual crops (Figure 1). We selected farmers who grew coffee as their main agricultural and economic occupation, most of whom were members of cooperatives exclusively devoted to coffee activities.

Western El Salvador

In El Salvador, we worked in the municipality of Tacuba in the western part of the country, with average elevations of 897 m above sea level (Figure 2). The climate is subtropical humid with average rainfall of 1,500 mm per year (Ministerio de Medio Ambiente y Recursos Naturales [MARN] 2002). The natural vegetation in the area is humid, subtropical forest,

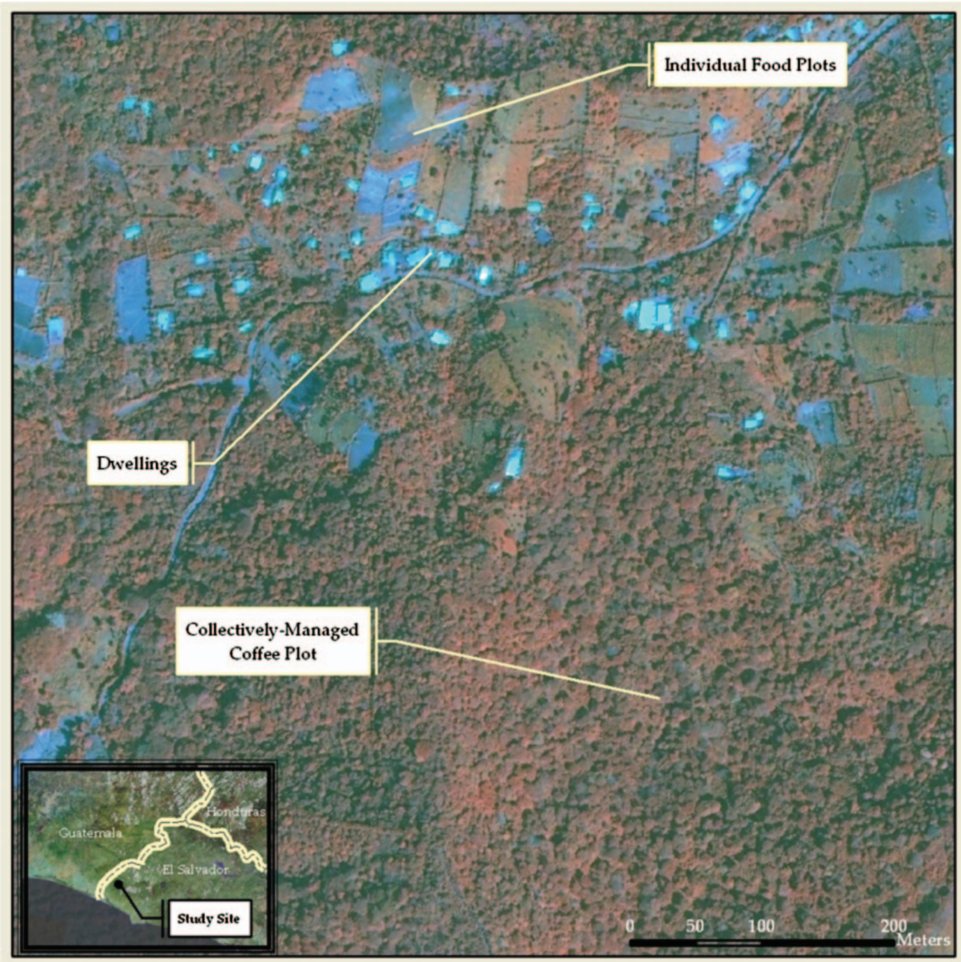

Figure 1 *Satellite image of the agricultural landscape where cooperative ES2 is located in Tacuba, El Salvador. High-resolution imagery by DigitalGlobe Inc., acquired on 27 October 2004.*

Figure 2 *Location of Tacuba, El Salvador, and Matagalpa, Nicaragua.*

and soils are predominantly volcanic Andisols (MARN 2003). The cooperatives were located in or near the buffer zone of El Imposible National Park, one of the largest protected natural forests in the country.

The PAR process has been carried out with four different types of cooperatives. Cooperatives ES1 and ES2 were collectively managed coffee farms, of 195 and 35 ha, respectively. Cooperative ES3 consisted of twenty-eight independently owned and managed farms, with average farm sizes of 0.94 ha, including residential and subsistence crop areas, and shade coffee (Méndez 2004). Cooperative 4 (ES4) was a union between organic farmers from cooperatives ES2 and ES3, which organized to improve their production and marketing efforts.

Northern Nicaragua

In Nicaragua, the research was conducted in the municipality of San Ramón, Matagalpa, and the surrounding communities of Yasika Sur and Yúcul (Bacon 2005b; Figure 1). The natural vegetation in this area is humid, subtropical forest, and farm elevations ranged between 700 and 1,150 m above sea level. Annual precipitation ranges between 1,600 and 1,800 mm (Gonda and Siadou 2002). The farms border the biological reserves of Yucul and El Salto in Yasika, which are private protected areas. In Nicaragua we worked with the following types of farmers: (1) agrarian reform cooperatives that were collectively managed during the early 1980s (N1, N3, N4, and N5); (2) marketing and service cooperatives that grouped individual farmers in an effort to access credit, markets, and support networks; and (3) farmers unaffiliated with a cooperative.

Institutions and Policies Affecting the Cooperative Coffee Sectors in El Salvador and Nicaragua

The farmers in this research have been influenced by the changing roles of the state, local cooperatives, different types of support networks, and access to organic and fair trade markets (Bacon, Méndez, and Fox 2008). In the 1980s there was a regulated international coffee market with strong domestic agencies and private exporters. In the 1990s, this shifted to market deregulation and the privatization of technical assistance and marketing (Bacon, Méndez, Gliessman, et al. 2008; Bray, Plaza-Sanchez, and Contreras-Murphy 2002). State-led agrarian reforms enabled access to land for all but two of the cooperatives (N2 and ES3), but many of these collapsed during the 1990s. Some of those that survived formed cooperative unions to gain better access to markets, credit, and development projects. After the retreat of the state and cooperative failures, transnational corporations gained more control over coffee exports. In El Salvador, the state never played a dominant role in coffee processing and exporting, as these largely remained in control of an agro-industrial elite (Paige 1997). In both countries, cooperatives used fair trade and organic markets to build relationships with coffee roasters and, in Nicaragua, this allowed them to become independent exporters (Bacon 2005b). Most cooperatives also developed relationships with nongovernmental organizations (NGOs) and solidarity and farmer organizations, both nationally and internationally (Méndez 2004; Bacon, Méndez, and Fox 2008).

Technical assistance in both countries was provided by state agencies and programs devoted to coffee until the 1990s (PROCAFE in El Salvador and CONARCA and UNICAFE in Nicaragua), focusing mostly on increasing production through intensification (i.e., high use of inputs and decreased shade levels) in larger plantations (Méndez 2008; Westphal 2008). After the 1990s, these agencies were considerably weakened, allowing for NGOs (e.g. Oxfam and TechnoServe) and farmer cooperatives (e.g., CafeNica) to take over technical assistance to coffee farmers (Méndez 2004). This resulted in a diversification of the content of technological offerings (e.g., organic production and value added) and a stronger focus on smallholders.

Research Approach and Methodology

Research in the two sites has been conducted through a PAR approach, which started in 1999 (Bacon, Méndez, and Brown 2005). Throughout this period we have carried out numerous data collection efforts from which we draw selected information for this article. Key partners in these activities have included professors and students from U.S. universities, different types of coffee farmer cooperatives in both countries, and national and international NGOs.

Household Livelihood Surveys and Focus Groups

Household surveys consisting of open- and closed-ended questions were conducted in 2000, 2002, and 2008. In the first rounds we surveyed fifty-two households in El Salvador and 105 households in Nicaragua. In 2008, sample sizes were twenty-nine households in El Salvador and seventy-nine households in Nicaragua. Data were collected on the following factors: (1) household demographics (age, gender, occupation, etc.); (2) household livelihoods (income sources, savings, debt, agricultural products, education, and support networks); (3) farmer's perceptions of biodiversity conservation; (4) agricultural management (crops, number of plots, and management practices); and (5) the functions, benefits, and challenges of cooperative membership.

Shade Tree and Epiphyte Biodiversity in Coffee Plantations

Shade tree biodiversity data were collected in forty-nine and fifty-one plots within coffee plantations of Nicaragua and El Salvador, respectively (Méndez and Bacon 2005). Tree species richness, abundance, and size (diameter at breast height and tree height) were measured in 1,000 m^2 plots. In the two collectively managed coffee cooperatives of El Salvador we established twenty (ES1) and fourteen (ES2) plots through a stratified random design. Stratification was based on shade types as described by Moguel and Toledo (1999). Seventeen farms were randomly selected in cooperative ES3, and plots were placed in the middle of the coffee parcels of each farm (see Méndez, Gliessman, and Gilbert 2007 for details). Nicaraguan inventories followed a similar sampling methodology. Tree species were identified by the National Herbarium in Nicaragua and La Laguna Botanical Garden in El Salvador.

Epiphyte surveys were conducted within the same thirty-seven plots used for tree inventories. Data collected included epiphyte presence on trees (orchids, bromeliads, mosses, and ferns). We were only able to identify orchids due to the availability of a specialist affiliated with the National Herbarium in Managua.

Medicinal Plant Surveys in El Salvador

Research was conducted between October and December 2005 and consisted of semistructured interviews and plant inventories on thirteen farms from cooperatives ES2 and ES3 (Shattuck 2005). Information collected also included perceptions and management of medicinals and a list of remedies. Common and scientific names were matched using Mendez (2004) and Ayala (1994).

Results

Types and Uses of Agrobiodiversity

Shade coffee households managed four distinct types of plant agrobiodiversity, including shade trees, agricultural crops, medicinal plants, and epiphytes (Table 1). Agrobiodiversity was

Table 1 *Characteristics of agrobiodiversity found in shade coffee households of El Salvador and Nicaragua*

Agrobiodiversity type	Growth habit	Location	No. of species	Uses reported	Sampling effort and method	Reference(s)
El Salvador						
Trees	Woody perennial	SCP	123	S, FW, Fr, M, T	Complete tree inventories in fifty-one 1,000 m^2 plots, and 52 household surveys in three coffee cooperatives	Mendez, Gliessman, and Gilbert (2007)
Agricultural crops	Herbaceous	AP	7	F, M	Semistructured interviews and participatory maps with 29 households	Olson (forthcoming ; data collected in 2008)
Medicinal plants	Woody perennial, shrubs, herbaceous	SCP, AP, HG	119	F, M, FW	Semistructured interviews and field identification in 13 households; informal interviews, direct observation	Shattuck (2005)
Nicaragua						
Trees	Woody perennial	SCP	106	S, FW, Fr, M, T	Complete tree inventories in thirty-seven 1,000 m^2 plots, and 34 household surveys in four coffee cooperatives	Bacon (2005b)
Agricultural crops	Herbaceous	AP	7	F, M	Household level surveys in 82 households	Bacon et al. (forthcoming)
Orchids	Primarily epyphites	SCP, HG	96	O	Orchid inventories on trees in and around thirty-seven 1,000-m^2 plots on 34 farms	Marcell-Velásquez (2008)

Note: For location, AP = agricultural plot; LF = live fence; HG = home garden; SCP = shade coffee plantation. For uses, F = food; Fr = fruit; FW = firewood; M = medicinal; S = shade; T = timber; O = ornamental.

found in four locations, including shade coffee plantations, homegardens, agricultural plots, and live fences. Shade trees, medicinals, and epiphytes were found in several locations, whereas crops were only found in agricultural plots (Table 1). Trees were the most species-rich group, with a total of 123 and 106 species in El Salvador and Nicaragua, respectively. Agricultural crop species diversity was similar in both countries, but differences were observed in the types of crops grown and the number of varieties. Nicaraguan households managed thirteen varieties of corn and nine varieties of beans. These numbers are higher than those observed in El Salvador (Table 2), but this could be due to a larger sample size in Nicaragua. The number of coffee varieties was also higher in Nicaragua (eight), compared to El Salvador (two). Medicinals in El Salvador were a very diverse group, both in terms of species and growth habit (119 species of trees, shrubs, and herbs).

The most frequent tree species were similar in Nicaragua and El Salvador (Table 2). Trees of the genus *Inga* were common in both countries, as they have desirable characteristics for shade, including nitrogen fixation, pruning tolerance, nondeciduousness, and fruit (Beer et al. 1998). The native timber tree Laurel (*Cordia alliodora*) was also common in both countries. Salvadorans planted a greater variety of vegetables (tomatoes, peppers, and cabbage), which were mostly used for sales. Nicaraguan households most frequently grew locally valued crops, such as cacao (*Theobroma cacao*) and passion fruit (*Passiflora* spp.) for sale. Most medicinal species reported in El Salvador had multiple uses, except for Epazote *(Chenopodium amrosoides)* and Savila *(Aloe barbadensis)*, which were exclusively medicinal.

Comparison of Agrobiodiversity Between Cooperative Types

Our previous studies demonstrated that type of cooperative management (i.e., collective or individual) is an important factor affecting shade tree biodiversity (Méndez, Gliessman, and Gilbert 2007; Méndez, Shapiro, and Gilbert 2009). In El Salvador, individually managed farms contained significantly higher levels of tree richness and abundance compared to collectively managed cooperatives (Table 3; Méndez, Gliessman, and Gilbert 2007), but trees in individual farms tended to be smaller. The findings from Nicaragua show a similar pattern, suggesting that farms with collective management practices have lower shade tree species richness and abundance but larger trees. Cooperatives ES1, ES2, N1, N3, N4, and N5 were large, private plantations prior to the agrarian reforms and were then transferred to resource-poor farmers. In Nicaragua, most of these cooperatives were subdivided into individual farms in the 1990s (except for N1), whereas in El Salvador they are still collectively managed.

Contributions of Agrobiodiversity to Household Livelihoods

Agrobiodiversity managed by coffee farmers contributed to household livelihoods by generating products for consumption, income through sales, or both (Table 4). Farmers reported seven plant uses (Table 1), which included food (grains and vegetables), fruit, firewood, medicine, shade, timber, and ornamentals. Trees provided the most diversity of uses, including fruit, medicine, firewood, and shade.

Agricultural crops were used for food and income generation, and medicinal plants were used exclusively for remedies. Food crops provided at least 40 percent of subsistence grains (corn and beans) for most families in both countries (Table 4). Coffee generated between 50 and 100 percent of the annual income of most households. Firewood for consumption and sales was collected from trees and shrubs in the coffee plantation, home gardens, and live fences. Farmers in both countries reported harvesting an average of 50 percent of the firewood they use, which amounts roughly to US$75 per year. This is a considerable amount for households reporting average monthly incomes below US$170 (El Salvador) and US$100 (Nicaragua).

Individual farmers obtained a higher diversity of products from agrobiodiversity than collective cooperatives. The number of fruit and other edible species in coffee plots of individual farms is considerably higher in both countries (Méndez, Shapiro, and Gilbert 2009; Bacon et al. forthcoming). In El Salvador, mean monthly household income showed no

Table 2 *Most frequent plant species managed by coffee households in El Salvador and Nicaragua*

Type, common name, and species	Uses reported	Location	Frequency (%)	No. of varieties	Sample size	Reference(s)
El Salvador trees						
Copalchi (*Croton reflexifolius*)	F, W	SCP, LF	57	N/A	$n = 51$ plots in shade coffee	Mendez, Gliessman, and Gilbert (2007)
Inga punctata	S, Fr	SCP, LF	57	N/A	$n = 51$ plots in shade coffee	Mendez, Gliessman, and Gilbert (2007)
Laurel (*Cordia alliodora*)	S, T	SCP, LF	55	N/A	$n = 51$ plots in shade coffee	Mendez, Gliessman, and Gilbert (2007)
Inga oerstediana	S, Fr	SCP, LF	49	N/A	$n = 51$ plots in shade coffee	Mendez, Gliessman, and Gilbert (2007)
Critonia morifolia	S, F	SCP, LF	45	N/A	$n = 51$ plots in shade coffee	Mendez, Gliessman, and Gilbert (2007)
Mango (*Mangifera indica*)	S, F, Fr	SCP, LF	41	N/A	$n = 51$ plots in shade coffee	Mendez, Gliessman, and Gilbert (2007)
Agricultural crops						
Corn (*Zea mays*)	F	AP	93	6	$n = 29$ household interviews and maps	Olson (forthcoming)
Bean (*Phaseolus vulgaris*)	F	AP	81	2	$n = 29$ household interviews and maps	Olson (forthcoming)
Tomato (*Lycopersicum esculenta*)	F	AP	33	Unknown	$n = 29$ household interviews and maps	Olson (forthcoming)
Chile verde (*Capsicum* spp.)	F	AP	30	Unknown	$n = 29$ household interviews and maps	Olson (forthcoming)
Coffee (*Coffea arabica*)		SCP	100	2	$n = 51$ plots in shade coffee	Mendez, Gliessman, and Gilbert (2007)
Medicinals						
Epazote (*Chenopodium amrosoides*)	M		62	N/A	$n = 13$ semistructured interviews and field surveys	Shattuck (2005)
Savila (*Aloe barbadensis*)	M		46	N/A	$n = 13$ semistructured interviews and field surveys	Shattuck (2005)
Izote (*Yucca elephantipes*)	F, LF, M, W		46	N/A	$n = 13$ semistructured interviews and field surveys	Shattuck (2005)
Chichipince (*Hamelia patens*)	M, S		46	N/A	$n = 13$ semistructured interviews and field surveys	Shattuck (2005)
San Andres (*Tecoma stans*)	FW, LF, M, S		38	N/A	$n = 13$ semistructured interviews and field surveys	Shattuck (2005)

(Continued on next page)

Table 2 *Most frequent plant species managed by coffee households in El Salvador and Nicaragua (Continued)*

Type, common name, and species	Uses reported	Location	Frequency (%)	No. of varieties	Sample size	Reference(s)
Nicaragua trees						
Guaba roja (*Inga edulis*)	S, FW	SCP	70	N/A	$n = 37$ plots in 34 shade coffee farms	Bacon (2005b)
Guaba negra (*Inga punctata*)	S, FW	SCP	59	N/A	$n = 37$ plots in 34 shade coffee farms	Bacon (2005b)
Laurel (*Cordia alliodora*)	S, T,	SCP	54	N/A	$n = 37$ plots in 34 shade coffee farms	Bacon (2005b)
Guasimo (*Guazuma ulmifolia*)	S, T, M	SCP	38	N/A	$n = 37$ plots in 34 shade coffee farms	Bacon (2005b)
Mampas (*Lippia myrocephala*)	S,	SCP	32	N/A	$n = 37$ plots in 34 shade coffee farms	Bacon (2005b)
Nogal (*Juglans olancha*)	S, T, M	SCP	32	N/A	$n = 37$ plots in 34 shade coffee farms	Bacon (2005b)
Guayaba (*Psidium guajava*)	S, Fr, M,	SCP	30	N/A	$n = 37$ plots in 34 shade coffee farms	Bacon (2005b)
Agricultural crops						
Corn (*Zea mays*)	F	AP	87	13	$n = 79$ households in structured surveys	Bacon et al. (forthcoming)
Bean (*Phaseolus vulgaris*)	F	AP	84	5	$n = 79$ households in structured surveys	Bacon et al. (forthcoming)
Musa spp.	F	SCP, HG	10	Unknown	$n = 79$ households in structured surveys	Bacon et al. (forthcoming)
Cacao (*Theobroma cacao*)	F	SCP, HG	5	Unknown	$n = 79$ households in structured surveys	Bacon et al. (forthcoming)
Chayote (*Sechium edule*)	F	SCP, HG	4	Unknown	$n = 79$ households in structured surveys	Bacon et al. (forthcoming)
Maracuya (*Passiflora edulis*)	F	SCP, HG	4	Unknown	$n = 79$ households in structured surveys	Bacon et al. (forthcoming)
Coffee (*Coffea arabica*)		SCP	100	8	$n = 79$ households in structured surveys	Bacon et al. (forthcoming)

Note: For location, AP = agricultural Plot; LF = live Fence; HG = home garden; SCP = shade coffee plantation. For uses, F = food; Fr = fruit; FW = firewood; M = medicinal; S = shade; T = timber; O = ornamental ; N/A = not applicable.

Table 3 *Comparison of agrobiodiversity in different types of shade coffee cooperatives of El Salvador and Nicaragua*

	Nicaragua				El Salvador				
	N1	**N2**	**N3 & 4**	**N5**	**ES1**	**ES2**	**ES3**	**ES4**	**Reference(s)**
Cooperative management type	Collective fair trade	Organic and individual fair trade	Individual fair trade	Conventional individual[a]	Organic collective and fair trade	Collective organic and individual	Individual conventional	Individual and collective, both organic and conventional	
Land management history	Agrarian reform collective (1982–1984)	Individual histories	Agrarian reform (1980s), collective (1990) individual	Agrarian reform (1980s), collective (1990) individual	Agrarian reform collective (1980)	Traditional collective (1984)	Individual farmer association (2001)	Farmer and cooperative association (2007)	
Total area managed (both collective and individual) (in ha)	100	117	173	49	195	35	Estimate of 53 in 2004	45	
Average farm size per member[b]	6.3	6.5	4.9	2.9	2.0	2.5	0.7	No data[c]	
Number of 1,000 m^2 plots	12	8	11	7	20	14	17	24	Méndez, Gliessman, and Gilbert (2007)
Total shade tree species richness[d]	38	58	52	47	69_a	48_a	93_b ($p <$ 0.0001)	No data	Méndez, Gliessman, and Gilbert (2007)
Mean tree species richness per 1,000 m^2 plot[d]	9	14	11	12	12_a	12_a	22_b ($p <$ 0.0001)	No data	Méndez, Gliessman, and Gilbert (2007)
Mean number of food crops grown per household	No data	No data	No data	No data	No data	2.58	No data	2.2	Olson (forthcoming)

[a] *Comparable individual farmers not affiliated with any cooperative.*
[b] *Collectively managed forests not included.*
[c] *No data available or data being processed.*
[d] *Means followed by the same subscript are not significantly different.*

Table 4 *Contributions of agrobiodiversity to shade coffee household livelihoods in El Salvador and Nicaragua*

Agrobiodiversity type	Location	Main contributions to household livelihoods	Value reported by farmers	Sampling	Reference(s)
El Salvador					
Trees	SCP, HG, LF	Firewood, fruit, timber and shade, and income	Firewood obtained from shade trees saved households an average of $71.50 per year in 2002	Complete tree inventories in fifty-one 1,000 m^2 plots, and 52 household surveys in three coffee cooperatives	Mendez, Gliessman, and Gilbert (2007)
Agricultural crops	AP	Food and income	62% of the sample ($n = 18$) reported producing at least 40% of the food used by the family in one year	Surveys and semistructured interviews with 29 households	Morris (2008)
Medicinal plants	SCP, AP, HG	Medicinal remedies	Medicinal plants are valued because farmers cannot afford modern medicines or health care	Semistructured interviews and field identification in 13 households; informal interviews, direct observation	Shattuck (2005)
Nicaragua					
Trees	SCP, HG, LF	Firewood, fruit, timber and shade, and income	Farmers reported an average of $167 per year from firewood sales, in addition to covering their own firewood needs	$n = 37$ plots in 34 shade coffee farms	Bacon (2005a, 2005b)
Agricultural crops	AP	Food and income	Average of 50% of food is produced in these fields	Surveys and semistructured interviews with 79 households	Bacon et al. (forthcoming)
Orchids	SCP, HG	Ornamental and income	Aesthetic and ornamental	$n = 37$ plots in 34 shade coffee farms	Marcell-Velásquez (2008)

Note: For location, AP = agricultural plot; LF = live fence; HG = home garden; SCP = shade coffee plantation.

significant differences between individual farms and collective cooperatives (Méndez 2004). A similar trend was also observed in Nicaragua (Bacon et al. forthcoming).

All respondents in El Salvador interviewed for medicinal plant use ($n = 13$) reported having little or no access to health services. Medicinal plants were only used for common ailments such as aches, diarrhea, common colds, and so on. For serious illnesses respondents went to public clinics or hospitals, which tend to be short-staffed and ill-equipped facilities. Families expressed a desire to reacquaint themselves with medicinal plant knowledge and expressed concern that this knowledge is becoming scarce. Nonetheless, Shattuck (2005) was able to collect 260 remedy recipes for sixty-two ailments.

Nicaraguan farmers stated that epiphytes have an important aesthetic value for them. Many farmers "rescue" epiphytes from fallen tree branches and perch them on trees near their houses, and the cooperatives use epiphytes as a tourist attraction. Epiphytes can also be sold to local restaurants and wealthier households, but this is illegal and thus goes largely unreported.

Seed Sources and Exchanges

Farmers in El Salvador ($n = 29$) reported obtaining corn and bean seed from the following sources: (1) saving their own seed, (2) buying from another farmer, (3) local extension office, (4) local agricultural store, or (5) a combination. Six varieties of corn were reported in El Salvador, including an improved hybrid, which is bought locally or obtained from the extension service, and five local varieties maintained by farmers (*criollo*). Thirty-six percent of households in El Salvador used only the seed they saved, with a similar percentage only buying or receiving improved seed. The rest used a combination of both. Salvadoran coffee farmers used only two coffee varieties, *Borbon*, an older variety known for its quality and high shade requirements, and *Pacas*, a hybrid of *Borbon* bred specifically for Salvadoran conditions. Most farmers save their own coffee seed.

Nicaraguan farmers reported higher diversity of varietals of corn (thirteen) and coffee (eight) than Salvadoran households. These farmers received support from the *Campesino a Campesino* (farmer-to-farmer) movement, which has been active in this region for two decades (Bacon 2005b). Local NGOs, the cooperatives, and the local *Campesino-a-Campesino* chapter have organized annual seed exchanges, promoted seed saving, and encouraged traditional seed use. Although these programs promote the more traditional corn varieties such as *criollo* and *maizón* and the *Arabigo*, *Borbón*, and *Maragogype* coffee varieties, most coffee farmers also use coffee hybrids, such as *Caturra*, *Catimor*, and *Catuai*. A similar pattern was observed for corn varieties, with 71 percent of households planting one or more traditional varieties, 29 percent using only newer varieties, and 19 percent planting both. Farmers have accessed these newer varieties through purchases in regional markets and through the government's agricultural ministry.

Discussion

Agrobiodiversity in Smallholder Shade Coffee Households

Although there were some differences between the study sites, overall, households managed high levels of plant agrobiodiversity. The diversity of trees found represents relatively high levels of species richness compared to other studies of shade coffee in Mesoamerica (Philpott et al. 2008). Farmers at both sites also managed a diversity of food crop species and varieties. A high number of orchid species was also found in Nicaragua, as compared to a similar study in Mexico (Hietz 2005). In El Salvador, more than 100 medicinal species were found, and farmers highlighted the importance of the knowledge associated with this type of agrobiodiversity.

Individually managed small farms contained higher levels of shade tree agrobiodiversity in coffee plantations than collectively managed cooperatives at both sites. This supports other research highlighting the importance of small-scale tropical farms as reservoirs of agrobiodiversity (Gliessman, García-Espinosa, and Amador 1981; Altieri 2004; Perfecto and Vandermeer 2008; Scales and Marsden 2008). The higher levels of agrobiodiversity in individual farms were the result of growers seeking to obtain a diversity of products (e.g., fruit, firewood and timber), whereas larger, collectively managed cooperatives concentrated on coffee production and did not prioritize product diversification (Méndez, Shapiro, and Gilbert 2009).

Our plant agrobiodiversity findings are comparable to those found in shade cacao agroforestry systems. Although less research is available on shade cacao, recent studies have reported on the biodiversity of numerous taxa in several regions (Schroth and Harvey 2007). Shade tree species richness of shade cacao plantations in Costa Rica was lower than at our sites, with a total of fifty-four and a mean of seven species in fourteen plots (Harvey and Villalobos 2007). Indonesian shade cacao farms contained a higher number of tree species than those in our study, with a total of 189 species and a mean of twenty-six species per plot (Steffan-Dewenter et al. 2007). Similar results were found in southern Cameroon, with a total of 206 tree species and a mean of twenty-one species per plot (Sonwa et al. 2007).

Contributions of Agrobiodiversity to Household Livelihoods

The agrobiodiversity managed by coffee households, in both countries, produced food, firewood, and timber for consumption. These products also generated income through sales. Taken as a whole, this accounts for at least 50 percent of household income (roughly half of which comes from coffee) and at least 40 percent of the household's staple food supply. Farmers also appreciated plants for their ornamental and medicinal value.

Less research is available on the livelihood contributions of plant agrobiodiversity in shade cacao plantations. Bentley, Boa, and Stonehouse (2004) reported that shade trees in cacao plantations of Ecuador were also sources of fruit and timber for household consumption and markets. Research in Costa Rica and Panama showed that diversified shade cacao agroforestry systems were economically less risky than monocultures, and could generate substantial timber yields of the native Laurel tree (*Cordia alliodora*; Ramírez et al. 2001; Somarriba et al. 2001).

Conserving Agrobiodiversity in Shade Coffee Landscapes

Providing incentives for farmers to continue to conserve agrobiodiversity could result in positive outcomes both for household livelihoods and conservation. An examination of the four biodiversity conservation initiatives we discussed can provide insight on how to develop more successful alternatives to support agrobiodiversity conservation in coffee smallholdings.

Although Rainforest Alliance certifiers have approached several of the cooperatives in this study, the farmers have remained suspicious of these certifications. This is largely due to certifiers initially working only with owners of larger plantations, who have historical tense relationships with smallholders. It also failed to engage rural social and cooperative organizations, which serve as a reference to smallholders and cooperatives (Bray, Plaza-Sanchez, and Contreras-Murphy 2002). This initiative has also focused exclusively on the coffee plantation and has shown no concern for other types of agrobiodiversity (e.g., agricultural crops and medicinal) that are important to smallholder coffee farmers.

PES has so far been implemented mostly through top-down mechanisms requiring a high level of capacity from participants, which has resulted in limited participation from smallholders (Corbera, Kosoy, and Tuna 2007). In both El Salvador and Nicaragua, government-led PES projects were initially interested in working with shade coffee farmers to conserve biodiversity (Rosa, Kandel, and Dimas 2004). Cooperatives in both countries attended workshops and were interested in the possibility of developing a PES initiative. To date, however, none of these initial efforts has materialized.

The PAR processes that have been carried out with the coffee farmers of Nicaragua and El Salvador have supported training and discussions related to agrobiodiversity conservation (Méndez 2004; Bacon 2005b; Bacon, Méndez, and Brown 2005; Méndez and Bacon 2006; Méndez, Gliessman, and Gilbert 2007). Researchers have accumulated a considerable amount of social and ecological information and have been able to change some of the farmers' negative assumptions related to conservation, but the PAR process has generally lacked the funds or capacity to implement initiatives, as most of the support has been in the form of capacity building, advising, and expansion of support networks (Bacon, Méndez, and Brown 2005).

Agroecotourism and PAR both emerged through a "bottom-up" approach, which allowed farmers to develop a sense of ownership in these activities. In 2003, a partnership between Nicaraguan cooperative unions, participatory action researchers, and alternative trade NGO networks launched an agroecoturism project (Bacon 2005b). This cooperative-based initiative sought to promote economic opportunities for youth and women, diversify smallholders' income, and conserve the environment (UCA San Ramón 2008). This project has received more than 1,200 visits from fair trade networks, foreign universities, and solidarity organizations. Despite these accomplishments, the farmers face persistent challenges, including an insufficient number of visitors to cover the costs of the program (UCA San Ramón 2008). In El Salvador, agroecotourism was also facilitated through the PAR process and took the form of educational exchanges from solidarity organizations and U.S. universities (Méndez 2008). Although these activities were developed with high farmer participation, they have had limited resources and only reached a small number of beneficiaries.

As has been discussed in the Integrated Conservation and Development Project and community-based conservation literature, top-down conservation initiatives that fail to integrate community participation have been largely unsuccessful with small-scale farmers in developing countries (Barrett and Arcese 1995; McShane 2003; Rosa et al. 2004; Wells and McShane 2004). This is also illustrated by two of the cases presented earlier. On the other hand, many grassroots initiatives lack the resources to provide sufficient benefits and to scale up to larger areas and higher numbers of beneficiaries. This argues for a hybrid model, which is able to integrate community-based projects with the resources from top-down approaches (Berkes 2007; Amend et al. 2008).

Conclusions

Our research demonstrates that shade coffee smallholder households in El Salvador and Nicaragua manage high levels of agrobiodiversity, both within and outside the coffee plantation. Households use these products for direct consumption and income generation through sales. The agrobiodiversity managed by smallholder coffee households was able to almost fully provide for their basic needs. This measure of success was tempered, however, by the fact that the levels of income of these households were at or below the poverty line (Bacon, Méndez, Flores Gomez, et al. 2008) and that households continue to face food shortages on an annual basis.[2]

Our results support other work demonstrating that agroforestry systems, such as shade coffee and cacao, have great potential to conserve plant agrobiodiversity in tropical landscapes (Schroth et al. 2004). In addition, our suggestions for improving support initiatives should be applicable to other settings and agroforestry systems that are managed by smallholders and cooperatives.

Cooperative types and land use management history had a strong influence on the levels of agrobiodiversity found, with small, individually managed farms containing higher levels of shade tree agrobiodiversity than larger collectively managed cooperatives. Smallholders have repeatedly been left out of conservation initiatives, such as the ones discussed in this article. Based on our findings, we argue that they should be supported and included in future conservation efforts.

More in-depth research is necessary to better understand how food security,[3] landscape-scale conservation, and climate change will affect the agrobiodiversity conservation potential of shade coffee smallholders in the future. In this light, PAR approaches can make important contributions to these endeavors because they are done with the participation of communities, produce relevant and necessary data, and facilitate capacity building and support networks. For this approach to scale up to larger areas and more beneficiaries, however, it will need to seek partnerships with more conventional models (i.e., top-down projects) that are able to contribute the necessary financial and human resources. An integration of these distinct models will require a deliberate and respectful dialogue, which takes into account the complexity of conditions and needs of multiple stakeholders (Berkes 2007). ■

Notes

[1] Food security is an issue that has been largely ignored by the biodiversity conservation literature

on shade coffee, but it has been addressed by social and interdisciplinary studies (e.g., Jaffee 2007; Bacon, Méndez, and Fox 2008). Agrobiodiversity is critical to food security, as the increasing homogenization of agriculture often raises the vulnerability of smallholders (Thrupp 2000; Caceres 2006). This relates to our argument that previous studies have had an exclusive focus on the coffee plantation, rather than all land units for agricultural production. Our recent research (Bacon, Méndez, Flores Gomez, et al. 2008; Morris 2008; Olson forthcoming) directly addresses food security, both in terms of production of food crops in agricultural areas and the coffee plantation, as well as to related policy issues in El Salvador, Nicaragua, and Central America.

[2] Of key importance is the fact that most smallholder coffee farmers face a persistent shortage of food for up to two to three months (*los meses flacos*) when income from coffee has been spent and the new crop of corn and beans has not been harvested (Jaffee 2007; Morris 2008).

[3] Fully addressing food security for the farmers who participated in this study requires a shift in policy, rural development initiatives, and household management so that it integrates food and coffee production as equally important livelihood strategies. To date, policy and rural development efforts have concentrated on improving coffee production and sales, leaving food production mostly unattended. A promising initiative led by progressive coffee importers and buyers in North America (e.g., Green Mountain Coffee Roasters and Cooperative Coffees) has recently addressed food security issues by funding research and food security projects in collaboration with several of the cooperatives mentioned in this article, and the first and second authors.

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