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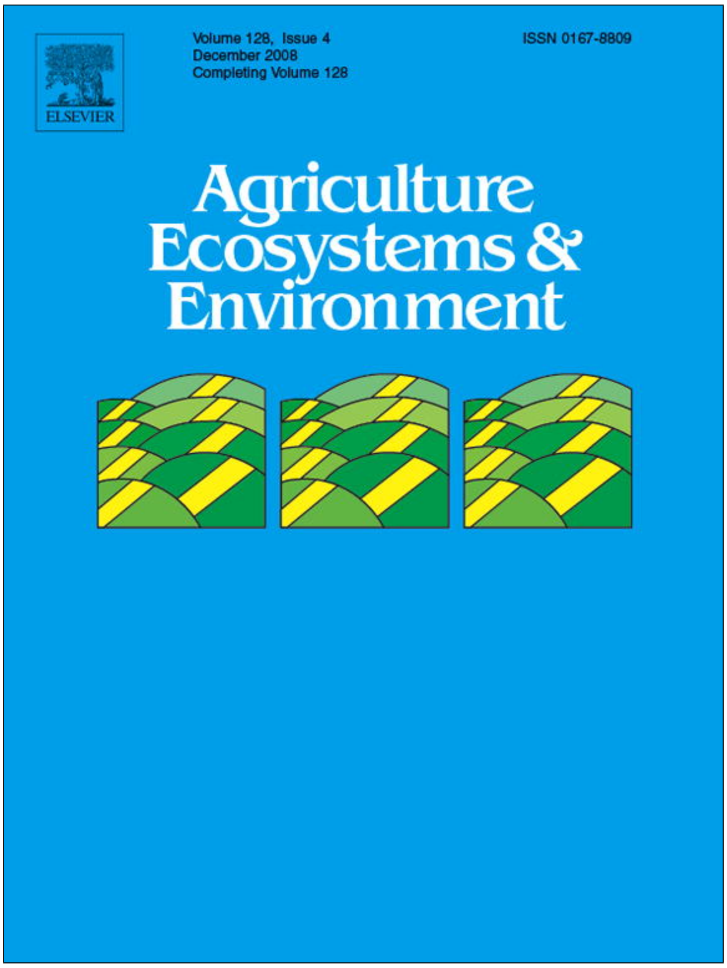

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Agricultural intensification within agroforestry: The case of coffee and wood products

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A R T I C L E I N F O

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A B S T R A C T

Compared to the environmental and conservation value as refuges for biodiversity, less is known about the social and economic value of shaded coffee systems. The agroforestry system can serve as a source of non-coffee products for diverse purposes. This study focuses on the role of shade trees in smallholder coffee farms, examining the wood products derived from the shaded coffee system. Data presented from surveys with 185 growers in Peru and 153 growers in Guatemala show that the consumption and sale of all non-coffee products account for a fifth to a third of the total value realized from the agroforestry system. Fuelwood and construction materials account for much of this value. Differences seen between countries can be traced to agricultural intensification – the degree to which the coffee agroforestry system is "technified" (i.e., managed with a reduced shade tree cover and diversity, high-yielding cultivars, agrochemical inputs, etc.) – as well as the relative demand for wood resources and farmers' access to natural forest systems.

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1. Introduction

Agroforestry systems harbor a diverse collection of plant-derived goods. Such vegetation complexes, though differing in composition from place to place, provide products of multiple uses to land managers beyond that of the principal crop. Within the agroforestry literature, the agronomic and biophysical aspects of such systems have received a disproportionate attention compared to the socioeconomic features (Nair, 1999), a situation which persists—especially in the case of coffee[1] (*Coffea arabica*). The voluminous literature related to ecological features in shaded coffee (and cacao) systems (Beer et al., 1998) contrasts sharply with the few, but emerging, studies on such systems' socioeconomic contribution to producers' livelihoods—with those being nearly restricted to African countries (Leakey et al., 2005; Gockowski et al., 1997; Awono et al., 2002; Ndoye et al., 1997) Recent academic interest in managed lands as potential habitat reveals the ecological and conservation value of shaded cropping systems as refuges for wildlife and/or areas capable of providing ecological services (Mas and Dietsch, 2004; Wunderle and Latta, 1996, 1998, 2000; Perfecto et al., 1996; Greenberg et al., 1997, 2000; Rice and Greenberg, 2000; Rice and Ward, 1996; Sherry, 2000; Roubik, 2002; Ricketts, 2004; Philpott, 2005; Solis-Montero et al., 2005; Pineda et al., 2005). Many of these studies focus on shade coffee. While work on a number of commodity systems' impact on overall biodiversity maintenance has been reviewed (Donald, 2004), the value of the *managed* biodiversity – the shade itself – and its contribution to the farmer's welfare have received scant attention. As any casual walk through a coffee farmer's holding attests, the socioeconomic axis of a coffee farm can be substantial—especially for small producers (Goday and Bennett, 1989). A host of products other than the coffee can be harvested from a "coffee" holding (Muschler, 1999; Albertin, 2002; Albertin and Nair, 2004). Yet, their importance often goes unnoticed, constituting what is a shadow economy alongside the recognized coffee production.[2] Moreover, all agroforests are not equal; even within these multi-species systems

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[1] An examination of 717 paper and poster presentations at the well-organized 1st World Congress of Agroforestry reveals that the term "coffee" appears only 10 times in the titles, accounting for 1.3% of all presentations. Work on the shade (tree) component's income-generating potential in coffee is also scant. A search for the words "income," "value," and "revenue" in titles produced seven, sixteen, and one hit(s), respectively—and in only one instance was there overlap of one of these terms with the word "coffee".

[2] Some of my own interviews with Guatemalan producers, for instance, attest to this, in that growers in the indigenous town of San Antonio Aguas Calientes in the department of Sacatepequez maintain that, without the income generated from "nísperos" (persimmons) harvested from trees mixed in their coffee holdings, they would be hard-pressed to make it economically from year to year.

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we can find differing levels of agricultural intensification which, jointly with the social landscape, results in discernable contrasts in how producers use the resources from the agroforestry system.

Agroforestry practices in both Peru and Guatemala have a long history (Chepstow-Lusty and Winfield, 2000; Alcorn, 1984), and the integration of trees in coffee systems yields an array of products both used (consumed) and exchanged (marketed). Recent assessments of specific agroforestry products elsewhere (Sullivan and O'Regan, 2003; Shackleton et al., 2003) reveal the economic potential such agroforestry tree products – or AFTP's, as Simons and Leakey (2004) have termed them – can generate. Aside from studies in Costa Rica (Lagemann and Heuveldop, 1983; Lagemann, 1982), little information exists about the value of AFTP's from coffee holdings. Understanding the value of shade from the grower's perspective and the potential it represents in terms of a community's socio-cultural well-being (Alcorn's account of the Huastec "te'lom" or *cafetal* is excellent, and stands virtually alone in this regard) provides an added dimension to the overall role of a shaded system.

Agricultural land use has not escaped the trends in global change, where agroecosystems have become increasingly more simplified (Vandermeer et al., 1998). For coffee systems, this has often meant significant alteration of the agroforestry system. The introduction and proliferation of no- or low-shade coffee systems throughout much of Latin America in recent decades has sought to control disease and increase yields (Rice, 1999; Perfecto et al., 1996), even though the use of shade can improve coffee quality (Muschler, 2001). Relative to South America, Central American countries received significant development funding for such efforts (Rice, 1999), leading to more intensely cultivated systems. A reduced shade component can eliminate many of the non-coffee products, creating a higher dependence on the successful harvest and sale of the coffee crop for producers wishing to survive year-to-year. Although agricultural extension projects aiming to diversify farmers' holdings and reduce their dependence upon single crops can be found in nearly all coffee producing countries (Goday and Bennett, 1989), their success has been spotty and students of agroforestry have largely ignored the socioeconomic value of the shade-derived products.[3] This study assesses the manner and degree to which wood products derived from coffee agroforesty systems in Peru and Guatemala figure into farmers' livelihoods.

2. Materials and methods

This study is based on structured surveys and field observations made between 1999 and 2003 in Peru and Guatemala, and on field observations and informal interviews in a number of Latin American coffee settings. Through a series of specific and open-ended questions, data were gathered on the type, quantity and value of goods associated with the coffee agroforest system. "Value" refers to both the *exchange* value of products (i.e., realized from products sold locally, regionally, and – in the case of the coffee itself – internationally), as well as the *use* value (realized from in situ consumption by the farm family) of products derived from the shade component. The "shade component" refers to the shade trees themselves. Local market prices provided the metric for both types of value.

The Peru site encompasses the valley and upland areas adjacent to the Apurimac and Ene Rivers, centered near the towns of San Francisco and Quimbiri in southern Peru. The Apurimac River drains in a generally northwest orientation within an area stretching between 11°30′ and 13°00′ latitude south and 73°30′ and 74°30′ longitude west. The area straddles the departments of Ayacucho and Cuzco, and the coffee area has long intermixed with other land uses at elevations between 800 and 1450 m above sea level (SCIPA, 1961). For Guatemala, several areas form the basis of the study, including the department of Sacatepequez near the colonial town of Antigua, the borders of Lake Atitlán and the highland area of the department of Huehuetenango near the Mexican border. These Guatemalan sites range in elevation from 900 to 1400 m above sea level.

Interviews were completed with 186 producers in Peru and 153 in Guatemala. While visits to individual farms occurred during many of the interviews, the information presented is based on answers provided by the producers. Information obtained from interviews includes farm level information on farm characteristics, as well as income from coffee and other products derived from the coffee agroforestry system. One-way analysis of variance has been used to determine significant differences between the two countries' coffee sectors. Contrasts are drawn from the entire data set for both countries. Note is made when subsets of the entire sample are used. Data on population were drawn from available national and global records.

3. Results

Basic data on farms and income from coffee are compared graphically in Fig. 1. While Guatemalan producers have smaller total farm areas and coffee areas compared to their Peruvian counterparts, their production and income are greater.[4] With a greater fraction of the farm area planted to coffee, a typical Guatemalan producer captures more than three times the income (in dollar equivalents) than a Peruvian grower makes per harvest, due to higher yields (volume per unit area) and greater income per hectare. Access to forest products is less in Guatemala. An individual farm in Peru has nearly 2.25 ha in forest and 3.6 ha in second-growth fallow. Guatemala growers, by contrast, have little to no forested area associated with their holdings, although communal forests exist in some areas. Growers in both groups take advantage of the forest-like cover associated with the coffee, exploiting the non-coffee products derived from their holdings.

3.1. Sources of value from the shade coffee holding

Fig. 2 shows that coffee accounts for a large proportion of the total farm income in both countries, with the shade component contributing similar aggregate percentages. "Other" sources include loans, other crops, remittances from outside the country, or contributions from family members involved in non-agricultural work. While coffee generates a majority of the value in the Guatemalan case, we find that in Peru coffee's fraction of total farm income is second to the "other sources"—a fact attributable to the rather hefty incomes these farmers make from the coca trade in that country.[5]

Fig. 3 shows the categories of value attributable to the shade coffee holding itself. Peru and Guatemala display a significant difference, with 28.5% (±1.87) and 18.77% (±2.08) of the total value coming from shade-derived sources, respectively ($F = 11.98$, d.f. = 1,

[3] See footnote #1.

[4] Differences in coffee prices vary according to country, with some countries receiving more per pound than others. These are largely historically based differences, and relate to the overall quality of the coffee produced and processed at origin. Guatemalan coffee usually receives a relative high price; Peruvian usually sells relatively cheaply (John Cossette at Royal Coffee, Emeryville, CA, personal communication).

[5] For all value generated on that portion of the farm not within the coffee producing area, coca accounts for nearly thirty percent (sometimes, coca *is* found intercropped with the coffee).

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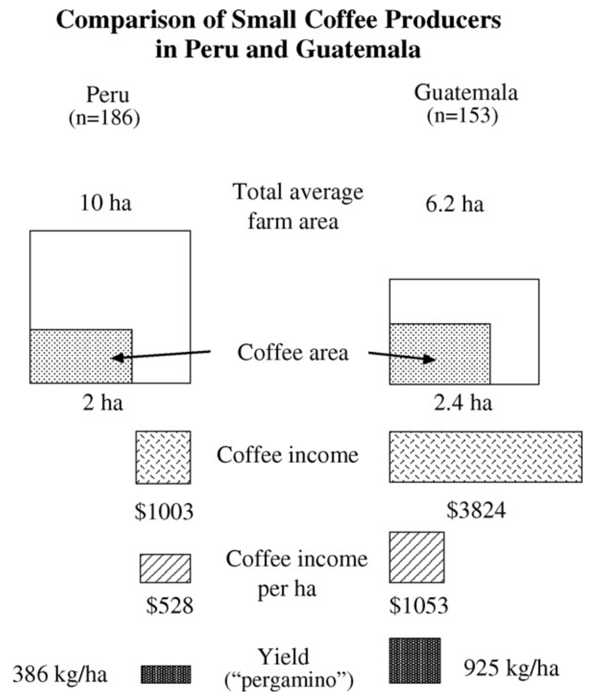

Fig. 1. Relative profiles of small coffee producers in Peru and Guatemala.

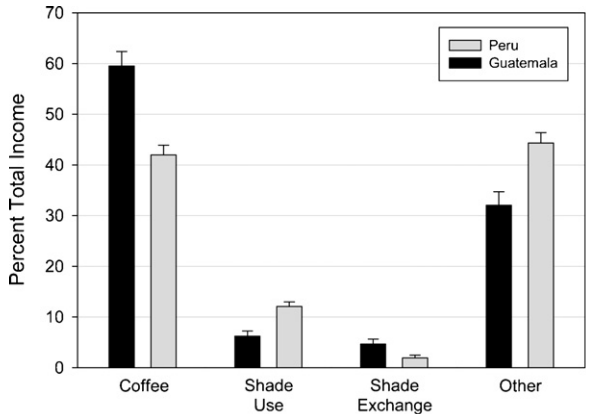

Fig. 2. Percent of value ("income") derived from different sources of the coffee farm, with emphasis on use (on-farm consumption) and exchange (sales) of non-coffee products, by source. *Note*: "use" refers to shade products consumed by farm family; "exchange" refers to those products sold.

327, $P = 0.0006$). Table 1 summarizes the relative value obtained either through direct use or sales of products harvested from the shade component. Firewood ("*leña*") and fruits account for the bulk of the use and exchange value coming from the holdings in both countries. Fuelwood weighs in with 60 and 35% of the total value generated by the shade component in Guatemala and Peru, respectively. (The role of fruits will be addressed elsewhere.) The sale of firewood (its "exchange" value) ranks as inconsequential within the Peruvian context.

3.2. Managing shade

Peruvian farmers report managing an average of eight species of shade trees in their cafetales (coffee areas), with the total number of individual shade trees per hectare averaging 135. Guatemalan growers make use of only four distinct trees on average, with 163 total individual trees per hectare. Leguminous species of the genus

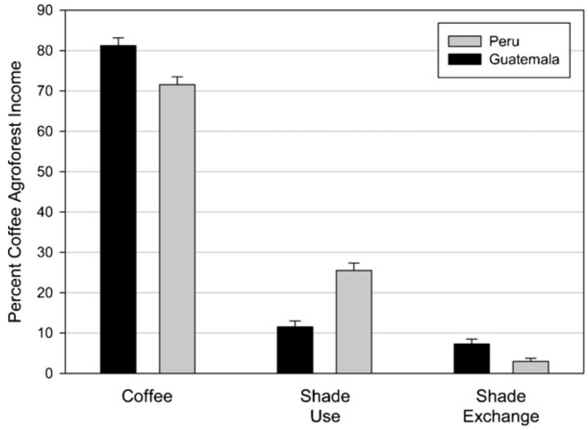

Fig. 3. Percent of value ("income") derived from the coffee production area only, showing the use and exchange value realized from the coffee and the shade component. *Note*: "use" refers to shade products consumed by farm family; "exchange" refers to those products sold.

Table 1
Percent contribution to non-coffee products' value in shade coffee systems, separated by use (consumption) and exchange (sales) value

	Peru	Guatemala
Fuelwood		
Consumed	35	52
Sold	n/a	8
Fruit[a]		
Consumed	42	15
Sold	3	19
Lumber		
Consumed	5	5
Sold	1	1
Animals		
Consumed[b]	12	[c]
Sold	2	[c]

Note: see Section 1 for explanation of "use" and "exchange" value.
[a] A detailed account of fruits' role in the shade coffee systems will be addressed elsewhere.
[b] "Consumed" refers to animals making use of the coffee area in foraging, as well as their products, such as eggs from chickens.
[c] Negligible.

Inga often comprise the principal shade tree in both countries, with other species being mixed in to satisfy a given farmer's needs. Collectively across all growers surveyed, four different species in the genus *Inga* are used in Guatemala's coffee farms, compared to 17 species in Peru. At the individual farm level, we can see from Table 2 that, while small, there is a significantly different number of species used by farmers in the two countries, with Peru having an average of one-half more species per farm than Guatemala. Yet, the absolute number of *Inga* trees (individuals) in Guatemala exceeds that in Peru by more than two and one-half times. Summing all species of trees used by all farmers, we find 62 species reported by growers in Guatemala, while their Peruvian counterparts make use of 77 species collectively.

Producers in both groups manage certain trees that reach heights well over 20 m. However, the height of the canopy at the individual farm level averages 7 m in Guatemala and 13 m in Peru. At (and just below) the level of the coffee, there is an herb layer that is also managed by these farmers. Although not part of the shade component per se, this layer indeed adds to the overall socio-economic utility for growers (in the form of edible or ornamental/ritual plants) and habitat offerings for the associated fauna such as

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Table 2
The use of shade trees in the genus *Inga* on coffee farms in Guatemala ($n = 153$) and Peru ($n = 186$)

Variable	Peru mean (error)	Guatemala mean (error)	*F*-stat (d.f.)	*P*-value
# Inga species per farm	1.49 (0.06)	1.04 (0.07)	24.11 (1, 339)	<0.0001
# Inga trees per hectare	43.45 (6.86)	111.21 (8.71)	37.37 (1, 301)	<0.0001

insects, birds, reptiles/amphibians, and mammals. Respondents report exploiting an average of six different herb species per farm in Peru's Apurimac Valley region, while the Guatemalan growers report making use of one or two herb species.

A major use of the woody species in the coffee agroforesty system involves energy. Of the total value generated from the coffee agroforestry, Peru and Guatemalan farmers reap 35 and 52%, respectively, of the total value realized from the non-coffee products. Cooking, heating of the home, boiling water for drinking, bathing or washing clothes are all activities which demand fuelwood in the remote rural settings. The amount of firewood harvested from the Guatemalan coffee area is more than one and one-half times that obtained from a Peruvian farm, evidenced by 3500 and 2100 kg/ha harvested, respectively. In both cases, wood from the pruned wood from shade trees as well as from the coffee shrubs themselves make up the fuel resource.

Periodic pruning of shade trees – a practice realized on a yearly or biennial basis by many – and occasional removal of whole trees may also yield construction material. For Peru, the average value of lumber actually sold for the entire group of farmers surveyed is only 25 soles (US $6.33) per year. For that used on the farm itself in some way, the average value climbs to 71 soles (US $23.66) per year. These figures include all growers interviewed, whether they report using shade trees as a source of lumber or not. The major trees used for lumber include "nogal" (*Juglans* spp.), "roble" (*Quercus* spp.), "cedro" (*Cedrella* spp.), and a few other forest species.

Yet, only 18% of the Peruvian growers harvest lumber from the coffee holding. Within this group, we find the agroforest acting as "warehouse", witnessed by the 20:80 split in that portion of lumber sold and used, respectively. The income brought in for lumber sold averaged 138 soles (US $46.00). The value of the lumber used by these producers is even greater, averaging 400 soles per year (US $133.00). The range of the value realized – up to US $700 in use-value and US $1000 in sales – reveals that for Peruvian growers making use of these lumber sources, the benefits can be hefty.

In Guatemala, more than three-quarters of those surveyed (77%) harvest lumber from the coffee holding, revealing a greater dependence upon this source than in Peru. Fence posts and housing materials such as beams, upright supports and boards for walls comprise the principal uses. Data on the actual value of lumber shows that the average value generated for the entire group sampled is US $40. Yet, when we calculate the value for only those who report using lumber, that per-farmer value climbs. For those selling lumber, the average income generated was US $138, compared to US $162 of value for those using the lumber themselves. As in the Peruvian case, the maximum value realized is not trivial. The value of on-farm lumber use can reach US $1165, compared to US $760 for that being sold.

4. Discussion

A side-by-side comparison of coffee agroforests from these two countries brings to relief some of the nuances of agricultural intensification within agroforestry systems. Comparing the typical systems of Peru to those of Guatemala reveals how intensification within agroforestry and social landscapes can affect resource use at the farm level. Obviously, not all coffee regions present identical social and/or agricultural landscapes. Both countries in this study exhibit significant indigenous cultures, a demographic reality not uncommon in Latin America. Although the indigenous population compositions for Peru and Guatemala are relatively high (45 and 41%, respectively), the urban–rural split for the general populations differs greatly. Peru is a much more urban society. Its capital city, Lima, harbors more than one-quarter (27.5%) of the country's population (INEI, 2005; PRB, 2005). Only 27% of Peru's population is rural, with about the same fraction classified as being in the agricultural population. Guatemala contrasts with this profile with over half (54%) the population classified as rural and 49% of Guatemalans belonging to the agricultural population (UN FAO, 2005; INEI, 2005). Moreover, population densities in the agricultural areas of Peru and Guatemala differ by an order of magnitude, with 20 and 140 people per square kilometer, respectively, (calculations based on FAO data). Indigenous populations play a major role in the rural landscape and the agriculturally active population in both countries (The World Bank, 2005).

In terms of coffee "culture", which can be defined as the degree to which the coffee sector is linked to and satisfies the demands of global coffee consumers vis-à-vis quality and consistency, Guatemala is one of the better-known and better-rewarded countries in terms of prices. A long-standing, well-developed coffee research and marketing group, known as the Asociación Nacional de Cafetaleros (Anacafe) has had a tremendous impact on Guatemala's coffee sector over the years. Some of its activities have been helped with programs funded by the United States Agency for International Development (US-AID), while much of the effort directed to growers has been of the homegrown nature. By comparison, the Peruvian coffee sector has received little aid, with many grower communities essentially abandoned to fend for themselves in remote, difficult regions characterized by broken terrain, heavy rainfall, and poor infrastructure. Most growers in both countries are peasant producers with a risk-averse philosophy and admirable pluck and perseverance when it comes to producing coffee.

As a group, Guatemala's growers report slightly fewer species compared with Peru's growers (63 *vs.* 77), as well as less than a quarter of the number of species in the commonly used genus *Inga* (4 *vs.* 17) These differences may be due simply to a greater overall species diversity from which to draw for shade trees, but I would argue that the forces of agricultural technification[6] and modernization in Guatemala have also shaped these landscapes. The average number of species used at the individual farm level is four and eight, respectively, for Guatemala and Peru, which also bolsters the modernization argument. Yet, the average number of individual trees per hectare in Guatemala surpasses that of Peru (163 compared to 135). This higher density of shade trees, managed at a lower height with a regularized pruning regime, may also be a strategy to acquire more fuelwood from the system (see next section).

[6] This term comes directly from the Spanish *tecnificación*, which refers to the transformation of the coffee agroforestry system from a traditional low-input, highly diverse system to one that is more dependent upon agrochemicals, and high-yielding coffee varieties managed beneath a reduced and relatively depauperate shade cover.

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The shade component of coffee holdings clearly offers both environmental and socioeconomic benefits to growers. Due to the higher coffee yields and consistently higher prices enjoyed by Guatemalan producers, the value of the coffee accounts for a relatively greater fraction of the total value derived from the holding compared to Peru. Guatemala's "shade products" weigh in with just under one fifth of a holding's value. By contrast, in Peru these products account for 28% of the total value associated with the shade system. Of course, as the international price of coffee fluctuates, the fraction of a holding's value attributable to the coffee itself will also change—a fact that underscores the importance of the other agroforestry products for a farmer's use and income, especially in times of low international coffee prices.

4.1. Energy field: shade trees and coffee plants as fuelwood

Firewood today is the major source of energy for many people on Earth. Present conditions in both Guatemala and Peru attest to this, even though electric service is available to many. In Guatemala, for instance, 85% of the households are connected to the electrical grid, yet fewer than 1 in 35 actually cooks with electricity. Whether due to the cost of the energy itself, the expense of the appliances needed to use electricity in cooking, or both, more than half of all Guatemalan homes use wood for cooking. In rural areas, more than 86% do so (Miranda, 2005; Winrock International, 2004).

Though the use of liquid propane gas (LPG) has increased in recent years, only 4% of the rural population use it to the exclusion of wood as an energy source (Winrock International, 2004). Moreover, as a Winrock report makes clear, it

> "...is important to note that when lower-income households and those in rural areas adopt LPG stoves, they tend to still use fuelwood either as the main cooking fuel, or as a secondary fuel for the cooking of energy-intensive foods such as beans and corn. In addition, many families with improved stoves still use open fires to prepare large amounts of food (i.e. for celebrations) and to warm homes in colder climates. When the weather is cold and wet, open fires are used to dry clothes. Open fires are also used for complementary illumination, primarily in rural homes" (Winrock International, 2004:19).

Peruvians are even more dependent upon wood, as 24% of all households and 68% of rural homes lack electricity Ninety percent all fuelwood consumption there goes toward household energy of some kind, with 80% of rural households using fuelwood (Miranda, 2005).

The discrepancy in the amount of firewood used in Peru (2.1 metric tons per year) *vs.* Guatemala (3.5 mt) can be linked to demographics, as well as specific practices in coffee management and the availability of other fuelwood sources due to land use differences. The population density in the rural sector is an order of magnitude greater in Guatemala, generating greater demand for fuelwood. Moreover, alternative sources of firewood exist in the Peruvian context, where forest and second growth vegetation account for 48% of the average farmer's land. This contrasts greatly with the Guatemalan case, where little to none of a grower's land is forested or in second growth. Because of the influx of seasonal labor associated with the harvest (Guatemalan yields surpass those in Peru), the use of firewood increases significantly during this period, when additional farm workers use fuelwood for cooking and other activities. And though Guatemalan producers manage fewer shade trees per hectare, the coffee planting density is much higher (4400 plants per hectare, compared to 2500 in Peru), allowing for more coffee prunings to be used as firewood. Moreover, Guatemala's coffee grower association has, over the decades, inculcated a rather widespread national philosophy of pruning-for-enhanced-production (both coffee and shade trees), which generates substantial fuelwood.

When listing the "best" firewood species, Peruvian growers mentioned a total of 19 species. The most preferred fuelwood belongs to the genus *Inga*, used by 64% of the informants. Eleven percent of the growers claim "quinacho" (an unidentified species thought to be in the family Solanaceae; Carlos Reynel, personal communication) as their best firewood, while 4% listed coffee wood as the best one. Guatemalan growers mentioned only 13 species from the coffee holding used as firewood. The genus *Inga* accounted for 36% of the "best firewood" responses, with different oaks (*Quercus* spp.) and coffee prunings accounting for 15 and 11%, respectively, of the preferred fuelwood. A popular exotic species, *Gravillea robusta*, the Australian "silky oak" or "lacewood", was the first choice for 14% of the Guatemalan farmers. A number of other types rounded out the various types used, contrasting with the Peruvian case where *Inga* spp. dominated.

The most common rationale for using a particular wood relates to its heating qualities (i.e., references such as "burns well," "gives more heat," "makes good coals/embers", etc.), followed by its ease of use, particularly the way it can be lit or started. Finally, the ease with which a certain fuelwood can be split and/or readied for use ranked as the third reason for its popularity. There seems to be a gender-based preference in selecting one type of wood over another (and subsequent informal inquiries confirm this). Men tend to prefer light, less dense, more easily split wood. They are often the ones within the family to haul and/or split it. Women prefer woods that burn well, last long, and make good coals.

4.2. Building from coffee: lumber and construction materials

Aside from a shade cover's agronomic purposes and/or the ecological services of erosion control, leaf litter production, carbon sequestration, and general watershed health, a tree can also be viewed as "stored capital" or "money in the bank", in that it can be used as lumber. If specific needs arise within a farmer's family, trees can be felled and either used (if the need relates to construction) or sold, providing a pulse of cash. While research on combining timber tree species with coffee has identified a host of benefits from such practices (Beer et al., 1998), we still know little about the specifics of such use and even less about differences between places.

Demand for wood products from any agroforestry will undoubtedly be influenced by the presence and proximity of natural forestlands—a situation exemplified by contrasting the Peruvian growers to their Guatemalan counterparts. Recalling that few growers in Peru's Apurimac Valley region use lumber from the coffee holding, the explanation most likely relates to other land uses practiced by these small coffee farmers. Although the typical Peruvian farmer's coffee area averages 2.11 ha, the area of forestland exceeds that. In fact, of all the land uses reported by growers, forest area was exceeded only by fallow land, which itself can provide construction or fuel materials if the fallow period is long enough (Table 1). With these other forested areas available to them, few Peruvian growers need to harvest timber from the coffee shade component.

4.3. Agricultural intensification within agroforestry systems

Small landholders make use of an array of products from their coffee farms, validating the notion that peasant producers often make their living in a number of ways—including tapping non-farm sources when possible. The data here confirm the overall

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Table 3
Factors related to a more intensified ("technified") coffee system and more pressure upon the wood resources in Guatemala ($n = 153$) relative to Peru ($n = 186$)

Variable	Peru mean (error)	Guatemala mean (error)	*F*-stat (d.f.)	*P*-value
Avg. # tree spp. per farm	7.57 (0.23)	4.05 (0.25)	107.65 (1, 334)	<0.0001
Avg. # trees/ha	135 (13.9)	184 (15.4)	5.66 (1, 334)	0.02
Avg. shade height (m)	12.8 (0.37)	5.4 (0.42)	179.9 (1, 327)	<0.0001
Avg. # herb spp. per farm	5.68 (0.15)	1.12 (0.17)	393.98 (1, 335)	<0.0001
Avg. # coffee plants/ha	2500	4400	n/a	
Population density (#/km^2)	20	140	n/a	
% Rural population	27	54	n/a	
Relative access to forest	High	Low		

"n/a" = figures obtained from non-survey source and hence not comparable via ANOVA. Population data source: The World Factbook, 2005.

trend in global agricultural practices, which involves the gradual replacement of multi-species systems with more simplified – and more intensely managed – ones. This study reveals how this trend in global land use change manifests itself within agroforestry systems, providing an example of how geography matters and of just how differently and to what degree coffee agroforestry systems in far-flung places can be tapped for useful products—in this case wood products.

Guatemala's coffee sector is more "technified" or intensively managed than Peru's. A relatively depauperate tree diversity managed at lower heights, compared to that of Peru, is offset by a higher density of trees within the coffee holding. Guatemalan growers report incorporating fewer species of the common shade tree genus (*Inga* spp.), yet plant them at significantly higher densities (Table 2). The issue of fewer species may indeed simply reflect the geographic distribution of that genus, where many more species are found as one moves south into Peru and Brazil. What is clearly a trend toward intensification and simplification of the system, however, is the significant preponderance of the genus in terms of density in Guatemala. Growers there received international funding (via the United States Agency for International Development—USAID) for a number of decades, whereas Peruvian producers have seen relatively sparse funding until recently. These differences, jointly with historically higher prices and better quality coffee, undoubtedly helped nudge Guatemalan policy-makers and producers toward the intensification of the coffee sector. National differences in rural population and access to natural forests have also played some role in of the degree to which and the manner in which the wood from these systems is used.

The less diverse system found in Guatemala is more intensely harvested for its wood products, with 66% more wood being taken per hectare than in Peru. A greater demand for wood created by Guatemala's higher rural population density undoubtedly provides coffee growers the rationale to harvest and use (or sell) these wood products. The more intensively managed system characterized by high-density plantings and the diligent pruning means that the coffee plants themselves provide significant amounts of firewood. Extant forests undoubtedly play a role as well. Table 3 shows the differences in shade coffee's vegetation complex, rural population density and relative access to forested areas for both study areas. Guatemala exhibits one-half as many tree species, 36% more trees per hectare averaging nearly half the height, and a coffee plant density 76% greater than Peru. All of these parameters point to a more intensified, highly managed agroforestry system for Guatemala. Given that the landscape mosaic in Guatemala contains less forested area, together with a more densely packed rural population, the Guatemalan coffee systems represent, in essence, "forests" available for exploitation. Intensification of the production system is mirrored by a more intense exploitation of the associated wood products.

Where certification of shade coffee systems is involved, it is worth contemplating the potential impact such initiatives might have upon timber production and other wood product exploitation from certified farms. On the one hand, certifications involving specific shade criteria – and especially those requiring minimal numbers of trees per unit area – might well inhibit the exploitation of wood products from a shade coffee farm. Retaining certification might mean exploiting nearby forests for wood products. On the other hand, the incorporation of the timber products into the farm's certification could enhance the value of timber derived therein. Targeted removal by the grower could allow for both certification and limited (but valuable) timber extraction.

The data presented clearly show that not all coffee agroforestry systems are managed or exploited in the same way. A country's or region's land use history, demographics and degree of insertion into commodity trade may all have traceable elements that have helped shape the social and physical landscapes. Given that there are many other countries that currently harbor significant areas of coffee agroforests, the differences revealed here point to the need for similar investigation in other regions.

5. Conclusion

This study reveals that, alongside the obvious coffee economy and accompanying the recently recognized value of agroforestry systems as potential habitats and refuges for diverse taxa, there also exists a reliance on diverse wood products integral to these systems. The shaded coffee system has not only environmental value due to the forest-like setting, but that same shade component generates significant socioeconomic benefit. The income stream generated by an agroforestry system can be varied, evidenced by small coffee producers in Peru and Guatemala. The "income" – either from direct consumption or from market sales – flows from a variety of sources, many of which have little connection with the coffee itself. Teasing out the value of the coffee and the shade-derived products for Peru reveals a full 28% of the value coming from the shade trees and 72% accounted for by the coffee itself, compared to 19 and 81%, respectively, for Guatemala. Uncounted – but not discounted – are a number of products with intangible, culturally based uses like medicinal or ritual plants. Acknowledgment and study of these non-commercial uses and benefits of shade coffee systems are sorely needed.

As coffee prices fluctuate, so, too, will the percentage of income associated with the shade component. For instance, when coffee prices are high and producers enjoy greater incomes because of them, farm income increases and the fraction of value attributed to the shade component will be relatively low. Conversely, as coffee prices fall – as was the case in the late 1990s and early 2000s – the total income generated by the coffee plot will decrease, but the fraction attributable to non-coffee products will likely climb, providing a greater percentage of the total income from the holding. Such relationships are not lost on small peasant producers, who know well that a plot of land must be managed in ways that best position them for the vagaries of nature and the

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marketplace. Even in coffee areas where an intensification of the agroforestry system has occurred, the available trees (including the coffee plants themselves) are exploited as wood sources. Whatever the final contribution of the shade component in any given year, researchers and others need to acknowledge small farmers' reliance upon these products—an enterprise that constitutes a shadow economy alongside the obvious coffee production.

Finally, the cultural and economic importance of the shade component deserves mention. These managed ''forests'' could be a productive focus for policymakers concerned about the double-edged challenge of rural development and biodiversity maintenance, as well as issues of natural forest deterioration and agroforests' potential for stemming the pressure upon them. Obviously, where such systems serve as sources of fuelwood and/or construction materials, local forests may be the beneficiaries. Exploiting the wood resources from an agroforestry system relieves the pressure upon forest resources demanded from daily life in a rural setting. More work is needed to see exactly how these dynamics of demand and use from different sources actually function.

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