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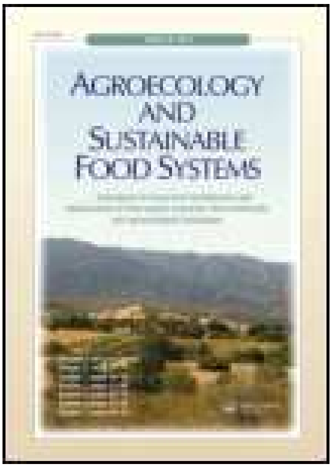

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The Coffee Crisis, Fair Trade, and Agroecological Transformation: Impacts on Land-Use Change in Costa Rica

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This research evaluated the impacts of Fair Trade marketing networks and shade-tree diversification on the reduction of land-use change out of coffee production in the district of Agua Buena, Costa Rica. These resistance strategies were deployed by smallholder coffee farmers in response to the "coffee crisis," which involved record low coffee commodity prices and record high external input costs. This research found that Fair Trade price premiums were inconsequential in providing support for smallholder resistance to land-use change out of coffee production. In contrast, the adoption of agroecological practices such as shade-tree diversification reduced reliance on costly external inputs, which allowed adopting producers to keep land in coffee production at a significantly higher rate than non-adopters. One conclusion drawn is that when addressing agricultural development crises, the promotion of agroecological practices that cut costs may be as good a strategy or better than one that focuses on enhancing yields or establishing price supports.

KEYWORDS agroecology, Fair Trade, land-use change, impact monitoring, sustainable agriculture

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INTRODUCTION

In July of 1989 one of the oldest and most successful worldwide commodity trading accords, the International Coffee Agreement (ICA), collapsed. The ICA set a target price and managed supplies with a country by country export quota system to keep the international market within a reasonable "price band" and tempered the impact of free market fluctuations on coffee production, national balance of payments, and rural stability in many countries of the "developing" world (Ponte 2002). After the ICA's dissolution and following 10 years of price volatility, year 2000 prices fell to the lowest real amounts in over 100 years (Ponte 2002). The 2000–2008 global coffee crisis resulted in hunger, homelessness, school drop-outs, heightened out-migration, and the conversion of conservation-friendly agroforestry systems to ecologically damaging pasture systems within coffee producing communities throughout the world (Varangis et al. 2003; Lewis and Runsten 2006; Méndez et al. 2006; Jha et al. 2014). With coffee providing a livelihood to over 100 million people worldwide, a development disaster unfolded as coffee farmer livelihoods and landscapes soon became some of the biggest and most widespread victims of the neoliberal political and economic project (Bacon 2005).

The Coffee Crisis in Costa Rica

While average production costs hovered around $1.00 per pound, the average Costa Rican farm-gate price, or price per-pound received by the farmer, was $0.48 per pound in the year 2000, dropping to an all-time low of $0.46 in 2001 before increasing slightly to $0.53 in 2002, $0.61 in 2003, $0.85 in 2004 and $0.89 in 2005 (Instituto del Café de Costa Rica [ICAFE] 2010). This translated to an average loss of over $1100 per ha for Costa Rican farmers during the 2001 harvest (Varangis et al. 2003). As shown in Figure 1, just as international coffee commodity prices began to slightly rebound in 2005, fertilizer prices jumped to 4.5 times higher their year 2000 prices (World Bank 2011). This price squeeze caused the number of coffee producers to drop 35% between 2000 and 2009 in Costa Rica, from 73,707 to 48,256 (ICAFE 2010). With coffee volumes also declining over 30% between 1999 and 2008, Costa Rica had earned the dubious honor of being the hardest hit Latin American nation by the coffee crisis when measured in terms of the proportion of total production and producers lost (International Coffee Organization [ICO] 2011).

Samper (2010) identified 20 of the most common short-term strategies taken by Costa Rican coffee producers following 1989's deregulation. While these 20 strategies represent a wide-array of potential responses, they can all be usefully categorized within one of the following three broader strategic response groups:

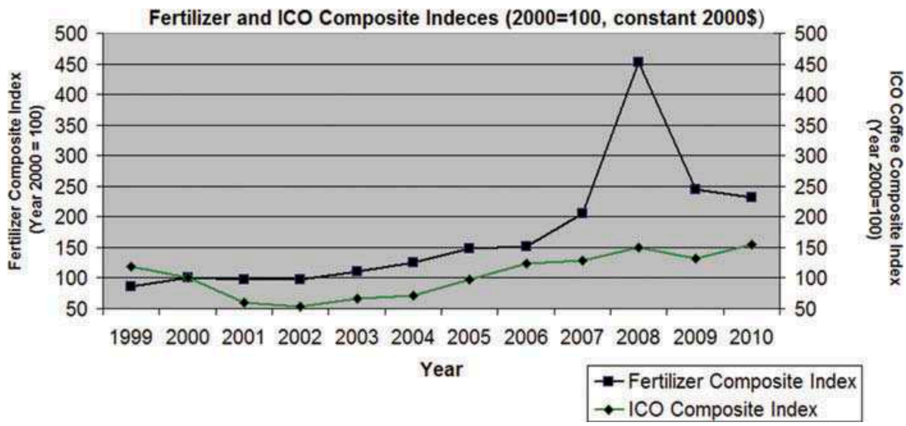

FIGURE 1 Fertilizer and ICO composite indices, year 2000 = 100 in constant 2000$. Sources: World Bank 2011; International Coffee Organization 2011.

1. *Land-use change and coffee abandonment*: Farm-level diversification partially out of coffee, combining on- and off-farm work, selling part of their land, temporary migration to work for wages elsewhere, selling all of their land and emigrating.
2. *Coffee agroecosystem transformation*: Cost reduction by reducing chemical inputs, the pruning back of coffee and planting of annual crops for household consumption, the adoption of low-external input farming systems, the inter-planting of additional shade-trees.
3. *Alternative marketing*: Value-added marketing using environmental or social-justice certification such as “Fair Trade” or “Bird Friendly,” farm-level quality enhancement (including harvesting only ripe fruit, variety choices, geographical origins, estate coffees and traceability), agroecotourism. (modified from Samper 2010).

Less understood is how well each of these responses perform. Previous research, reviewed below, has most often only looked at one isolated response category at a time. However, these strategies are interrelated and reducing the research scope to the evaluation of a single group of responses, while methodologically simpler, runs the risk of being empirically unsound. This interdisciplinary research fills this gap, harnessing over 6 years of ethnographic community-based fieldwork, more than 70 agrobiodiversity inventories, as well as a randomized survey of more than 100 farm households to assess the impacts of the coffee crisis on land-use change, coffee agroecosystem transformation and the utilization of alternative markets in Agua Buena, Costa Rica between 2000 and 2009.

What follows is the conceptual framework used in this research to understand the relationship between these three categories of responses as well as a review of the relevant literature regarding land-use change and coffee abandonment, coffee agroecosystem transformation, and alternative marketing. This is followed by a presentation of the case study site, the research questions and hypotheses evaluated, the research design and methodologies employed, and the presentation of the results.

Conceptual Framework

In order to connect the interrelated and interconnected causes and conditions of the coffee crisis with the three response strategies evaluated in this study, a conceptual framework was adapted from risk and hazard studies that understands crises to be a function of both a hazard event and particular vulnerabilities (Wisner et al. 1994). In this conceptualization there are three elements that can be schematized as an equation: disaster (D) = hazard (H) × vulnerability (V). Particular vulnerabilities interface with a specific hazard to produce crises with unique dimensions and magnitudes. Applied to the circumstances of this study in Figure 2, the disaster (D) is the coffee crisis. The impacts of the coffee crisis are manifest as the first response category identified by Samper (2010); land-use change and coffee abandonment. This category is assessed in this study by a survey of 104 farm households from Agua Buena, Costa Rica that analyzed change

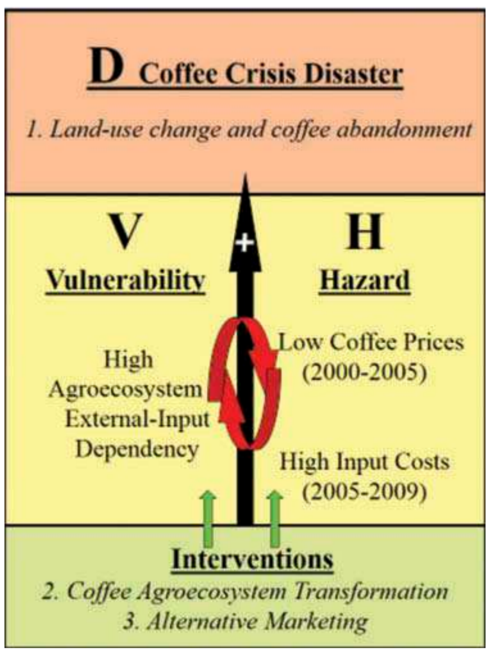

FIGURE 2 Conceptual framework for the research.

in coffee area experienced between 2000 and 2009. Existing vulnerabilities (V) of livelihoods over-reliant on coffee income and high agroecosystem external input dependency, the exact conditions of which are detailed below, have interacted with the specific hazards (H) of extremely low coffee prices and high costs of conventional coffee inputs. This interaction amplified the preexisting vulnerabilities and produced the coffee crisis. The final piece of this conceptual framework consists of the intervention strategies, which if designed, targeted and implemented correctly, are hypothesized to release farm-household vulnerability and diminish the impact of hazards or shocks encountered (diminish the rate of land-use change and coffee abandonment). The intervention strategies that undergo assessment in this study are coffee shade-tree diversification (coffee agroecosystem transformation response outlined by Samper [2012]) and participation in Fair Trade marketing networks (alternative marketing response).

Literature Review: Land-Use Change and Coffee Abandonment

Land-use change is one of the major components of global environmental change and the sum of worldwide land-use change has a significant impact on biological diversity, climate change, soil conditions, human livelihoods and the ability of ecosystems to support human needs (Vitousek et al. 1997). While conservation strategies have been historically focused on the creation of parks to "lock up" tropical forest resources such as carbon and biodiversity, both the land available for parks and enforcement in these parks have proved limiting factors to their success (Terborgh and Schaik 2002). Increasingly, efforts have focused on agricultural lands to provide for the conservation of these resources. Shade-coffee agroforestry systems are especially good candidates for conservation because they can contain high amounts of biodiversity (Perfecto et al. 1996; Méndez et al. 2007; Méndez, Bacon, Olson, Morris, et al. 2010; Jha et al. 2014) and have the potential to conserve and sequester large amounts of carbon (Dossa et al. 2008; Soto-Pinto et al. 2010).

However, one of the most frequently hypothesized but understudied results of the coffee crisis has been the abandonment of coffee agroecosystems in favor of pasture systems with little of the ecological benefits of shaded coffee. One of the few attempts to document and understand the extent and scope of coffee abandonment and land-use change comes from a recent study of the Costa Rican region of Turrialba (Bosselmann 2012). Analyzing the reduction of coffee area between 2000 and 2009, Bosselmann (2012) found that coffee area was reduced nearly 50% during the period and that the principle mediating factors correlated with the retention of coffee areas were family labor availability, age of household head, higher coffee prices, and the use of shade-tree products. However, due to the design of this study, which relied upon survey data correlations acquired from a single, simple randomized group, the sources of higher prices are not identified and evaluated and the mechanisms by which shade-tree product usage translates to less coffee land-use change are not explored. The research presented in this article takes these findings one step further by utilizing a quasi-experimental research design to compare rates of coffee abandonment and land-use change among two groups of farmers that differentially received treatments of the two policy sensitive driving factors of coffee land use retention identified by Bosselmann (2012); higher coffee prices and the use of shade-tree products.

Coffee Agroecological Transformation

All of the agroecological transformation responses outlined by Samper (2012)—cost reduction by reducing chemical inputs; the pruning back of coffee and planting of annual crops for household consumption; the adoption of low-external input farming systems; the inter-planting of additional shade trees—indicate the flexibility and internal logics of the smallholder production units which dominate the Costa Rican coffee sector. They are all farmer responses geared towards increasing farm-household resilience to the dual threats of commodity and input price volatility. While the complex interplay between the subsistence and commercial orientation of family-farmed coffee production has been acknowledged (Bacon et al. 2008), its formative role, along with that of low-external input sustainable agricultural practices, in buffering price-volatility resulting from supply-chain restructuring is poorly understood (but see Westphal 2008 and Méndez, Bacon, Olson, Morris, et al. 2010). This research aims to improve our understanding of these factors and relationships by assessing the role of shade-tree diversity in providing functional benefits that could explain coffee area retention.

Alternative Marketing

Most research evaluating the impact of alternative marketing as a response to the coffee crisis has looked at Fair Trade coffee marketing networks and commodity chains. The Fair Trade coffee commodity chain is a model of alternative trade where licensed roasters and retailers purchase coffee directly from democratically organized smallholder cooperatives at a fixed minimum price set higher than that of the conventional market. This is also often accompanied by important pre-harvest financing extended by exporters, importers, roasters or retailers located in either producing or importing countries. Fair Trade also requires the adoption of best management practices (BMPs) that limit the use of agrochemicals and fertilizers and that protect soil, water and biodiversity. However, unlike the strategies of agroecological transformation detailed above, which are "free" and "voluntary," Fair Trade certified farmers are subject to the not-inconsequential costs of certification. Research in the central and meso-American contexts points out that, while Fair Trade can provide much needed additional income to cooperatives when commodity prices are especially low (Bacon 2005), the financial benefits often do not trickle down to the farm-household level (Méndez et al. 2006) and even when they do are still often not enough to stave off radical changes in the farm-household mode of production such as migration and land-use change out of coffee (Lewis and Runsten 2006) or have a positive impact on household education, migration and food security levels (Méndez, Bacon, Olson, Petchers, et al. 2010; Bacon Sundstrom et al. 2014). Surprisingly, there has been little Costa Rican research which evaluates the direct financial benefit of higher-farm-gate prices resulting from participation in Fair Trade marketing networks. Instead, research in the Costa Rican context has focused on evaluating the indirect benefits leveraged by second-level coops (Ronchi 2002), the variation of discourses surrounding Fair Trade by cooperative leaders and smallholder producers (Luetchford 2008), and the perceptions of the level of impact of Fair Trade by longtime farmers and leader participants in the network (Sick 2008). There, thus, remains a serious gap in scholarship, which this research aims to fill, surrounding the impacts of Fair Trade in the face of the coffee crisis in Costa Rica.

Research Site: Agua Buena, Costa Rica and the Coffee Crisis

While coffee landscapes and livelihoods within Costa Rica have been hit hard by this coffee "crisis" of low farm-gate prices, the coffee sector within the district of Agua Buena, Costa Rica was hit especially hard. The district of Agua Buena encompasses 6,118 ha on the border with Panama (Manger 1992). It is the southernmost and smallest of the four districts that make up the county of Coto Brus within the province of Puntarenas. Coto Brus is one of the seven major recognized coffee producing zones in Costa Rica. Opened to settlement a little over 50 years ago, primary forest cover in Coto Brus dropped 76% from 31,660 ha in 1973 to just 7,577 ha in 1984, mostly to make way for smallholder (less than 5 ha) coffee production systems (Manger 1992). In the early 1960s, ICAFE introduced the "green revolution" technified coffee package and by early 1990s Coto Brus became the nation's highest-yielding coffee growing region (Cole-Christensen 1997). Local livelihoods were also completely dependent on coffee production, with more than 82% of the county's 3,179 farms producing coffee, and coffee accounting for 99.8% of the area planted in permanent crops (Rickert 2005). At the time the coffee crisis hit in 1999, the area was completely dominated by smallholder open-sun production systems that could produce high-yields (between 3,500 and 6,000 lb/ha) but were heavily dependent on external-inputs, especially agrochemicals (D. Cole, personal communication, May 15, 2009). The record low farm-gate prices between 2001 and 2005, combined with the 2005 spike in agrochemical prices to create the perfect storm of out-migration and land use change out of coffee in the district. Agua Buena lost 34% of its population between 1998 and 2010 (Instituto Nacional de Estadistica y Censo [INEC] 2011) and between 2000 and 2012 the number of hectares dedicated to coffee in Agua Buena decreased from 1,247 to 336, a colossal 73% reduction (ICAFE 2013). The impacts on the local environment and biodiversity as a result of this drastic change in land use are unknown, but will depend in large part on the types of land uses that these coffee lands were converted to, which is a central inquiry of the present study.

Agroecological Transformation

As coffee prices dropped and input costs increased, many Agua Buena producers were forced to minimize their use of agrochemical inputs, especially fertilizers. This was the inspiration for the formation, in 1999, of the "sustainable group" (SG) of 61 farmers organized within the 700 member CoopaBuena producer cooperative in Agua Buena. In the year 2001, worst ever for Costa Rican producers in terms of the final farm-gate prices received, the SG joined a new program launched by the Costa Rican Ministerio de Agricultura y Ganadería (MAG; Ministry of Agriculture and Livestock). The free government program, Caficultura Sostenible en Pequenas Fincas (Sustainable Coffee Production in Small Farms), provided structure, leadership, training and resources to organized producer groups to guide the transition to sustainable coffee production (Garcia 2005). This included financial support and technical advisors, as well as a set of congressionally approved certification standards (Obando Jimenez 2004). The standards were based on policies of the United Nation's Food and Agriculture Organization (FAO), the Smithsonian Institute, and the International Coffee Organization (ICO). The 61 members of the SG signed voluntary agreements committing themselves to the MAG's Café Sostenible program and the transformation of their coffee agroecosystems such that by 2005 they would be found in fulfillment with the following five core principles:

1. Maintenance of between 30% and 50% shade level.
2. Erosion control and soil conservation measures established throughout the farm.
3. Minimum of 10 different species of shade-tree per hectare of coffee.
4. Protection of natural water sources.
5. At least 50% reduction of chemical fertilizer use (MAG 2002).

This entailed a widespread and rapid transformation of SG agroecosystems. The agroecological diversification program promoted the diversification of the structure and function of coffee shade trees, especially focusing on the planting and management of leguminous service trees. Immediately following the SG's written commitment, MAG organizers began an eleven-day orientation course outlining the main principles of the program and creating action plans with each farmer. This was followed by a suite of courses; in 2003 and then again in 2004 a three-week organic production course was facilitated by MAG instructors. This was followed by a 15-day farm-accounting class given by Instituto Nacional de Aprendizaje (INA [National Institute of Learning]), which also offered a two-week *buenas practicas agricolas* (best agricultural practices) course in 2004. Also in 2004, MAG offered two different 15-day organic compost courses along with an agroforestry design, shade management, and soil conservation module. These above-mentioned courses comprised less than half of the full array of courses offered by INA and MAG between the years of 2001 and 2008. The fieldwork undertaken during the course of this article's research grew out of this program of coursework and certification as the SG expressed a need for evaluation of the impact of this program on farm-management and household livelihoods.

Fair and Direct Trade Marketing

In 2003 the SG established an alternative, direct marketing partnership with a U.S nongovernmental organization, the Community Agroecology Network (CAN), which returned over $3 per pound to the CoopaBuena cooperative instead of the conventional market's average $0.53 (2002 Costa Rican average farm-gate price) per pound. The additional profit was generated with the intention of supporting the SG's agroecological transition. However, the drop in global coffee prices, combined with a processing accident, hindered CoopaBuena's ability to repay outstanding loans and by the first months of 2004 the debt ballooned to approximately US$3 million (Garcia and Babin 2006). The cooperative declared bankruptcy and ceased operations in May of 2004. As the community searched for viable alternatives, the sustainable group of farm families committed to agroecological practices formed the Cooperativa Agroecológica CoopePueblos (CoopePueblos Agroecological Cooperative) in May of 2004. The SG's new cooperative sold over three-quarters of their coffee to value added markets during the five harvests between 2005 and 2009. While 10% (32,826 lb) of value-added sales were realized through the direct-market program managed with CAN, certified Fair Trade (FT) markets accounted for 66% (207,034 lb) of this.

This research compares farm-household land-use change, coffee agroecosystem diversity and farm-gate price between the SG and a control group (CG) of randomly selected farm households who did not participate in either program. This will provide a much needed evaluation of the effectiveness of alternative marketing and agroecological conversion programs on reducing land-use change out of coffee.

RESEARCH QUESTIONS AND HYPOTHESES

The following three research questions and associated hypotheses guided this work:

1. How did processes of Agua Buena, Costa Rica coffee sector land-use change advance between the years of 2000 and 2009 and how did experiences differ between the SG and the CG?

   H1: The SG persisted in coffee significantly more than the CG due to their employment of alternative markets and agroecological practices.

2. What was the effect of alternative markets in mitigating these changes; did the SG's connection to Fair Trade and direct-trade networks lead to higher farm-gate prices than those received by CG farm households connected to other Agua Buena marketing networks?

   H2: Higher farm-gate prices resulting from the SG's connection to Fair Trade and direct markets helps explain their persistence in coffee.

3. What was the effect of agroecological practices in mitigating these changes; did the SG's promotion of an agroecological transformation lead to more diverse and resistant agroecosystems?

   H3: The diversification of SG coffee agroecosystems helped maintain production while heavily reducing or eliminating costly external inputs, helping explain their persistence of coffee.

RESEARCH DESIGN AND METHODOLOGY

A quasi-experimental, case controlled research design was utilized (Campbell and Stanley 1963). The experimental "treatment" in this "natural experiment" was farm-household participation in alternative markets and the agroecological transformation process. The coffee price crisis of 2001–2004, combined with the peak-oil agricultural input price crises from 2004 to 2007 provided a "natural experiment" to compare the impacts of these interventions on coffee abandonment and land-use change.

Research Question 1: Land-Use Change

Research Questions 1 and 3 feature a two-staged sampling design. In the first stage disproportionate, stratified, random sampling was utilized to assign households to one of the two groups (CG and SG). The sampling frame used to draw the two stratified random samples was the CoopaBuena producer cooperative database containing every producer who processed coffee in the year 2000. After eliminating from the database all producers not located within the geographical confines of the district of Agua Buena, the resulting sampling population consisted of 1,903 household heads. The 2000 Costa Rican National Census recorded 1,702 occupied households in the district of Agua Buena, an indication that the sampling frame utilized was an accurate representation of the district's year 2000 population (INEC 2000). The following two stratums were drawn from this frame:

Stratum 1: Sustainable Group ($n = 50$*):* A randomized sample of 50 of the 61 SG farm households contained in the CoopaBuena 2000 register. None denied participation.

Stratum 2: Control Group ($n = 54$*):* Eighty-one farm households were randomly sampled from the unbiased 1,841 remaining in the database. Twenty seven of the 81 farm households (35%) had moved out of the district between 2000 and 2009 while each of the remaining 54 participated in the research. This sample size is consistent with a 95% confidence level and a (+ or –) 11% margin of error (confidence interval).

This 35% emigration rate compares very favorably with the rate of population loss reported by the INEC between 1998 and 2010. According to INEC, the population in Agua Buena dropped 34% from 9,445 persons prior to the coffee crisis in 1998 to just 6,286 persons by 2010 (INEC 2011).

Land-use change data comes from a farm-household survey completed between January and April of 2009. The survey elicited information on household demography, education, income, employment activities, land-use, labor allocation, coffee management, and coffee yields ($N = 104$). Variable values from the harvest year of 2000 and 2008–2009 were recorded.

Research Question 2: Alternative Markets

Archival research, email communications, accounting records, annual reports and board of director meeting minutes from CAN and the SG's CoopePueblos Cooperative were used in combination with the active-participant observations derived from the author's role as CAN's Agua Buena community research liaison between 2005 and 2009, in order to assemble the sales and farm-gate price data utilized in this research question.

Research Question 3: Agroecological Inventory

In the second stage of disproportionate, stratified, random sampling the following two stratums were drawn from the first sample utilized in Research Question 1:

*Stratum 1: Sustainable Group (*n = *32):* A random sample of 32 of the 50 SG farm households sampled during the first stage. All continued to produce coffee and each agreed to participate in the study.

*Stratum 2: Control Group (*n = *40):* Of the 54 farm households that remained in the district out of the 81 sampled during stage one of the sampling process, 40 farm households (74%) continued to produce coffee in 2009. Each agreed to participate in the study.

The agroecosystem inventory took place between March and June 2009. A 1000 meter squared plot was randomly established and all trees with a diameter at breast height (DBH) of over 5 cm were included in the study. Identification of genus and species were recorded as well as the height and DBH of each individual. The number of diverse vertical strata formed by the shade-layer was also recorded. Average coffee planting density was obtained by counting individual coffee plants in a 50 m^2 subsample plot. Slope and percentage of shade were measured at four randomly chosen points in the quadrant and averaged. The horizontal arrangement of the tree and crop species were sketched and soil conservation works such as contour planting, terracing and drainage canals were noted.

RESULTS

Research Question 1: Land-Use Change

1. How did processes of Agua Buena, Costa Rica coffee sector land-use change advance between the years of 2000 and 2009 and how did experiences differ between the SG and CG?

Coffee and pasture

Table 1 displays the total area in hectares for the CG and SG across the different land uses as well as the total percentage of change in each land use between 2000 and 2009. Notably, this table indicates that SG farm-household retained 82% of their coffee farmlands between 2000 and 2009 while the CG only retained 24%. Table 2 displays average per farm area in hectares as well as an average per farm percentage of total farm-size dedicated to each land use. The SG's year 2000 mean farm size was 3.47 ha. By 2009 the SG's average was 3.73 ha. In 2000 the average CG farm size was 3.04 ha while the average dropped to 2.78 ha in 2000. In neither year were the differences in average farm size significant.[1] Even though the CG began with a statistically significant higher average area in coffee (SG 2.19 ha or 63%,[2] CG 2.28 ha or 75%), and both groups experienced statistically significant losses of coffee farmland between 2000 and 2009 (SG −0.4 ha or –15%,[3] CG –1.72 ha or –55%), SG farm households had a significantly greater area and proportion

TABLE 1 Agua Buena total area and percentage of change per land use 2000–2009

	Sustainable group (n = 50)				Control group (n = 53)			
Land use	2000 ha	2009 ha	△ ha 2000–2009	△% 2000–2009	2000 ha	2009 ha	△ ha 2000–2009	△% 2000–2009
Coffee	109.31	89.52	19.79	−18%	120.84	29.47	91.37	−76%
Pasture	26.03	50.36	−24.33	94%	22.56	54.52	−31.96	142%
Annual crops §	5.21	9.33	−4.12	79%	1.61	16.21	−14.60	906%
Fallow	8.68	9.33	−0.65	8%	1.61	20.63	−19.02	1180%
Forested/reforested	12.15	16.79	−4.64	38%	3.22	2.95	0.28	−9%
House and yard	8.68	7.46	1.22	−14%	9.67	0.00	9.67	113%
Others	3.47	3.73	−0.26	8%	1.61	2.95	−1.34	83%
Total	173.50	186.50	−13.00	8%	161.12	126.71	34.41	−9%
Coffee persistence (2009/2000) ×100			82%				24%	

TABLE 2 Agua Buena proportion area per land use 2000–2009

Land use	Mean ha	Mean 2009 ha	Δ 2000–2009	2000 % of total	2009% of total	%Δ
Sustainable group ($n = 50$)						
Coffee	2.19**	1.79***	−0.40###	63%	48%	−15%
Pasture	0.52	1.01	0.49###	15%	27%	12%
Annual crops†	0.1	0.2	0.1	3%	5%	2%
Fallow	0.18**	0.18*	0.01	5%	5%	0%
Forested/reforest	0.24**	0.34**	0.09	7%	9%	2%
House and yard	0.17	0.15**	−0.02	5%	4	−1%
Others	0.06	0.07	0	2%	2	0
Mean farm size	3.47	3.73	−0.26	100%	100%	N/A
Control group ($n = 53$)						
Coffee	2.28	0.56	−1.72###	75%	20%	−55%
Pasture	0.43	1.03	0.6###	14%	37%	23%
Annual crops†	0.03	0.31	0.28##	1%	11%	10%
Fallow	0.03	0.39	0.36###	1%	14%	13%
Forested/reforest	0.06	0.06	0	2%	2%	0%
House and yard	0.18	0.39	0.21##	6%	14%	8%
Others	0.03	0.06	0.03	1%	2%	1%
Mean farm size	3.04	2.78	0.26	100	100	N/A

*Mean values are significantly different than the control group at 10% level.
**Mean values are significantly different than the control group at 5% level.
***Mean values are significantly different than the control group at 1% level.
#2000–2009 within group means values are significantly different at the 10% level.
##2000–2009 within group means values are significantly different at the 5% level.
###2000–2009 within group means values are significantly different at the 1% level.
†Corn, beans, and vegetables.

of total farmland in coffee by 2009 (SG 1.79 ha or 48%, CG 0.56 ha or 20%). The difference was highly statistically significant (see Table 2).

The most dynamic land-use besides coffee was pasture where both the SG and CG began with statistically similar areas and percentages of total farmland devoted to pasture (SG 0.52 ha or 15%, CG 0.43 ha or 14%). While both groups statistically significantly increased their respective areas and percentages of farmland in pasture between 2000 and 2009 (SG +0.49 ha or +12%, CG +0.6 ha or +23%), the CG had a significantly larger average area and percentage dedicated to pasture by 2009 (SG 1.01 ha or 27%, CG 1.03 ha or 37%). Thus, for both groups the conversion of coffee was mostly to pasture systems.

Other land uses

The SG had an insignificant increase in farmland dedicated to annuals (+ 0.1 ha or +2%), while a statistically significant increase was observed in CG farmlands (+ 0.28 ha or +10%) between 2000 and 2009. SG farms began 2000 with a significantly higher area and percentage of land in fallow but while between 2000 and 2009 they experienced no change in area, CG farmlands significantly increased by an average of 0.28 ha per farm, or 10%, and were significantly higher than the SG by 2009 (SG stable at 0.18 ha or 5%; CG 0.03 ha or 1% to 0.38 ha or 14%). While there were no significant changes between 2000 and 2009 in the area and average percentage of forested/reforested lands within either group, SG farms had significantly more forested/reforested lands in both 2000 (SG 0.24 ha or 7%, CG 0.06 ha or 2%) and 2009 (SG 0.34 ha or 9%, CG 0.06 ha or 2%). Both groups began with similar areas dedicated to the house and yard (SG 0.17 ha or 5%, CG 0.18 ha or 6%). Between 2000 and 2009, the CG experienced a significant increase in the area and proportion dedicated to the house and yard (+0.21 ha or +9%) and by 2009 the groups had significantly different areas and proportions (SG 0.15 ha or 4%, CG 0.39 ha or 15%).

The major finding from this research question was that 82% of the SGs while only 24% of the CGs coffee persisted through the crisis. The statistical significance ensures that it was not due to just one large reduction or gain but that it was a consistent persistence on the part of the SG and an equally consistent abandonment by the CG. Additionally and notably, the results of this research indicate that these two samples did not diverge significantly in terms of year 2000 farm sizes and land-use allocations. The first research hypothesis was confirmed, giving added weight to the proposition that some type of intervention strategy adopted following the onset of the crisis explains the great differences in 2009 land uses detailed above. Since production costs vary with farm-size and farm-size was not found to significantly differ and can be held constant, the SG's persistence in coffee is due to higher farm-gate prices (Research Question and Hypothesis 2) or reduced production costs (Research Question and Hypothesis 3).

Research Question 2: Alternative Markets

2. Between 2004 and 2009 did the SG's connection to Fair Trade and direct-trade networks lead to higher farm-gate prices than those received by CG farm households connected to other Agua Buena marketing networks?

Over the five harvest years studied, the SG's CoopePueblos Cooperative sold 315,968 lb in all, 66% to certified Fair Trade, 10% through direct-trade and 24% to conventional markets. This means that over three quarters (76%) of all coffee sales of the SG's Cooperative were made to alternative marketing networks. SG alternative market prices were compared to those of two other conventional markets utilized by members of the CG: CooproSanVito and CoopeSabalito.

During the 2004–2005 harvest the SG's farm-gate price of $1.07 was $0.38 greater than the CooproSanVito farm-gate price, $0.25 higher than the CoopeSabalito farm-gate price, and $0.07 greater than average national production costs for that harvest year (see Table 3). However, while the final farm-gate price received was $0.25 greater than the nearest competitor CoopeSabalito, the SG's total sales were very low this initial year, totaling 7,869 lb or an average of only 129 lb sold per household based on a total of 61 households in the SG. According to the farm-household survey utilized for the first research question, SG members averaged 2160 total pounds of coffee production annually. This means that only around 6% of SG member's total production was sold through the SG for the 2004–2005 harvest and the rest sold to other marketing channels serving the district. Thus, for the harvest year 2004–2005, this 6% of production sold through the SG generated only an average of $32.25 per SG household in gross price-premium revenue over the nearest farm-gate price competitor.

Sales jumped 84% to 14,509 lb sold by the SG in the harvest of 2005/2006, with an average 238 lb (or 11% of SG member's total production) sold per SG member. However, the SG's farm-gate price of $0.93 was only $0.11 greater than the CooproSanVito farm-gate price, $0.02 higher than the CoopeSabalito farm-gate price, and $0.05 greater than average national production costs for that harvest year. This translated to an average additional profit made per SG household of only $4.75 over the nearest farm-gate price competitor CoopeSabalito.

Sales jumped 427% to 76,500 lb sold for the harvest of 2006/2007, with an average 1,254 lb (or 58% of SG member's total production) sold per SG member. However, the SG's farm-gate price of $1.00 was only $0.11 greater than the CooproSanVito farm-gate price, $0.09 higher than the CoopeSabalito farm-gate price, and $0.18 greater than average production costs for that harvest year. This translated to an average additional profit made per SG household of $113 over the nearest farm-gate price competitor CoopeSabailto.

Sales jumped again, this time 47% between the 2006–2007 and 2007–2008 harvests to 113,000 lb, with an average of 1852 lb (or 86% of SG member's total production) sold per SG member. However, while marketing the great majority of each member's coffee, the 2007–2008 SG farm-gate price was $0.97 per pound, only $0.04 greater than the CooproSanVito farm-gate price and actually falling $0.04 below the CoopeSabalito farm-gate price while remaining just $0.01 above average national production costs. This complete lack of a price-premium existed despite the fact that 90% of all SG sales in this harvest year were to alternative markets (84% to FT and 6% to FT direct).

Sales dropped 8% between the 2007–2008 and 2008–2009 harvests to 103,700 lb, with an average of 1700 lb (or 79% of SG member's average total production) sold per SG member. The 2008–2009 SG farm-gate price was $0.91 per pound, only $0.07 greater than the CooproSanVito farm-gate price and falling $0.05 below both the CoopeSabalito farm-gate price and

TABLE 3 Difference between CoopePueblos farm-gate price and select indicator prices, 2004–2009

Harvest year[a]	CP farm-gate price (US$/lb)[b]	Difference between CP and CooproSanVito farm-gate price[c]	Difference between CP and CoopeSabalito farm-gate price[c]	Difference between CP farm-gate price and average production costs[b,d]	Total CP sales (lb)[b]	Direct trade (DT) total lb (%)[b]	FT total lb (%)[b]
2004–2005	1.07	−0.38	−0.25	−0.07	7,869	5203 (66%)	0% (0)
2005–2006	0.93	−0.11	−0.02	−0.05	14,509	5375 (37%)	0% (0)
2006–2007	1.00	−0.11	−0.09	−0.18	76,500	4214 (6%)	31,574 (41%)
2007–2008	0.97	−0.04	+0.04	−0.01	113,000	6443 (6%)	95,460 (84%)
2008–2009	0.91	−0.07	+0.05	+0.16	103,700	11,591 (11%)	80,000 (77%)

[a]All US dollar/pound weight measurements are converted from fanegas. A fanega is equal to 400 liters of ripe coffee berries, and when processed yields an assumed 101.4 lb of unroasted coffee beans per fanega.

[b]Sources: CoopePueblos 2005, 2006, 2007, 2008, 2009.

[c]Sources: ICAFE 2005, 2006, 2007, 2008, 2009.

[d]Sources: Centro de Investigación del Café 2005, 2006, 2007, 2008, 2009.

$0.16 below average national production costs. Again, even though 88% of all SG sales were made to alternative markets in this final harvest year studied (77% to FT and 11% to FT direct) there was no price-premium realized.

After incorporating the findings from this research question we can now express Hypothesis 1 through the following reformulation; how did SG coffee farmers persist so much more in coffee land uses without receiving a substantial premium in any year studied of the SG's CoopePueblos? This is perhaps even more of a mystery if we recall that 82% of year 2000 SG farm-household coffee land use was still persistent in coffee in the year 2009 and only 24% of CG farm-household coffee land use persisted as coffee over this same time period. The decay in profitability experienced by the SG's market meant that by the 2008–2009 harvest, the CoopePueblos farm-gate price return was more than fifteen cents less than the national average coffee production costs per pound. One way to reduce this vulnerability, as well as to explain SG persistence in coffee when farm-gate prices did not differ substantially between the groups, is through the agroecological transformation of production, especially when this transformation is accompanied by a reduced need for formerly purchased external inputs for the farm households managing them. The following, final research question of this article explores whether these mechanisms do in fact explain the comparative persistence of the SG's farm households through the years of coffee crisis evaluated in this research.

Research Question 3: Agroecological Transformation

3. What was the effect of agroecological practices in mitigating these changes; did the SG's promotion of an agroecological transformation lead to more diverse and resistant agroecosystems?

Species richness[4]

In the 72 total plots studied (40 CG and 32 SG), 81 tree species (5234 individuals) belonging to 41 botanical families were identified. The total observed number of tree species was 61 in the SG and 58 in the CG (see Table 4). Because of bias introduced by unequal sample sizes and variation in tree stem-densities within and between quadrants in each group, sample-based tree species accumulation curves[5] were transformed into individual-based accumulation curves[6] (Gotelli and Colwell 2001; Colwell 2009). Both tree individual-based species accumulation curves reach a near asymptote, indicating that the sample-size was nearly comprehensive. The total tree species richness per group when corrected for by the individual-based rarefaction curves was still greater in the SG; 61.2 versus 57.5 total tree species. While the magnitude is slight, the one standard deviation error bars on the

TABLE 4 Summary of key agrobiodiversity results

Variable	Sustainable group ($n = 32$)	Control group ($n = 40$)	p value*
Number of 1000 m^2 quadrants	32	40	N/A
Observed tree species richness per group	61	58	
Total tree species richness per group[a]	61.2 (±13)	57.5 (±12)	Non-overlapping error bars
Maximum expected tree richness (Michaelis Menten)	74.72	73.75	N/A
Mean tree species richness per quadrant	8.4 (±3.27)	5.6 (±2.98)	0.001*
Mean tree Fisher alpha diversity index	2.57	1.68	0.009*
Mean coffee density (plants/hectare)	8379 (±2278)	7469 (±1790)	0.45
Mean percent plot slope	25.13 (±19.96)	17.14 (±17.44)	0.29
Mean tree diameter at breast height (cm)	6.5 (±2.6)	6.1 (±2.48)	0.41
Mean tree height (m)	1.67 (±0.38)	1.58 (±0.39)	0.31
Mean percent shade rainy season	29.22 (±18.57)	25.64 (±18.82)	0.07

[a]Data were transformed for comparison using Coleman individual-based rarefaction calculated with the software package EstimateS version 8.2.
*Differences statistically significant at p value < 0.05 in a two-tailed unpaired t test.
(±) Standard deviation.

individual-based accumulation curves did not overlap and so the difference in total tree species was determined to be statistically significantly greater in the SG. In addition, the maximum expected richness of each community was extrapolated[7] for comparison with the total tree species richness observed in the individual-based curves, predicting a maximum of 74 SG and 73.5 CG tree species (Table 4). Comparing total observed species richness with the predicted values, fully 83% of the SG's tree diversity, and 78% of the CG's estimated maximum tree diversity was encountered in the quadrants inventoried.

Overall, while these results reveal that the tree and crop sampling effort was fairly comprehensive and that total tree and crop species richness was statistically significantly greater in the SG, the magnitude of this effect was minimal. The effect of the SG diversification program becomes more apparent when we compare average per quadrant species richness between the two groups. The CG averaged 8.4 tree species observed per quadrant, 50% greater than the CG's average of 5.6 tree species and highly statistically significant ($p = 0.0001$). This suggests that while the number of total species encountered was similar between the groups, each individual farm of the SG harbored significantly more tree species richness per quadrant.

Species diversity

Diversity indices take into account both species richness and abundance, making them the most common tool for comparing the overall diversity of a particular set of species distributions. However, the accuracy of a particular index in comparing overall diversity between two or more distributions varies, with some indices suited for some comparisons better than others based on the shape or model of the distributions being compared. Tree species rank-abundance distribution curves were elaborated for both the CG and SG (Figure 3), and a goodness of fit chi-square test[8] revealed that each curve conformed to the log series distribution best paired with the Fisher's alpha (α) parametric index of diversity. Fisher's alpha is one of the most commonly used indices when comparing communities that vary in sample size and stem number (Colwell 2009). In each quadrant individual Fisher's alpha diversity index scores were calculated[9] and the resulting mean Fisher's alpha index of tree diversity was 2.57 in the SG and 1.68 in the CG and highly significantly different ($p = 0.009$).

The highly statistically significant and substantially larger Fisher's alpha index of tree diversity scores indicate that the distribution of tree species in the coffee plots of the SG is markedly more diverse than in the CG. Thus, we can answer the first part of Research Question 3 in the affirmative; that the

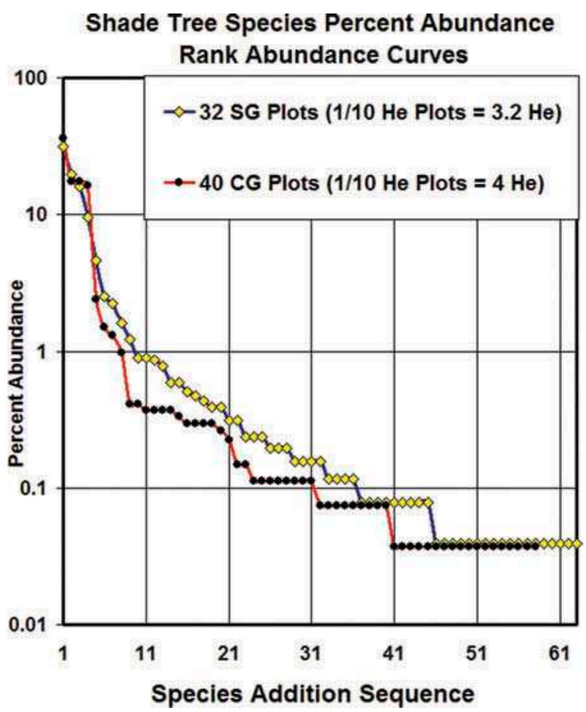

FIGURE 3 Shade-tree rank abundance curves.

SG's promotion of an agroecological transformation did indeed lead to more diverse agroecosystems. But what about this diversity made the SG's agroecosystems more resistant to land-use change out of coffee? They are richer, both in terms of total and average tree species richness and they are more diverse, when diversity accounts for both richness and evenness. However, species richness, abundance and evenness are measures that alone cannot capture the mechanisms by which agrobiodiversity is able to reduce the vulnerability to events such as the coffee crisis. To examine and understand the properties of these agroecosystems that conferred resistance, closer attention to the functional impact of individual species and groups of species becomes important. The analysis of whether agroecological diversification catalyzed emergent qualities of agrobiodiversity such as resistance to economic disturbance, thus, requires a focus on higher levels of organization in the agroecosystem. Accordingly the next section moves to the evaluation of tree functional diversity.

Functional Diversity

The steep slope at the beginning of the shade-tree rank-abundance curves (Figure 3) confirmed field observations that these systems feature a few species at very high abundances with potential effects that may dominate agroecosystem functioning. Indeed, the five most abundant tree taxa in each group account for 5% of the species richness and 81% of all individuals and 9% of the species richness and 89% of all individuals in the SG and CG, respectively. An examination of functional diversity, or how individual species' characteristics contribute to overall agroecosystem functioning, was thus conducted. Functional diversity is understood agroecologically as emerging from the interactions, energy flows, and recycling of material between the different components of the agroecosystem (Gliessman 2007). These emergent system qualities have been conceptualized utilizing the concept of functional effect groups, which are groups of species that have similar effects on the functioning of these higher level system attributes (Gitay and Noble 1997; Lavorela et al. 1997; Gliessman 2008). This analytical strategy has roots in theoretical ecology, where it has been used to unravel and understand the types and arrangements of diversity behind emergent kinds of ecosystem qualities such as resistance, resilience and stability (Hooper and Vitousek 1998; Naeem 1998; Symstad 2000).

In the demarcation of which species present in the SG and CG species distributions belong to which functional effect groups, every tree species was apprised for their principal effect on agroecosystem functional properties and processes. The determination of the groups was, thus, the result of a systematic review and assignment of each tree species to one of two functional effect groups. The principle backbone species utilized in each group were identified and are listed in Table 5, with the top four backbone

TABLE 5 Top five most abundant shade-tree species by group*

Sustainable group				Control group			
Species name	Local name	Use	% Total trees	Species name	Local Name	Use	% Total trees
Erythrina poeppigiana	Poró gigante	N/O	31.3	*Musa X paradisiaca*	Plátano	Fr	35.8
Musa acuminata	Banano	Fr	19.7	*Erythrina poeppigiana*	Poró gigante	N/O	17.4
Musa X paradisiaca	Plátano	Fr	15.9	*Erythrina berteroana*	Poró pequeno	N/O	17.3
Erythrina berteroana	Poró pequeno	N/O	9.6	*Musa acuminata*	Banano	Fr	16.4

*Fr = fruit; N/O = nitrogen fixing legume/organic matter incorporating.

species identical across the two groups; *Erythrina poeppigiana, Musa acuminata, Musa X paradisiaca*, and *Erythrina berteroana*. The functional effect of each of these four key species on the structure and function of the coffee agroecosystem is either fruit bearing/nutrient extracting (*Musa spp.)* or nitrogen fixing and organic matter incorporating/nutrient cycling (*Erythrina spp..*) species. Ninety-eight percent of all tree species encountered in both groups belong to the following two principal functional effect groups.

Functional Effect Group 1: Nutrient Extracting/Productive Biota. This group is characterized by fruit, timber and living fence trees. They provide for household reproduction in the form of animal feed, market sales, gifting and household consumption.

Functional Effect Group 2: Nutrient Cycling/Resource Biota. This group is characterized by fast growing leguminous tree species such as those from both the *Erythrina* and *Inga* genera. The species in this group provide ecological services such as the rapid accumulation of soil organic material by way of natural litter dispersion and farmer management of regular pruning's, as well as increased efficiency of nutrient cycling processes and soil fertility subsidies from the fixation of atmospheric nitrogen.

The distribution of species has been tallied in Table 6 in terms of average total number of tree stems per functional group in both the SG and the CG. In parenthesis is given the relative proportion of the SG and CG total tree stems that have been dedicated to each of the three functional effect groups. Most notably, the SG has a statistically significantly higher average total number of nutrient cycling/resource biota stems per quadrant than the CG (SG 40.9 vs. CG 22.3; $p = 0.007$). While the average total number of nutrient extracting/productive biota stems per quadrant is not statistically different between the SG and the CG, the proportion of total stems from the *Musa* genera is of a much higher magnitude in the CG (52%) than the SG (35%).

TABLE 6 Functional effect groups

Functional effect group	1. Nutrient extracting/ productive biota			2. Nutrient cycling/ resource biota	Total average trees per quadrant (total %)
Tree category	1.A *Musa* fruit trees	1.B Other woody fruit trees	1.C Timber/living fence trees	Leguminous service trees	
SG ($n = 32$)	28.5 (35%)	4.4 (5%)	4.8 (6%)	40.9 (51%)	80.3 (100%)
NG/C ($n = 40$)	35.1 (52%)	5.5 (8%)	3.9 (5%)	22.3 (33%)	67.1 (100%)

Nutrient extracting number of trees per quadrant not significantly different.
Nutrient cycling number of trees per quadrant $p = 0.007$.

Both of the above discussed functional effect groups are strongly related to the emergence of either resistance or vulnerability to external shocks such as the coffee crisis. Following the collapse of coffee prices in the year 2000, external labor and agrochemical inputs were no longer affordable to many farmers, causing the conversion of their land uses out of coffee. When oil prices skyrocketed in 2007, fertilizer prices were more impacted than herbicide and fungicide prices, leading to costs of fertilization in Costa Rican technified systems to more than double on a cost per hectare basis. The statistically significantly higher quantity of shade trees per quadrant dedicated to the provision of soil fertility in the SG helped substitute for the formerly purchased off-farm agrochemical inputs. In addition, in Agua Buena the heavy inclusion of *Musa spp.* within coffee agroecosystems, such as that suggested by the CG's distribution of individuals to functional effect groups, requires even more soil amendments to maintain the level of fertility needed to support both coffee and fruit production. Thus, this combination of increased on-farm, shade-tree based production of formerly purchased external inputs and avoidance of intensified *Musa spp.* based production systems that required additional soil fertility amendments, provides a partial explanation for the persistence of the SG in coffee production following the price crises that characterized the first decade of the 2000s.

DISCUSSION

The magnitude of the coffee crisis in Agua Buena, Costa Rica, as measured by the rate of LUC out of coffee recorded between 2000 and 2009, was severe. In the randomly selected and statistically representative CG, over three quarters (76%) of the lands dedicated to coffee in the year 2000 had been removed by 2009. This compares favorably with ICAFE estimates, based upon remotely sensed images and producer surveys, that 73% of the coffee in the district was removed (27% persisted) between 2001 and 2012 (ICAFE 2013). However, Hypothesis 1 was confirmed as the SG persisted in coffee significantly more than the CG as only 18% of the SG's coffee was removed between the years 2000 and 2009.

Pasture was by far the most popular replacement for coffee agroecosystems with pasture's average proportion of total farm-area increasing from 15% to 27% in the SG and 14% to 37% in the CG. In places such as Agua Buena where the main alternative land use to coffee is pasture, the decision to convert to this land use is a critical one because once converted the land is fairly path dependent in use as the soil structure often becomes damaged enough that subsequent conversion to another cropping system is difficult, if not impossible. The ecological ramifications of this widespread shift to pasture call attention to the need to identify those strategies that incentivize the persistence of coffee.

Research Questions 2 and 3 and their accompanying hypotheses were levied to explain this overwhelming persistence of the SG farm households. The goal of Research Question 2 was to determine whether a farm-gate price subsidy existed between 2004 and 2009 and if so to determine its role in helping SG farm households persist in coffee. The major finding from Research Question 2 was that in not one single year was the SG farm-gate price premium large enough to realistically impact the SG members' persistence in coffee compared to their CG counterparts. The reasons for the failure of this market to deliver on its promises are discussed elsewhere at length (Babin 2012). Briefly, they can be attributed to the high administrative costs and lower than promised profit structures inherent to each alternative market, usurious lending practices by the second-level Costa Rican FT exporting cooperative, SG cooperative mismanagement and questionable business practices. While this is just one case study, it is one of the first published evaluations of farm-gate price paid in Costa Rica and as such supports a much more cautious view of FT as an effective intervention and calls into question the purported benefits of FT as reported by other work done in the Costa Rican context (esp. Ronchi 2002). The results of this study also corroborates with other Central American research that finds both average annual FT certified household coffee sales and the proportion of that total annual volume sold through alternative markets as too low for certification alone to adequately relieve the vulnerability faced by these smallholder coffee farmers (Méndez, Bacon, Olson, Petchers et al. 2010).

The major finding from the third research question was that total, average and indices of coffee shade-tree diversity were greater in the SG and that SG functional diversity in the form of significantly more tree diversity dedicated to the provision of formerly purchased agrochemical inputs helps explain why farm- households were able to persist in coffee more than those in the CG, even when farm-gate-prices were not significantly higher than those received by the CG. This intensification of functional and species diversity was promoted because of its potential to fuel the emergence of system-level qualities of internal nutrient cycling, energy usage, and farm-household stability. These qualities, in turn are clearly linked with developing resistance to coffee land-use change and this research confirms the third hypothesis as true; the diversification of SG coffee agroecosystems helped maintain production while heavily reducing or eliminating costly external inputs, helping explain their persistence of coffee. Thus, the puzzle of why there was such high levels of SG persistence in coffee, with fully 82% of SG coffee lands persistent between 2000 and 2009 versus 24% in the CG, is explained by distinct differences in the overall level and type of functional diversity found within the coffee systems of the CG and SG. The program of agroecological transformation focused diversification almost exclusively on the reduction of external inputs in order to bolster farm-household resistance to future economic shocks. This focus on external input reduction is a unique contribution of this study, as other research has emphasized the links between coffee agroecosystem production of food, firewood and timber and smallholder resistance and resilience to external shocks like the coffee crisis (Méndez, Bacon, Olson, Morris et al. 2010).

CONCLUSIONS

This research compliments a growing body of findings concerning the impacts of liberalization upon the persistence of smallholder agriculture. These findings have been eloquently summarized by Van Der Ploeg (2010):

> The less commoditized parts of agriculture that are able to distantiate decision-making from the "logic of the market" are the ones that are best placed to face the current crisis; this is in line with historical precedents . . . (O)ver the last fifty years peasantries have experienced massive and multi-faceted processes of agrarian modernization. During this period it has become increasingly clear that this particular form of modernization not only excludes the majority of farmers, but that in the end, it also tends to destroy those farmers who have followed the modernization script and converted themselves into agrarian entrepreneurs . . . In this respect the most telling reversal is that at present (due to the financial and economic crises) relatively small-scale, peasant-like farms are generating incomes that are often superior to those of far larger, entrepreneurial farms. (2 and 11)

The persistence of smallholder forms of household production in many countries of the developing world parallels chronic agrarian crises of food, labor, and land characterized by food riots, rural displacement and rising income inequalities (Bello 2009; Holt-Jimenez et al. 2009). Researchers and activists have pointed out key vulnerabilities in the conventional paradigm of neoliberal agricultural development, calling into question the project's worth as a model for the millions of resource poor farm households in the global south. This has dovetailed efforts by transnational agrarian social movements of rural workers and farmers, as well as food-system advocates, informed consumers and progressive nongovernmental organizations, in the revival, adaptation and creation of new models of agricultural development which challenge the conventional, historical relations between capital, nature and agriculture (McMichael 2004). Increasingly, sustainable agriculture and access to alternative, value-added food networks like Fair Trade have been promoted as measures that can reduce producer vulnerability to increasingly common shocks like natural disasters and price crises (Holt-Gimenez 2002; Bacon 2005; Méndez et al. 2006).

While a body of research evaluating farm-household experiences with these types of programs does exist, the number of programs and agricultural systems evaluated to date is extremely low compared to the great diversity of smallholder agricultural systems and the sheer magnitude of both alternative marketing initiatives and potential sustainable agricultural practices. Identifying the circumstances and strategies that explained the SG's persistence in coffee contributes to our understanding of the conditions under which landscape conservation and grassroots rural development are compatible in the coffee highlands of the world.

This research finds pivotal the role played by Costa Rican governmental institutions in a successful agroecological transition that reduced external input costs. This is significant because the process took place amid the backdrop of "roll-back neoliberalism" characterized by privatization and declining state involvement in the provision of services. With no market, not even a "fair" one, able or willing to provide the training and unique resources these smallholders needed, the state not only stepped in, but was successful according to the results of this study. With innumerable environmental, social and economic spillover effects of this transition process accruing at several scales, the results of this study argue for the creation or redirection of state-led institutions with the power and support to conduct agroecological research and training, especially in the detechnification transitional process to low-external input agriculture. A final related conclusion drawn by this research is that when thinking about possible interventions or solutions to agricultural development crises, the promotion of agroecological practices that cut costs may be more effective than those approaches that focus on enhancing yields or establishing price supports.

NOTES

1. In Table 2, a Welsh's one-way analysis of variance test was utilized to compare land use means between the groups. A Welsh's test was chosen over a standard *T* test because it allows the unequal variances as well as nonequal standard variations that characterize this dataset.

2. Percentages given in this section correspond to the average area per group dedicated to particular land uses in the given year divided by the average farm-size per group in the given year.

3. Percentages given in this section simply correspond to the 2000 percentages minus the 2009 percentages for each group.

4. Tests of statistical significance and calculations of standard errors were performed by JMP (JMP, Version 9. SAS Institute Inc., Cary, NC 1989–2010). All tables and graphs were produced in MS Excel.

5. Generated using the Sobs (Mao Tau) function of EstimateS 8.2.

6. This variation meant that sample-based species accumulation curves were measures of species density instead of species richness. Curves were transformed to feature individuals instead of quadrants as the x-axis unit of measure using the Coleman rarefaction function of EstimateS 8.2 (Gotelli and Colwell 2001).

7. The Michaelis Menten (MM) richness estimator function of EstimateS 8.2 was utilized.

8. Both the figure and the chi-square test were elaborated using a spreadsheet-based abundance curve calculator tool developed by Dr. James A. Danoff-Burg and X. Chen from Columbia University. The chi-square test evaluated whether the distributions conformed to any of the four most common species distribution models, (geometric, log series, log-normal, and broken stick). This tool can be downloaded from: http://www.columbia.edu/itc/cerc/danoffburg/Biodiversity%20Calculator.xls

9. Species diversity indices were calculated with the software package R2.12.2 (Team 2011).

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