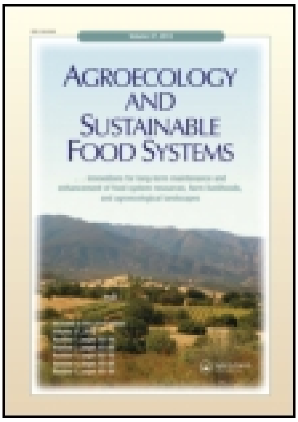

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Conventional Food Plot Management in an Organic Coffee Cooperative: Explaining the Paradox

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This research analyzes farmers' motivations for conventional management of subsistence food crops, in contrast to organic management of coffee destined for export. Semistructured interviews, focus groups, and financial analyses were conducted with farmers from a small organic coffee cooperative in western El Salvador. We sought to identify what factors have motivated peasant farmers to manage subsistence crops, primarily maize and beans, with agrochemicals. We found that a combination of environmental, economic, social and political factors have driven agricultural management decisions. The environmental requirements of coffee are distinct, where coffee in a diverse shaded agroecosystem responds better to low-input management than maize grown on steep slopes in nutrient-poor soil. In addition, there are no direct economic incentives for subsistence farmers to manage food crops organically, while the benefit of a price premium does exist for organic coffee. Finally, institutional support for agriculture encourages organic production for export crops and generally overlooks subsistence farming. Our data show that half of the farmers lost money on their food plots, with agrochemicals representing the largest cost. This research suggests that small-scale

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farmers need support in transitioning to more economically and environmentally sustainable farming practices.

KEYWORDS subsistence agriculture, agrochemicals, maize, agroecology, Central America

INTRODUCTION

Since the 1960s international agencies, such as United States Agency for International Development (USAID) and the World Bank, have promoted large scale export agriculture in Latin America (Stonich 1993). Many governments have also supported export crop production over subsistence agriculture in order to build foreign exchange, a pattern that has encouraged larger scale agriculture and consolidation (Ehrlich et al. 1993). The replacement of domestic subsistence production with high value export-oriented ventures was promoted through much of Latin America in the 1980s (Perez et al. 2008), prompting many farmers to shift their production orientation. These policies have undermined food sovereignty, increased the vulnerability of small-scale farming households (Altieri and Toledo 2011), and left most peasant farmers without access to credit or technical assistance for subsistence farming (Thrupp 1990; van Heijningen 2000).

In El Salvador, the expansion of coffee production beginning in the 1920s resulted in export crops replacing crops to feed the local population—evident in today's agricultural landscape (Rice 2003). Although institutional support for agriculture has shifted toward large-scale export crop production, many rural households throughout Central America continue to grow staple crops (e.g., maize, beans, and rice) for household consumption. One common arrangement for many peasant farmers is to grow both subsistence crops for consumption and export crops for sale, in an effort to participate in agricultural markets, while still maintaining some control over their food production (Isakson 2009).

Maintaining both subsistence crops and coffee requires farmers to divide their labor, land, and other resources between two agricultural activities (Steinberg and Taylor 2009). In order to maximize efficiency and yields, some small-scale farmers choose to utilize agrochemicals for food production even when producing an organic crop for export, despite their extremely limited income. Poor farmers may buy pesticides on credit to avoid the risk of losing their crop (Dinham 2003), and in some cases banks require farmers to use agrochemicals in order to receive formal credit (Thrupp 1990).

This seemingly paradoxical situation, in which farmers produce organic crops for export alongside subsistence food crops managed with agrochemicals, is problematic both in terms of the conservation value of the "organic" farming system and the livelihoods of the farmers involved.

Organic shade coffee in particular has been praised for its biodiversity conservation value, but its conservation potential may be limited if management of the broader landscape contributes to environmental degradation, such as the potential impacts of agrochemical runoff (Bray et al. 2002). Additionally, the extra income provided by export crops may not improve overall quality of life if it is used to purchase agrochemicals for subsistence crops.

We are not aware of any studies that have addressed the role of agrochemicals for smallholder coffee farmers who balance subsistence farming with export production. Understanding how farmers assess the costs and benefits of different management practices can guide programs that support farmer livelihoods and environmentally sustainable agriculture. This case study analyzes the multitude of considerations that small-scale Salvadoran farmers face in their dual management of organic coffee and conventional food crops. In particular, we address three questions: 1) Why do farmers use agrochemicals in their subsistence crops while growing coffee organically? 2) Why do farmers continue to grow maize and beans alongside their coffee crop? 3) What barriers exist to using more agroecological methods for subsistence crops? These questions are relevant for attaining both a more sustainable agriculture and food security in the developing world, where contradictions persist in the management and environmental impacts of different types of agricultural crops.

STUDY SITE

We conducted research with the 29 members of the coffee cooperative, Asociacion de Caficultores del Occidente de El Salvador, or Association of Organic Coffee Producers of Western El Salvador (ACOES), in the municipality of Tacuba in western El Salvador. Tacuba (population 30,000) is located 18 km from Ahuachapan, the nearest medium-sized city (population 110,000) and 188 km northwest of San Salvador. ACOES farms are located between 3 and 10 km from the town of Tacuba in a rural setting, lacking paved roads and regular access to water and electricity. Access to the town of Tacuba is by a steep, dirt road that can be impassible by vehicle during heavy rains and mud. No ACOES households owned vehicles, and there was no regular vehicle service between Tacuba and the communities where ACOES farmers lived. Altitudes in the region range from 600 to 1400 m above sea level, with a rainy season between May and October. The natural vegetation of the region is classified as Holdridge life zone 4,[1] or humid subtropical forest (Holdridge 1987; Ministerio de Medio Ambiente y Recursos Naturales 2003). The ACOES cooperative is comprised of two smaller cooperatives, one comprised of 19 farmers who collectively own and manage a 35 ha coffee farm and the other comprised of 10 farmers who individually own and manage small coffee plots but do not have ownership of the collective farm. In both cooperatives, the farmers managed their subsistence plots individually, apart from the coffee. We chose to work with this cooperative because we have been involved with the farmers in a 13-year participatory action research process (Bacon et al. 2005; Mendez 2008; Mendez et al. 2010). We believe that the mutual trust built throughout this relationship yielded more thorough and candid responses.

ACOES coffee is shade grown and organically managed, which has been shown to conserve biodiversity, enhance the quality of the coffee and provide farmers with a variety of products, such as fruits, firewood, and timber (Perfecto et al. 2005; Mendez et al. 2007; Mendez et al. 2009). Coffee sales accounted for approximately half of household income on average, with the remaining income from working as a day laborer on another farm, selling food or goods locally, or provided by children who had migrated to nearby cities for work (Morris et al. 2013). In addition to coffee, all households in the cooperative maintained subsistence plots of maize (*Zea mays*) and beans (*Phaseolus vulgaris*), which are staples in their diet. Some farmers also produced vegetables such as tomatoes and peppers for consumption and local sales. Intercropped maize and bean plots, called *milpa*, were located some distance from the home, separate from the coffee, and usually on steep slopes. Nearly all agriculture in the area, including coffee production, is on hillsides. The majority of the 29 farmers surveyed owned land for maize and bean farming (83%), acquired by most during the 1980s land reforms. Four of the farmers who owned land for milpa also rented an additional plot, and five farmers grew maize and beans exclusively on rented land. The mean size of land used by each farmer exclusively for food crops, including land both owned and rented, was 0.58 ha. Most households of the cooperative owned some small livestock, including chickens, ducks, and rabbits that were kept at the home; only one household owned large livestock (a single horse).

Beginning in the early 1980s, many farmers began to manage their personal food plots using chemical fertilizers and pesticides to produce higher yields with lower labor investments. Although the cooperative has received support for managing coffee organically, few projects have addressed the potential for organic food crop management (i.e., maize and beans). Previous work with this coffee cooperative revealed that nearly all farming households experienced annual periods when they were unable to meet their family's basic food needs, despite using agrochemicals and having diverse sources of food and income. Farmers cited insufficient food crop yields, lack of available work, and the high cost of food and other goods as reasons for facing periods of hunger each year (see Morris et al. 2013). In past focus groups, most farmers also agreed that the high cost of agrochemicals used to produce food was a major factor limiting their food security. Although farmers adopted conventional management techniques for their food crops in an attempt to achieve greater food security through higher yields, they have continued to face food shortages and contend with the added financial burden of purchasing chemical inputs.

RESEARCH METHODS

Our research combined quantitative and qualitative methods and examined the environmental, political, historical, economic, and social factors motivating particular agricultural management practices.

Semistructured Interviews and Focus Groups

We conducted semistructured interviews with all 29 cooperative members in August 2009. Interviews lasted between 2 and 3 h and were conducted in Spanish with each member of the cooperative, which in 28 of 29 cases were males. Questions were primarily qualitative and covered historical information including why and when farmers began using chemicals to manage food plots; how they managed nutrients, weeds, and pests before using agrochemicals; how they first learned about chemical products; and how chemical product prices, quantity used, and crop yields have changed over time. Other questions focused on current management practices, including how farmers determine the frequency and quantity of chemical applications (including whether farmers spray pesticides preventatively or in response to pests); farmers' perception of the advantages and disadvantages of agrochemicals; environmental, and health effects from chemical use; and awareness of organic management techniques. Qualitative data were translated from Spanish to English and coded by theme and topic.

We conducted two full-day focus groups at the end of the data collection period to discuss results, both in individual terms and in terms of group trends. Farmers had the opportunity to ask questions about the results of their economic analyses and discuss their reactions as a group. Where farmer names are included below, only first names are given to maintain confidentiality.

Economic Analysis

We also collected quantitative data on current food crop management practices, comparing economic expenditures and the value of maize and beans produced during the 2008 growing season (see below for formula). An individual economic analysis of food crop production was performed for each of the cooperative members in order to determine if farmers were breaking even under current management practices.

Gross crop value was based on reported maize and bean yields for 2008 (converted to kilograms) multiplied by the price per unit of each of the two crops (average prices reported by all respondents were \$0.16/lb and \$0.57/lb for maize and beans, respectively). Farming costs encompassed the amount spent on chemical inputs including all fertilizers, herbicides, and insecticides; paid labor (number of worker days times \$6/day[2]); seeds; transportation of chemicals or harvested crops; and land rental. Cost of seeds and rented land were based on farmer reports, and prices of agrochemicals were reported by each farmer and also verified at three different local suppliers. The following calculation was used to determine net crop value:

net value of crops = (yield of maize*\$0.16/lb) + (yield of bean * \$0.57/lb)− (quantity fertilizer * fertilizer cost per unit) − (quantity herbicide * herbicide cost per unit) − (quantity pesticide * pesticide cost per unit) − (paid labor days * \$6) − (total cost of seeds) − (total cost of rented land) − (total cost of farming-related transportation).

One third of farmers grew a small amount of vegetables, such as tomato and peppers, in addition to maize and beans. The value of these crops was not included in calculations because the quantity produced and sold was generally very small. Opportunity costs for labor were not included for two reasons: Most farmers had difficulty recalling the exact number of hours they and their families had worked, and paid labor was not readily available locally, so unpaid work did not represent a lost opportunity. A rough estimate of labor opportunity cost is reported (hours invested in food production multiplied by average daily wage) as a point of reference; however crop values were generally considered without farmer and family labor costs.

Statistical Analysis

The statistical analysis explored relationships between agricultural management practices, land tenure, and maize yield. Pearson's correlation was used to test relationships between maize yield and fertilizer and herbicide application per hectare (Table 1). Bean yields were excluded from statistical analysis because they were unusually low in the year of our research due to heavy rains, and because maize was the crop of primary importance. Fertilizer use per hectare was calculated for each farmer by adding total kilograms of nitrogen applied in each of the two fertilizers used (16-20-0 and ammonium sulfate).[3] Because a total of nine different insecticides were used with different target pests and active ingredients, we used total expenditures on insecticides per hectare as the variable to determine if greater insecticide expenditures affected maize yield per hectare. Since 27 farmers of the cooperative applied the same herbicide (Gramoxone, a broad-spectrum, nonselective herbicide), we analyzed the effect of quantity of Gramoxone

TABLE 1 Variables tested through Pearson's correlation to assess effects of agrochemicals on maize yields in Tacuba, El Salvador

Dependent variables	Independent variables
Maize yield- kg/ha	Quantity of herbicide applied (L/ha)
	Quantity of fertilizer applied (kg N/ha)
	Total expenditure on insecticide ($/ha)
	Total expenditure on all agrochemicals ($/h)

TABLE 2 Summary of agrochemical use, by percentage of farmers who applied each category of product and total average expenditure

	% Farmers	Total average expenditure for all users
Fertilizer	97%	$173
Herbicide	97%	$29
Insecticide	93%	$16
		$218

applied per hectare on maize yield per hectare. We also tested the relationship between total expenditures on agrochemicals and maize yield. Results from one of the 29 respondents were omitted for suspected inaccuracy; for all quantitative data below, $n = 28$.

RESULTS

Key Inputs and Outputs of the Milpa Agroecosystem

Fertilizer

Synthetic fertilizer represented the largest cost in maize and bean production. Ninety seven percent of farmers in the cooperative used fertilizer (Table 2); all 97% used a fertilizer formula containing 16-20-0 of N-P-K, and 90% used ammonium sulfate. An average of 661 kg/ha of 16-20-0 and 378 kg/ha of ammonium sulfate were applied in either one or two applications. Including both fertilizers, an average of 185 kg of Nitrogen was applied per hectare.

Herbicides

In terms of labor efficiency, farmers commented that chemicals work quickly and minimize labor requirements. Farmers noted that herbicides had significantly reduced the amount of time they spent weeding the milpa. Ninety seven percent of respondents used at least one herbicide to weed (Table 2), with a total of four different herbicides reported among the study group (Table 3). Many farmers

TABLE 3 Agrochemicals used for food crop production in the coffee region of Tacuba, El Salvador

Product	Description/ Purpose	Active ingredient	% farmers	Avg. quantity applied	Avg. applied per ha	Active ingredient applied per ha	Recommended application rate (kg ai) for maize
Fertilizer							
16–20–0 formula	Nitrogen fertilizer	16% N by weight	97%	190 kg	661 kg/ha	106 kg N/ha	} 150 kg N/ha
Ammonium suttate	Nitrogen fertilizer	21% N by weight	90%	128 kg	378 kg/ha	79 kg N/ha	
Herbicide							
Paraquat/ Gramoxone	Broad spectrum	Paraquat dichloride- 21bs/gallon	90%	3.2 litres	5.92 L/ha	1.41 kg ai/ha	1.12 kg ai/ha
Atrazine/ Gesaprim	Broadleaf, grassy weeds	Atrazine- 90g/kg	52%	2.7 kg	4.21 kg/ha	0.379 kg ai/ha	1.5 kg ai/ha
Hedonal	Phenoxy herbicide for broadleaf weeds	2–4 Dichloro phenoxyacetic acid- 40 g/L	21%	2.8 litres	4.15 L/ha	0.166 kg ai/ha	0.08–0.12 kg ai/ha
Glyphosate/ RoundUp	Broad spectrum	Glyphosate (N-(phosphono methyl) glycine) -360 g/L	7%	2 litres	2.86 L/ha	1.02 kg ai/ha	1.68 kg ai/ha
Insecticide							
Marshal	Broad spectrum carbamate insecticide/ miticide/ nematicide for white grubs	carbosuttan 5G	59%	48 g	119 g/ha	5.95 g ai/ha	0.5–1 kg ai/ha
Parathion/ Folidol*	Broad spectrum organophosphate insecticide	methyl parathion or dimethyl parathion (450g/L)	17%	1.4 litres	2.76 L/ha	1.24 kg ai/ha	Recommended application information not available

(*Continued*)

TABLE 3 (Continued)

Product	Description/ Purpose	Active ingredient	% farmers	Avg. quantity applied	Avg. applied per ha	Active ingredient applied per ha	Recommended application rate (kg ai) for maize
Counter	Broad spectrum organophosphate insecticide/ nematicide for wireworms	Terbufos (S-[[(1,1-dimethylethyl)thio [methyl]O,O-diethyl Phosphorodithioate) 150g/kg	14%	2.27 kg	5.86 kg/ha	0.88 kg ai/ha	1.95 kg ai/ha
Tamaron	Foliar insecticide for chewing/ sucking pests	O,S-dimethyl phos-phoramidothioate - 600g/L	14%	1.5 litres	1.91 L/ha	1.15 kg ai/ha	Recommended application information not available
Volaton	Organophosphate insecticide for soil pests	Phoxim 2.5%	10%	1.27 kg	8.36 kg/ha	0.21 kg ai/ha	Recommended application information not available
Malathion	Organophosphate insecticide/ acaricide	Malathion 1000; (O,O-dimethyl phosphorodithioate of diethyl mercaptosuccinate)	7%	1 litre	1.91 L/ha	1.91 kg ai/ha	0.5–1 kg ai/ha

Lannate	Broad spectrum insecticide for worms	Methomyl 90% (2.4 lbs/gallon)	7%	0.142 kg	0.263 kg/ha	0.237 kg ai/ha	0.25–0.35 kg/ha
Caracolex	Carbamate molluscucide	Metaldehyde, Methomyl, Methiocarb (5.95%)	7%	2.27 kg	3.9 kg/ha	0.23 kg ai/ha	0.38–0.595 kg ai/ha
Rienda	Pyrethroid/ organophosphate insecticide for armyworm	Deltamethrin (12 g/L), Triazophos (200 g/L); 21.2%	7%	2 litres	1.38 L/ha	16.56 g Deltamethrin/ ha; 276 g Triazophos/ha	3–6 g Deltamethrin/ha; 50 g Triazophos/ha

Notes: Pesticide averages are given for those farmers that used each product, not for all farmers in the cooperative.
Chemicals whose average application rate is more than double the recommended rate for maize are highlighted.
Recommended application rates were obtained from agrochemical company websites.
*An extremely toxic pesticide, parathion has been banned or limited in many countries.

made several applications of herbicide throughout the season, with the most important application before maize planting, followed by another application before bean planting in early September.

Insecticides

There was more variety in the insecticides used by respondents than with fertilizers and herbicides, with a total of nine different insecticides used by cooperative members (Table 3). One quarter of growers noted that pests including slugs, beetles, and worms had become more prevalent since introducing synthetic fertilizers to their food plots. Ninety three percent of farmers used at least one insecticide (Table 2), 52% used at least two different insecticides, and 5% used three or more different insecticides. For most products, the average amount of active ingredient applied did not exceed recommended application rates. In the case of Rienda insecticide, the average application rate exceeded the rate recommended for maize (Table 3); however, this does not account for the exact circumstances of application, including number of applications and timing. Overall, results did not indicate that farmers were significantly over-applying agrochemicals as compared to recommended rates of application for maize.

Crop yield

In 2008, average maize yield was 1283 kg/ha (with a range of 622 to 2904 kg/ha), less than half the national average of 2943 kg/ha for the same year (Ministerio de Agricultura y Ganaderia, El Salvador [MAG] 2012). On average, farmers produced 172 kg/ha of beans (max = 778 kg/ha, min = 0), which is significantly lower than the national average of 886 kg/ha for the same year (MAG 2012) (Table 4). Farmers indicated that yields vary considerably from year to year based on rainfall, extreme climatic events, and family circumstances; 2008 was a particularly bad year for bean yields in western El Salvador due to unusually heavy rains.

Maize yield was weakly correlated with fertilizer application and spending on agrochemicals; neither correlation was significant at a p value of 0.05 and only agrochemical spending was significant at a p value

TABLE 4 2008 average fertilizer use and maize yield for ACOES farmers versus El Salvador national data

	ACOES farmer average	El Salvador average
16–20–0 fertilizer use/ha	661 kg	276 kg
Ammonium sulfate fertilizer use/ha	378 kg	289 kg
Maize yield/ha	1474 kg	2943 kg

Source: Salvadoran Ministry of Agriculture (2010).

TABLE 5 Correlation between agrochemical use and expenditure, and maize yield per hectare

Agrochemical variable	Pearson's r	*P*/significance
Fertilizer (N) per hectare	0.298	.124
Total agrochemical expenditures/ha	0.319	.098
Total liters of Gramoxone/ha	−0.011	.954
Total spent on insecticides/ha	−0.094	.634

of 0.10 (Table 5). It is likely that there is some relationship between agrochemical use and yields; nearly all farmers reported that maize and bean yields increased significantly when they began to apply chemical fertilizer. However, the relationship is likely confounded by other factors potentially affecting crop yields including seed type and biophysical characteristics such as slope and soil type (Pender and Gebremedhin 2008). Research conducted at this site in 2009 showed that maize yields were highly negatively correlated with slope (Olson et al. 2012). Fertilizer application and seed type (hybrid vs. criollo) were both correlated with yield at a p value of 0.05, but these relationships were not significant when slope was controlled for, even at a p value of 0.10 (Olson et al. 2012).

Main Factors Driving Land Management Decisions

There were three main drivers motivating farmers to manage food crops conventionally: 1) social/political factors; 2) economic factors; and 3) environmental factors. These are summarized in Table 6 and discussed in detail in the following sections. Important management decisions for farmers included whether to use chemical products, which products to use, timing of application, quantity to apply, and whether to purchase and use safety equipment. Nearly all farmers applied synthetic fertilizer, herbicide, and insecticide on their food plots (Table 2). Most farmers followed roughly the same schedule each year. In early May, land was cleared of crop residues and the first round of herbicide was sprayed to prepare for planting. Maize was planted in mid-May and fertilized in June, with both 16-20-0 and ammonium sulfate.

TABLE 6 Main factors driving land management decisions for ACOES farmers

Sociopolitical	Economic	Environmental
Witnessing initial yield increases	Cost of chemicals	Distinct growing conditions
External support	Efficiency/ convenience	Depleted soils
Risk avoidance	Markets/price premium	
Land tenure		

Herbicide was applied a second time in mid-August to prepare for a late-August planting of beans. Maize was dried on the stalk in early November, and maize and beans were harvested in early December and stored in small silos inside the home. Many farmers sold a small amount of maize at harvest time when they were in need of cash, even though prices tend to be low at that time. Three quarters of farmers in the cooperative had to buy additional maize and beans for household consumption, generally starting in June or July when stored grains from the December harvest had run out. The average household spent an additional \$131 annually to buy maize and \$87 for beans.

SOCIAL AND POLITICAL FACTORS

Historical Process Leading to the Adoption of Agrochemicals

Most farmers began using chemical fertilizer and herbicide in the early 1980s. Several of the oldest farmers in the cooperative remembered when chemicals first became available. Daniel remembered seeing trucks full of chemical fertilizer coming to the larger farms in town and noticing that their yields started to increase. Among the 41% of farmers who noted the visible effects of chemicals suddenly available in the area ($n = 22$), Ricardo recalled, "People started coming to town and telling us how good the products were, and we saw that they worked well."

Many farmers indicated that their knowledge of management practices, pests, and agrochemicals came from neighbors and family members. Farmers gave a variety of explanations for beginning to use chemicals on food plots, including low maize yields and poor quality soils (55%), and efficiency and effectiveness (41%) ($n = 22$).

External Support

Farmers had received agricultural support from a variety of national organizations, including the Salvadoran National Center for Agricultural, Livestock and Forestry Technology (CENTA), the Salvadoran Foundation for Coffee Research (PROCAFE), and the Foundation for Socioeconomic Development and Environmental Restoration (FUNDESYRAM), as well as international aid agencies including Catholic Relief Services (CRS) and Cooperative League of the United States of America International (CLUSA). The majority of governmental and nongovernmental support has focused on improving coffee production, with an emphasis on organic compost, and generally overlooked production of staple food crops. One ACOES member, Francisco, noted, "Institutions only support us in organic coffee management, not in food crop management. They only give you a certain amount [of compost]-2 pounds per plant-based on the size of your coffee plot, so there is not enough for the food plot. It's a problem."

The small amount of external support farmers have received in recent years for food production has placed emphasis on conventional techniques. For example, El Salvador's Agricultural Ministry promotes the use of hybrid corn and bean varieties and provides specific guidelines on the dose and timing of application for a variety of herbicides, insecticides, and fungicides (MAG/CENTA 2011). The promotion of conventional food production by governmental agencies and non-governmental organizations has contributed to farmers' belief that synthetic fertilizers and pesticides are necessary to produce maize and beans.

Risk Avoidance

Many farmers were motivated to continue using agrochemicals once they had begun because they were unwilling to risk a potential yield reduction of essential food staples (78%, $n = 9$). Hernan expressed that, "If there were another way I would do it, but it would have to produce results. If it were possible to fertilize the maize in another way, we would stop using chemicals. But we are stuck with chemicals."

Willingness to experiment with agroecological methods may, therefore, depend on a farmer's individual comfort with risk, and the chance to witness alternative methods before trying them.

Responses indicated that concern for health effects did not affect farmers' use of agrochemicals. Although 63% commented that chemicals are bad for their health ($n = 19$), this did not motivate farmers to wear protective equipment or to discontinue chemical use.

Land Tenure

Land tenure was another factor that affected how farmers managed their plots; 9 out of 29 farmers in the cooperative rented land for food crop production in 2008. Several respondents used agroecological practices on their own parcels but not on their rented parcels. Faustino had planted live barriers of yucca around the boundary of his own parcel to minimize erosion but had not invested in erosion prevention in his rented parcel. He admitted to not practicing conservation on his rented land because of insecure land tenure. Similarly, Manuel managed his own parcel using organic compost when possible and his rented parcel completely with conventional methods. He said, "I appreciate the land that is mine, to maintain a fertile layer of soil. But the rented parcel- what good does it do me to treat it well? If I treat it well the owner will want it back."

Despite these observations, the mean amount of money spent on all chemical inputs was not significantly different between farmers who rented land and farmers who owned all of their land.

ECONOMIC FACTORS

Cost of Agrochemicals

Although most farmers had never calculated their total farm expenses or compared them with crop value, economic factors weighed heavily in food crop management decisions. Several farmers indicated that they determined what chemicals to use based on cost and that they applied the greatest quantities of fertilizer and herbicide they were able to afford. Economic considerations also determined the method of chemical application, including diluting chemicals so that they would spread further. All 16 farmers who responded to the question "How has the price of chemicals changed since you began using them?" said that the price had risen. Many respondents added that the price increase had caused them to limit their chemical use, despite feeling that they should apply more. Some commented that they used to receive bank credit to directly buy chemical inputs but that this is no longer available.

Our analysis showed that 14 out of 28 farmers[4] (50%) lost money on their food plots in the 2008 growing season. Including opportunity cost, 69% of farmers lost money on food crops. The average amount spent on all aspects of crop management, not including opportunity cost, was $359, resulting in an average net gain of $12 (Table 7). An average of $218 was spent on agrochemicals (Table 3), accounting for 61% of farm expenses. Paid labor represented another substantial expense, an average of $107, mainly for planting and harvesting maize and beans. Seeds did

TABLE 7 Summary of farm management and household characteristics of ACOES farmers, in Tacuba, El Salvador; agrochemical use and cost and yield data are per hectare

	Minimum	Maximum	Mean	Standard dev.
Milpa size (ha)	0.04	1.2	0.58	+/−0.36
Household income (US$/yr)	0	9680	2037	+/−2050
Fertilizer use (kg/ha/yr)	16	1429	851	+/−1664
Fertilizer cost (US$/ha/yr)	33	7318	583	+/−1346
Herbicide use[a] (L/ha/yr)	0	17	7	+/−4
Herbicide cost (US$/ha/yr)	0	150	53	+/−38
Insecticide cost[b] (US$/ha/yr)	0	215	50	+/−59
Total agrochemical cost (US$/ha/yr)	85	7581	672	+/−1378
Total farm expenses (US$/ha/yr)	251	7856	1118	+/−1788
Maize yield (kg/ha/yr)	622	2904	1283	+/−637
Bean yield (kg/ha/yr)	0	778	172	+/−188
Value of crops produced (US$/yr)*	45	1142	371	+/−280
Net gain from maize and bean production (US$/yr)*	−297	416	12	+/−198

*Crop value and net gain are totals for each farmer/household, not per hectare.

[a]Measures liters of Gramoxone per hectare, which was used by 27 out of 29 farmers. The other three herbicides used were not included because they were less commonly applied.

[b]Insecticide use per hectare was not included in the table because the nine insecticides used contain different active ingredients. Insecticides are instead reported in cost per hectare.

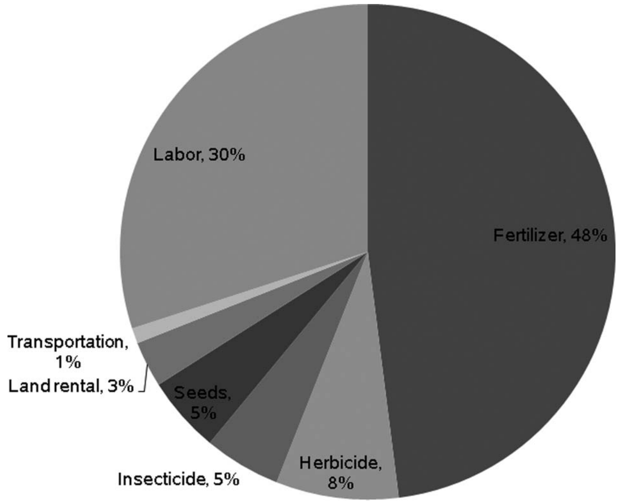

FIGURE 1 Average percentage spent on different aspects of food crop management. Agrochemicals represent 61% of the total cost.

not represent a major expense since most farmers used a combination of saved seeds and "improved seeds" donated by the government (Olson et al. 2012). Other minor expenses included rented land ($11; 9 farmers rented land) and transportation of inputs or crops ($5; 8 farmers paid transportation) (Figure 1). The average gain of $12 indicates that most farmers were barely breaking even given their current crop management practices and yields. Average household gross income in 2008 was $2037,[5] meaning an average of 18% of household income was spent on annual food crop production (not including long-term investments), most of which was spent on agrochemicals.

Focus groups provided an opportunity for members to discuss these results. Most producers had never before seen calculations outlining all of their farm expenses and the economic value of the crops produced. Many expressed surprise and frustration to discover they were losing money or just breaking even by growing food crops under current management practices. Farmers focused the discussion on potential ways to minimize the cost of inputs and the possibility of practicing organic or semi-organic management in the future.

ENVIRONMENTAL FACTORS

Environmental protection was generally not a major consideration for farmers in their crop management decisions. Although many farmers were aware of negative environmental effects of chemicals, this did not motivate them to change their practices. The main environmental impacts of agrochemical use observed were greater incidence of pests and disease, weakening of soils and nutrient loss, and the chemical residue that remains on the plant and in the soil.

Biophysical Factors

The biophysical requirements of maize and bean production help explain why farmers had not transferred organic practices from coffee to milpa production. When asked why they managed coffee organically and food crops conventionally**,** 67% of respondents explained that shaded coffee grows well organically while maize and beans grown in full sun require chemicals ($n = 9$). This is particularly true for improved hybrids (approximately 25% of milpa plots) (Olson et al. 2012), which have been bred specifically for high yields based on synthetic fertilizer inputs. Marcial noted, “In the milpa if we don’t spray chemicals it doesn’t produce. With coffee, it produces plenty with organic foliar fertilizers.”

Farmers used a system on coffee farms, called *cajuelas,* to make small amounts of organic compost at the base of each coffee plant or group of plants. Farmers dig small holes at the base of the plants and collect fallen leaves, fruit, and other organic matter from shade trees. The cajuelas collect rainwater which helps decompose organic matter and provide nutrients to the coffee, providing organic compost on site. In contrast, maize and beans grown in full sun contribute very little organic matter or nutrients to the soil. Nitrogen is a key limiting factor for maize production and usually needs to be added to the system, given that two thirds of nitrogen is removed in the harvest often leading to a negative nitrogen balance (Sanchez and Palm 1996). Intercropping with beans provides some nitrogen, but the bean crop is harvested for food which removes nitrogen and carbon from the system. Thus, maize requires soil amendments and/ or fallow periods for soil nutrients to regenerate. Many farmers observed that soils have become “tired” or “washed” after years of continuous cropping, and without the addition of soil organic matter and essential micronutrients.

DISCUSSION

Our results suggest that a variety of factors explain the continued use of agrochemicals in milpa production by ACOES farmers, including lack of support for alternative methods, risk aversion, economic considerations, and environmental factors. We found that economic considerations weighed heavily in food crop management decisions. Economic constraints often determined how, when, and which chemicals were applied (Galt 2009). However, farmers did not keep written records of their farm expenses so they were not aware of their costs and crop value until participating in this research. Half of cooperative farmers spent more money on staple crop farming than the value of the crops produced. A study of Zapotec villages in Mexico similarly showed that the cost to produce maize was only slightly less than the cost to buy it (without accounting for opportunity costs) (Jaffee 2007). The economic value of food crops would further decrease if opportunity costs were included in the total cost calculation. Our economic analysis showed that expenditures on fertilizers represented the greatest crop management cost.

Although ACOES farmers applied more than twice the quantity of 16-20-0 fertilizer than the national average for maize in 2008 (661 vs. 276 kg/ha), and more ammonium sulfate than the national average (378 vs. 289 kg/ha), their maize yields per hectare were roughly half the national average (1474 vs. 2943 kg/ha) (MAG 2012).[6] Several possibilities exist to explain the relatively low maize yields in our study. Maize yield varies based on climatic factors, seed variety, and management practices including the use of soil amendments (FAO and CIMMYT 1997; Mkhabela et al. 2001). Parallel research in our study site showed that slope, rather than fertilizer application or any other variable, was the strongest predictor of maize yield (Olson et al. 2012). This suggests potential to improve maize yields through soil conservation practices, rather than agrochemical products. Many farmers noted that maize yields had initially increased with fertilizer application but over time had leveled off or decreased. This is most likely due to low soil organic matter, because farmers have relied on synthetic nitrogen fertilizers for soil fertility. Several farmers also noted that pest pressure had increased since they began applying inorganic fertilizer and herbicide. This has also been observed in the United States, where reliance on agrochemicals and monocropping has led to increased pest pressure (Rosset and Altieri 1997).

An additional economic consideration for farmers is the lack of an organic price premium for grains. Since most maize and beans were grown for household consumption, organic premiums were not applicable as they were for coffee. For those that did sell grains and vegetables locally, market premiums were not available for organic products. The market for organic produce within El Salvador continues to be quite undeveloped, providing farmers with little direct economic incentive to grow staple crops organically (MAG 2008). This is true in many developing countries, where organic farmers often have difficulty identifying and reaching local markets for organic produce (Dinham 2003). Without the organic price premiums farmers receive for export crops including coffee, they may see no economic incentive to organically produce food crops for household consumption or local sale. However, this represents a contradiction, since changing practices could potentially reduce costs and increase production and economic gain.

Farmers continued to dedicate resources (land, time, money) to subsistence farming, and to manage crops with agrochemicals, despite the fact that it was not economically viable, indicating that farmer's rationalities were not limited to pure economics. Our research is consistent with findings in Mexico, Costa Rica, and Guatemala showing that, in addition to economic considerations, political, social, cultural, and environmental factors also affect land management decisions (Ponette-González 2007; Galt 2008, Isakson 2009). Under purely economic considerations, it would seem irrational for the coffee farmers in this study to continue milpa production using conventional methods, given that in many cases it is a net loss. However, beyond economic rationality a number of other possibilities exist to explain why ACOES farmers continue to manage milpa in addition to their export coffee crop. Max Weber's (1947) categorization of substantive rationality, which is based on values, and formal rationality, which entails economic logic, is useful to help explain this behavior. In addition to capitalist logic, individuals and groups are also driven by social, cultural, and political values and considerations. In our particular case, where much of the analysis had an economic and capitalist oriented bent, the question remains if the farmers perceived this as an imposed "rationality," but accepted it because it represents the more socially accepted and formal way of analyzing issues. Our focus groups did not clearly reflect a reaction against this, but rather a sense of inadequacy towards knowing how to perform this "formal" analysis. This represents an interesting area for further research in the future.

Bernal (1994) addresses the complexity of peasant motivations with regard to subsistence production and market agriculture, and the inherent interconnectedness of market-oriented and non-market agriculture. Although ACOES milpa farming is integrated into the market economy through the purchase of chemical inputs and the hiring of labor, a combination of formal (capitalist) rationality and substantive (non-market) rationality can help explain their motivations for growing maize (Mooney 1988). Focus groups and informal discussions with ACOES farmers suggest that maintaining the cultural tradition of maize production is one key motivation for these farmers. Similarly, Ponette-Gonzalez's (2007) research with Mexican coffee and maize producers showed the cultural importance of maize production, and Isakson (2009) found that Guatemalan peasant farmers maintained the culturally important act of household food provisioning to complement their cash crop production.

Another consideration for ACOES farmers is that keeping control of their food production helps minimize food insecurity. Although most households faced seasonal food shortages, they minimized the risk of household hunger by growing their own food, and used chemical fertilizers to produce the greatest possible amount of food. These findings are in line with research showing the importance of food sovereignty for smallholder farmers in the developing world (Altieri and Toledo 2011). Other reasons preventing ACOES farmers from giving up milpa production and purchasing staple foods include the physical difficulty of accessing markets (requiring them to hire a pickup truck to transport goods from Tacuba), and the unstable price of maize throughout the year, which fluctuates substantially based on supply, input prices, and weather.

Another explanation for farmers' differentiated crop management practices is that coffee and maize have distinct growing requirements. Coffee thrives in a shaded organic agroecosystem, where shade tree leaf litter suppresses weeds and provides in situ compost, contributing nutrients and soil organic matter (Lin 2009). In addition, coffee has very few insect pests, as alkaloids in the coffee leaf serve as chemical protection against herbivores, and biodiverse shade coffee farms support a variety of pest predators (Perfecto et al. 1996). Maize, on the other hand, has a high nitrogen requirement and is susceptible to erosion and pests in tropical settings (Kumwenda et al. 1996; Mkhabela et al. 2001; Osmond and Riha 1996; Sanchez and Palm 1996).

Underpinning farmers' decision to continue managing food plots with agrochemicals they could barely afford was the real concern that without fertilizer, they would have no production. Many believed there was no alternative to conventional management, and were not willing to alter their management practices and risk losing a key food source. Our yield data somewhat supported this, showing that fertilizer expenditures were correlated with maize yields, although fertilizer use was not correlated with increased maize yields. Previous research by Olson et al. showed that yields were not significantly correlated with nitrogen application when controlling for slope and seed type. It is likely that fertilizers help increase maize yields for ACOES farmers, yet, farmers themselves have noted a decline in their effectiveness over time. The average nitrogen rate applied by farmers in our study was 193 kg/ha, a fairly high figure for subsistence maize production.[7] Reducing fertilizer use and supplementing with organic sources of nutrients would add soil organic matter and macronutrients, increasing the effectiveness of fertilizers (Yanggen et al. 1998) and contributing to long-term sustainability (Sanchez and Palm 1996). Studies in smallholder systems have shown that maize and wheat yields can be optimized with a combination of inorganic and organic fertilizer in Southern Africa (Kumwenda et al. 1996) and China (Yang et al. 2006).

Finally, institutional support to ACOES farmers has treated coffee production and food production distinctly, promoting organic practices for coffee and conventional management for grains. Galt (2009) observed a similar double standard in Costa Rica, where crops for national markets were sprayed with excessive pesticides, while export crops were more strictly regulated. Relying so heavily on conventional agriculture has diverted resources away from other options that are generally considered more appropriate for small-scale farmers worldwide (Albrecht and Kandji 2003; International Assessment of Agricultural Knowledge, Science and Technology for Development 2009; De Schutter and Vanloqueren 2011; Holt-Gimenez and Altieri 2012; Seufert et al. 2012). Agroecological methods, such as barriers for sediment capture and cover cropping have been shown to reduce weed pressure, minimize erosion and increase yields without chemical inputs in Latin America (M. A. Altieri 1999) and China and Kenya (Uphoff 2002). One promising possibility, which has been adopted by many farmers in Mesoamerica, is the use of green manures such as velvet bean (*Mucuna spp)* to increase soil fertility and provide an additional food and income source (Buckles et al. 1998). Use of mucuna as a cover crop during the dry season in Guatemala and Honduras has been shown to limit erosion, ensure higher maize yields through nitrogen fixation, and minimize the need for herbicides by suppressing weeds (M. A. Altieri 1999; Shriar 2002). In many developing countries, ecologically based, low-input practices are better suited to the needs of smallholders, but they have not been prioritized or funded, particularly for food production (Otero and Pechlaner 2008; Gurian-Sherman 2009).

CONCLUSION

Although concentrated chemical fertilizers may be convenient and effective, critics have argued that agrochemical dependence has undermined local food security and long-term sustainability (M. Altieri 2004; Gliessman 2007; Perfecto and Vandermeer 2008; Scherr and McNeely 2008), and created vulnerability to rising oil prices for small-scale farmers in developing countries (Chappell and LaValle 2009). Programs and policies that continue to promote fertilizer use as the solution to food insecurity for small-scale poor farmers must address important questions of long term economic and environmental sustainability. Even if agrochemicals are initially subsidized, how will small-scale peasant farmers afford inputs when subsidies are removed and prices increase? Programs promoting the use of synthetic fertilizer should also emphasize the importance of building soil organic matter for long-term soil fertility.

Our research suggests that finding the right combination of agroecological practices, while potentially keeping some conventional methods, could increase the economic and productive viability of grain production in this region. We emphasize the term agroecological, rather than organic, because although similar, organic tends to be associated with a "certification" or label. Since most of the grain production is for consumption, there is no need to seek certification. A new challenge this change would introduce is the additional labor requirement required for such low-input, labor-intensive practices. One possible solution to this and other food production challenges that has not been explored in this community is to leverage the strengths of the cooperative to collectively address food production. Though the ACOES cooperative has focused exclusively on collective coffee management, there is potential for them to extend the scope of the cooperative to include food production as well. This may entail work exchanges on one another's food plots, collective management of a compost facility dedicated to food crops and/or collective ownership of equipment, or simply information sharing amongst farmers about their food crop management experiences. Other potential challenges in the transition to agroecological food crop management include potential yield loss and managing soil fertility. Because many farmers are risk-averse with regard to their main food source, adoption of new techniques may first require demonstration plots or some level of insurance to cover potential crop failure. Several ACOES members have recently received support from FUNDESYRAM to transition to semi-organic food crop management through an organic compost project. In addition, our research team has begun a demonstration project testing agroecological food crop management with 18 ACOES members. Although these are small steps, they represent important efforts toward improving maize and bean production in the coffee region of Tacuba. Farmers also need support in analyzing the economics of new practices (Greiner et al. 2009). This may be as simple as helping farmers keep better records of their costs and revenue.

Our research has shown the myriad reasons why smallholder coffee farmers have become dependent on costly agrochemicals for subsistence crops. These include the fact that synthetic inputs were initially cheap and effective and farmers' unwillingness to risk lower yields. In addition, institutional support for alternative practices has largely focused on organic coffee production and tended to overlook subsistence agriculture. Although this case study is focused on one small cooperative in El Salvador, the themes are common for small-scale farmers throughout the developing world, and lessons are applicable in a broader context. Low yields of subsistence crops are a common barrier to food security, yet attempting to increase yields through chemical fertilizer introduces new vulnerabilities and challenges. Farmers feel trapped in a cycle of agrochemical dependence, and in spite of their use of fertilizer they continue to produce insufficient food for the household. These results suggest that green revolution approaches to peasant food insecurity may be inappropriate in the long-term (Holt-Gimenez and Altieri 2012), although they may result in increased production in the short and medium term (see Denning et al. 2009). Rather than promote agrochemical use for small-scale farmers, low-cost, and environmentally and economically sustainable methods are needed to increase food production in developing countries, where many farmers cannot afford external inputs.

NOTES

1. Holdridge life zone classification system is based on local environmental conditions including altitude, rather than latitude alone.
2. Farmers indicated that the daily cost of labor was $4 plus lunch, which they valued at $2.

3. The nitrogen content per 100 kg of 16-20-0 fertilizer is 16 kg; nitrogen content per 100 kg of ammonium sulfate is 21 kg.

4. Twenty eight of 29 ACOES farmers were included in this calculation due to one data point being removed for suspected inaccuracy.

5. Household income was calculated in 2008 including all income made by all working members of the household. This data is reported in Morris et al. (2013).

6. As a point of comparison, typical maize productivity data of 1,905 kg/ha was estimated for Central America (FAO and CIMMYT 1997), 1,848 kg/ha estimated for Costa Rica based on agrochemical use (Thrupp 1990), and 1,200 kg/ha reported for the Brazilian Amazon (Hecht 1992).

7. Recommendations on fertilizer requirements for optimal maize production vary for different regions and different crops, soils, and climatic conditions. Osmond and Riha's (1996) model determined that 140 kg N ha-1 was recommended for optimal maize yields in Brazil, while rates of 65–75 kg of nitrogen per hectare are recommended for maize in Swaziland (Mkhabela et al. 2001).

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