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Cultivation of maize landraces by small-scale shade coffee farmers in western El Salvador

Meryl Breton Olson *, Katlyn S. Morris, V. Ernesto Méndez

University of Vermont, Jeffords Hall, 63 Carrigan Drive, Burlington, VT 05405, United States

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ABSTRACT

Small-scale shade coffee agroecosystems have been noted for their potential for tree, bird, and insect biodiversity conservation in the tropics. However, there is a lack of research on other productive areas managed by small-scale coffee farmers such as subsistence maize and bean (*milpa*) plots, which may be sites of important crop biodiversity conservation, particularly through the on-farm cultivation of native landraces. This study empirically examined the factors that influence farmers' choices between landraces and improved varieties of maize, how seed type interacts with management decisions, and how yields of local maize landraces compare with improved varieties on the farms of small-scale shade coffee farmers in western El Salvador. We conducted household interviews and focus groups with the membership of a 29-household coffee cooperative and tracked management and maize yields in the 42 *milpa* plots managed by these households. Farmers planted both a hybrid improved variety and five local maize landraces. ANOVA and Pearson's chi-square test were used to compare household characteristics, management, agroecological variables, and yields between plots planted with landraces and plots planted with the improved variety. Logistic regression was used to evaluate the strongest drivers of farmers' choice between landrace seed and improved seed. Analyses indicated that use of maize landraces was associated with higher household income and steeper plot slope. Landrace maize and improved maize were not managed differently, with the exception of synthetic insecticide use. There was no yield advantage for improved varieties over landraces in the 2009 growing season. Farmers appear to prefer local maize landraces for *milpa* plots on more marginal land, and continue to cultivate landraces despite the availability of improved seed. The farms of small-scale shade coffee farmers could have substantial conservation potential for crop genetic diversity, and the seed-saving and exchange activities among such farmers should be supported.

1. Introduction

Maize (*Zea mays*) is a critically important food crop in Latin America and much of Africa and Asia (Smale et al., 2001). Along with beans (*Phaseolus vulgaris*), it provides the sustenance for millions of people, particularly in rural areas, and is intricately tied to social and cultural traditions (Keleman et al., 2009; Staller, 2010). The ecology and genetic diversity of maize, the diversity and dynamics of maize populations, and the maintenance of maize landraces have been well-studied, particularly among subsistence farmers in Mexico, maize's center of origin (Bellon, 1991; Bellon and Brush, 1994; Bellon et al., 2003a; Bellon and Berthaud, 2004; Birol et al., 2009; Brush et al., 2003; Brush and Perales, 2007; Keleman et al., 2009). In particular, the diversity of maize populations has been subjected to intensive research due to a concern that widespread adoption of improved varieties is causing the loss of maize diversity present in local landraces (van Heerwaarden et al., 2009). We use the term "improved" to refer to those varieties or cultivars of maize that have been scientifically bred to be uniform and stable, as distinct from landraces (Badstue, 2006). A landrace is defined as a population of a cultivated plant having historical origin, distinct identity, and lacking formal crop improvement (Camacho Villa et al., 2005). Landraces also tend to be genetically diverse, locally adapted, and associated with traditional farming systems (Camacho Villa et al., 2005). Historically, landraces have been used as parent material for the development of improved varieties through plant breeding. Though formal breeding now tends to focus on a few in-bred lines, sometimes crossed to create hybrids, landraces continue to provide important genetic material, particularly for traits that enhance adaptation to marginal environments (Birol et al., 2009; Camacho Villa et al., 2005). There is also evidence that even farmers adopting improved varieties continue to maintain landraces due to their superior hardiness in marginal environments (Keleman et al., 2009), lower fertilizer requirements (Keleman et al., 2009; Bellon and Hellin, 2011), comparatively low seed cost (Almekinders et al., 1994)

* Corresponding author. Tel.: +1 603 440 5107.
E-mail addresses: Meryl.Olson@gmail.com (M.B. Olson), Katlyn.Morris@uvm.edu (K.S. Morris), emendez@uvm.edu (V.E. Méndez).

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better resistance to rot (Almekinders et al., 1994; Bellon et al., 2006), and superior culinary characteristics (Bellon and Hellin, 2011; Isakson, 2011) in comparison to improved varieties. The maintenance of maize diversity on-farm (*in situ*) is thus of interest both locally—for use by farmers—and globally—as a reservoir of genetic variety for potential future use (Ceroni et al., 2007; Isakson, 2011; Newton et al., 2010).

Although much research has analyzed maize landrace conservation and management by smallholder grain farmers, no studies have, to our knowledge, examined the dynamics of maize cultivation by small-scale coffee growers and cooperatives. On the other hand, the last two decades have seen a proliferation of studies demonstrating that shade coffee farms have significant biodiversity conservation potential (Blackman et al., 2007; Perfecto et al., 1996; Perfecto and Vandermeer, 2008a). Most of the research in this area has focused on how shade coffee plantations can act as extended habitat for birds (Komar, 2006), insects (Armbrecht et al., 2006; Perfecto et al., 1996), mammals (Gallina et al., 1996), and orchids (Solis-Montero et al., 2005), among other organisms. This has left an information gap on other types of biodiversity that may be conserved by coffee farmers within coffee agroecosystems or in separate plots, notably *planned biodiversity*, which refers to the species directly incorporated into the system by farmers (Altieri, 1999; Méndez et al., 2010a; Vandermeer and Perfecto, 2005). Recent studies of small-scale coffee farmers in Mesoamerica have documented that they often intercrop coffee with food crops or farm separate subsistence plots (referred to as *milpa*), which may be reservoirs of planned biodiversity, while providing an important source of food for the household (Bray et al., 2002; Jaffee, 2007; Méndez et al., 2010a; Trujillo, 2008). The impacts of the most recent coffee price crisis of 1999–2004 and the continued volatility of coffee prices have shown that smallholder coffee households face a number of vulnerabilities, including periods of seasonal food insecurity (Bacon et al., 2008; Jaffee, 2007; Méndez et al., 2009, 2010b). Thus, there is a need to better assess the challenges and opportunities associated with local food production by Mesoamerican coffee farmers as a strategy to mitigate episodic hunger (Morris et al., in press).

This study also fills a gap in the literature on conservation of maize diversity. With few exceptions (see Steinberg and Taylor, 2009), the vast majority of research on maize landrace conservation has focused on farmers in Mexico for whom *milpa* agriculture comprises the majority of their agricultural activities (see for example Badstue et al., 2007; Bellon and Brush, 1994; Bellon and Hellin, 2011; Bellon and Risopoulos, 2001; Keleman et al., 2009). El Salvador has not been considered an area of potential maize diversity conservation because of the high rate of use of improved varieties and the loss of indigenous agricultural traditions through several periods of civil unrest, starting in the 1930s. Furthermore, we document maize landrace conservation by farmers for whom maize is not their primary focus; the farmers in this studied identified primarily as coffee farmers, and were organized into a coffee cooperative. Few studies have considered the dynamics of maize diversity with farmers whose primary focus is export crops, whether coffee, cacao, or vegetables. Little is known about the *milpa* system as practiced by such farmers, and their priorities and practices may differ from farmers whose primary livelihood activity is *milpa* agriculture. These differences could be substantial, due to the different bioclimatic requirements of maize and other crops (e.g. coffee) and the smaller amount of time and labor they are able to devote to *milpa* farming. This study begins to address this gap by analyzing various factors that affect maize production and landrace conservation by coffee farmers in Central America. The specific objectives of this research were to understand what factors influence choice of maize seed, how seed type interacts with management decisions, and how yields of local maize landraces compare with improved varieties on the farms of small-scale shade coffee farmers in El Salvador.

1.1. Maize seed and landraces in El Salvador

El Salvador has the highest level of use of improved varieties of maize seed in Central America (Ferrufino, 2009). Improved varieties are generally referred to as *certificado* varieties by farmers in El Salvador. C*ertificado* is a legal designation under law in El Salvador and most other Central American countries (Ferrufino, 2009), which is given to seed of the highest level of genetic identity and purity. Ninety-one percent of the maize seed planted in El Salvador is *certificado*, while only 54% of maize seed planted in all of Central America is *certificado*. State research and extension is primarily directed towards *certificado* varieties, many of which are hybrids, with the aim of raising productivity and encouraging international market integration (Deleón et al., 2009). As in other Central American countries, the public sector (via the National Center for Agricultural, Livestock and Forestry Technology—CENTA—which is a division of the Ministry of Agriculture and Livestock) is primarily responsible for research and development of improved varieties, while the private sector is responsible for production and commercialization of these varieties (Ferrufino, 2009; Hult et al., 1995). The seed certification division of the Ministry of Agriculture and Livestock supervises and certifies all seed produced by the public and private sector (Ferrufino, 2009). Recent trends show a decrease in publicly-operated seed production, which struggles to compete with private, transnational seed companies. Cristiani Burkard, which is owned by Monsanto, produces 70% of the *certificado* seed sold in El Salvador, and four competing companies produce the rest (Ferrufino, 2009). Fifty-two percent of the maize seed used in El Salvador is purchased from these private producers by the government and distributed for free through the Programa Presidencial de Apoyo la Productividad (Presidential Productivity Support Program). This is one of the strongest seed distribution programs in Central America, and the only one that distributes primarily hybrid seed. Thirty-nine percent of this seed is sold through the private market in agricultural supply stores. The remaining 9% is *criollo* seed (translates as *creole* and is used to refer to local landraces), which is traded locally (Ferrufino, 2009).

The privatization of seed production is a symptom of a general decrease in public investment in the agricultural sector by the Salvadoran government since 1989 (Cuéllar et al., 2002). Evidence of this is the fact that CENTA cut its maize breeding staff from eight people to one person between 2000 and 2005 (Del Cid, 2008). Agricultural extension has been curtailed, and few new varieties of improved seed have been developed in recent years (Hult et al., 1995), with the exception of a high-protein variety aimed at improving the nutritive value of maize grown for human consumption (Deleón et al., 2009).

2. Methods

2.1. Study site

This research was conducted in the municipality of Tacuba in the department of Ahuachapan in western El Salvador. Though El Salvador is, latitudinally, located within the tropics, Tacuba is bioclimatically classified as subtropical wet forest due to its elevation (Tosi and Hartshorn, 1978; Holdridge, 1987). The elevation of the research area ranges from 738 to 980 masl with average rainfall of 1500 mm per year, concentrated between May and October. Soils are primarily volcanic Andisols (Méndez et al., 2007). All of the sample plots in this study were located near *El Imposible* National Park, one of the largest protected forest areas in El Salvador

(Fig. 1). Land use within a 1 km radius surrounding the plots is 74% forested (including shade coffee forest), 24% cultivated (primarily *milpa*), and 2% built or impervious cover (Fig. 2).

The 29 households involved with this study comprise the membership of an organic coffee cooperative that was formed in 2007 as the union of members from two smaller coffee cooperatives who came together to obtain higher prices for their coffee. One of these smaller cooperatives was formed in 1984, when its members took advantage of a window of opportunity created by the first phase of agrarian reform in El Salvador to obtain a loan and purchase land from a private owner (Méndez et al., 2009, 2010a). Of the 29 members of the larger cooperative, 19 are also members of this smaller cooperative. This cooperative collectively owns 35 ha, which is planted to shade coffee, and each member individually owns and manages parcels of land for their *milpa* and homestead. The remaining 10 members come from another small cooperative formed in 2001 as an individual farmer association (Méndez et al., 2009, 2010a). Coffee plantations as well as *milpa* plots are individually owned in this cooperative.

2.2. Study plots

All 29 farmers of the cooperative plant maize, beans, and small amounts of squash and other vegetables in small plots (0.22 ha on average) scattered around their homes and coffee plantations (Fig. 1). These plots are all individually owned or rented by the farmers. In order to integrate agroecological and livelihood variables in our analysis of farmers' seed choices, management, and maize yields, we used the *milpa* plot as the unit of analysis. Ten of the 29 households planted *milpa* in more than one location, so there were 42 plots included in this study, with a combined total area of 13.75 ha and an average area per household of 0.49 ha. This may have compromised the independence of some observations as some of the plots were owned by the same farmer. We compensated for this by including data on household income, household size, and education level in our analysis of factors associated with seed choice.

Milpa plots were mapped by georeferencing the corners of each plot, as defined by the farmer who cultivated the plot, with a Trimble GeoXH geographic positioning system (GPS) unit. Houses of farmers involved in the study and major landmarks were also georeferenced. Vector polygons of *milpa* plots were digitized by hand using the georeferenced corner points.

Because the plots were not randomly located, there existed the possibility for spatial autocorrelation in maize yield data due to biophysical variables not included in our analysis, such as differences in moisture. Nearly all ecological variables are spatially autocorrelated, meaning that they "take values, at pairs of locations a certain distance apart, that are more similar (positive autocorrelation) or less similar (negative autocorrelation) than expected for randomly associated pairs of observations" (Legendre, 1993, p. 1659). We tested for spatial autocorrelation of maize yields using Spatial Statistics in ArcGIS. Maize yields were not spatially autocorrelated (Moran's $I = 0.01$, $Z = 0.37$, $p \leqslant 0.355$), which reinforced our confidence in the spatial independence of the observations despite the non-random locations of the plots.

2.3. Data collection

Our analysis focused on three sets of variables: (1) livelihood characteristics of households; (2) variables related to management of *milpa* plots, including maize seed choice and yields; and (3) agroecological characteristics of *milpa* plots. (Table 1). We collected information on household livelihoods through semi-structured interviews (Leech, 2002) conducted in Spanish at the home of each participant in August of 2008. Additional qualitative

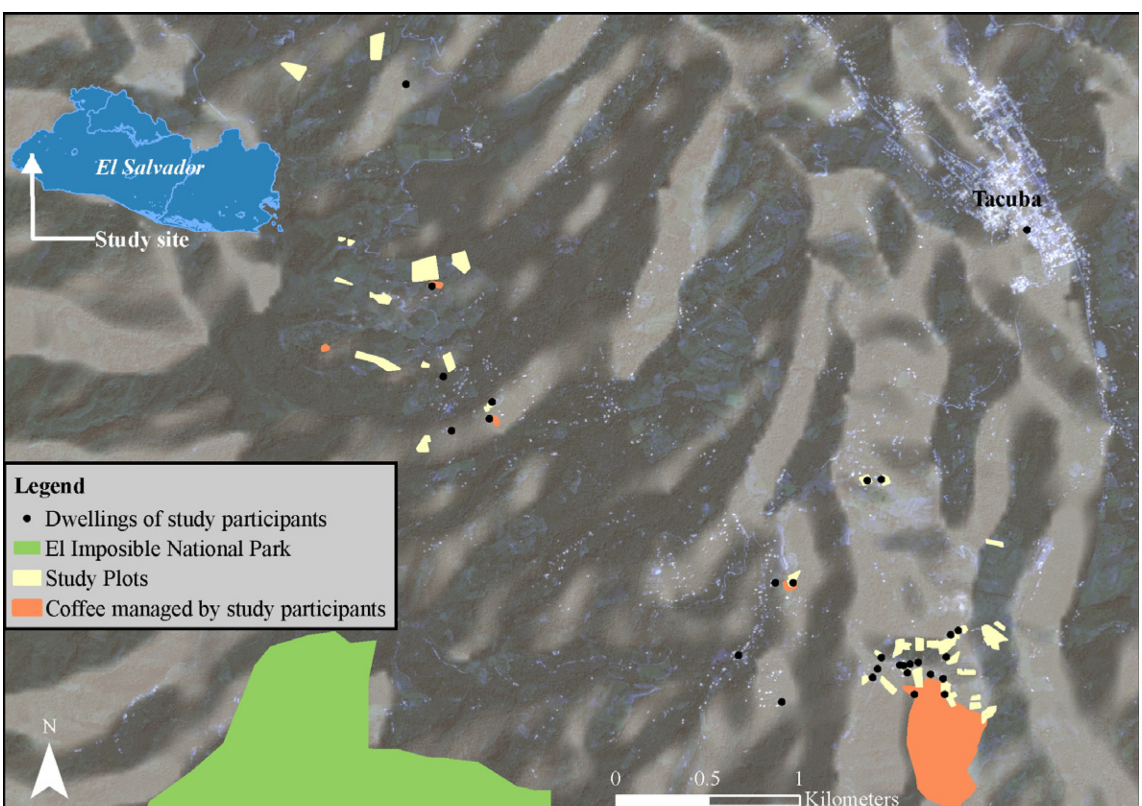

Fig. 1. Map of the study location with dwellings and agricultural plots.

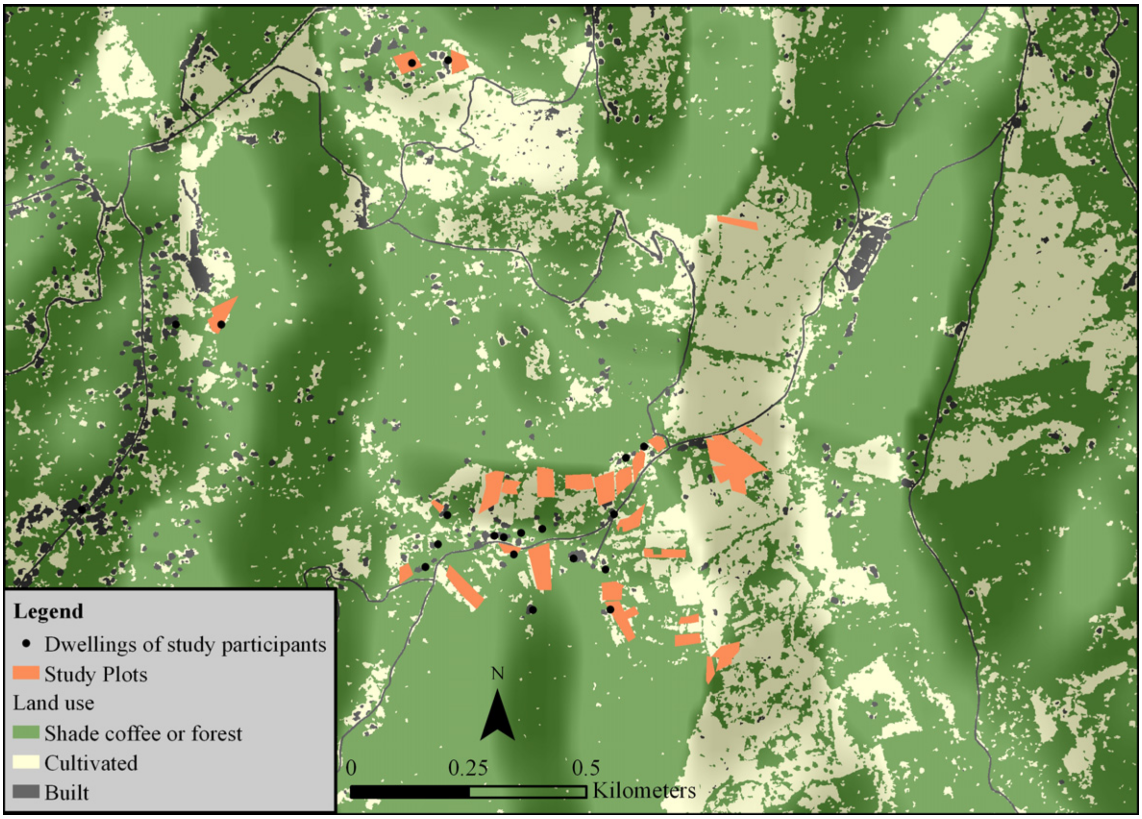

Fig. 2. Land use in a subset of the study area in western El Salvador.

information was collected during a focus group with the board of directors of the cooperative and during informal conversations throughout the field research. Data on plot management, including maize seed types planted and maize yields, was collected over the 2009 growing season with a series of four interviews with each cooperative member during June, August, October, and December. We chose to do four separate interviews in order to ensure accurate recall of management activities. Unlike in other areas of Central America, the farmers involved in this study only grow one maize crop per year, which is planted at the beginning of the rainy season (late May or early June) and harvested in November. This is partly due to the biophysical and climatic conditions not being favorable to two maize harvests. Beans are planted amongst the maize in late August as the maize matures and the stalk is folded so that the ear can dry. The rest of the year is devoted to the coffee harvest (which begins in December) and other coffee management activities.

We identified seed landraces by the names that farmers assigned to them. This does not presume genetic distinctiveness between landraces, as farmers' criteria for classifying landraces are not the same as geneticists' (Smale et al., 2001). We chose to use farmers' distinction between landraces, however, because farmers' naming systems for maize varieties have been shown to be a good entry point for representing genetic variation in maize populations (Sadiki et al., 2007). In addition, farmers' named categorizations of their seed types, generally based on appearance, represent the units upon which farmers make decisions (Bellon, 1991). In our analysis, we focus primarily on the differences associated with *criollo* seed and *certificado* seed, not between *criollo* landraces.

Information on agroecological characteristics of plots was gathered in 2009. To calculate elevation and slope, the georeferenced points were merged with a digital elevation model of the area (NASA Land Processes Distributed Active Archive Center, 2001) and the average elevation and slope were calculated for each plot. This merged elevation layer was also used to calculate the 3D surface area of each plot, as the plots are on very steep slopes. This area was also used to calculate maize yields per hectare. The calculated areas were triangulated with the farmers' estimates of their plot areas. All geographic analyses were performed using ArcGIS 9.3 geographic information systems (GISs) software. Soil characteristics in the plots were determined from samples collected during June of the 2009 growing season. We took 10–15 soil cores (depending on plot size) to a depth of 15 cm using a tube auger in a zig-zig pattern in each plot and combined them to create a composite sample (Brady and Weil, 2008). These samples were processed by the Analytical Services Laboratory of the Salvadoran Foundation for Coffee Research (*Fundación Salvadoreña para Investigaciones del Café* or PROCAFE). Analytical methods used to measure each characteristic are presented in Table 1.

2.4. Data analysis

2.4.1. Predictors of maize seed choice

We used logistic regression to analyze what household characteristics and agroecological variables were significant predictors of maize seed choice (*criollo* vs. *certificado*). Variables that we analyzed as predictor variables included household characteristics, agroecological variables, plot tenure, and existence of live erosion barriers in the plot (Tables 3 and 4). Other management variables were not included in this part of the analysis because we did not expect them to predict seed choice. Rather, they are analyzed as to how seed choice might influence management decisions as outlined in Section 2.4.2. Soil characteristics were analyzed in univariate analysis but ultimately not included in the logistic regression model because they were strongly correlated with slope, which was included in the model.

Table 1
Variables included in the study.

Variable	Description
Household characteristics	
Continuous variables	
Income	Annual household income per person (US$)
HH size	Number of people in household
Education	Mean grade level of household members over age 12
Age	Age of primary farmer in the household
Land	Total hectares of *milpa* cultivated by the household
Categorical variables and levels	
Migration	Household has – does not have one or more members that have migrated
Ag support	Household has – has not participated in agricultural training or support from NGOs or the government
Other support	Household has – has not participated in other training or support from NGOs or the government
Management variables	
Continuous variables	
Distance	Distance from plot to dwelling (m)
Fertilizer	Nitrogen application rate (kg/ha)[a]
Synth insect	Number of applications of synthetic insecticides/fungicides
Herbicide	Number of applications of herbicides
Categorical variables and levels	
Seed type	Primarily *criollo* – primarily *certificado* seed planted
Compost	Organic fertilizer (compost or manure) applied – not applied
Org insect	Organic insecticide applied – not applied
Barriers	Plot does – does not have live erosion barriers
Tenure	Plot owned – rented by farmer
Agroecological variables	
Yield	Yield of maize (kg/ha)
Elevation	Elevation of plot (masl)
Slope	Slope of plot (percent slope)
pH	pH of plot soil[b]
N	Total nitrogen content of plot soil (%)[c]
P	Phosphorus content of plot soil (ppm)[d]
K	Potassium content of plot soil (ppm)[e]
Ca	Calcium content of plot soil (meq 100 cc^{-1})[f]
Mg	Magnesium content of plot soil (meq 100 cc^{-1})[f]
Al	Aluminum content of plot soil (meq 100 cc^{-1})[f]
SOM	Organic matter content of plot soil (%)[g]
Acidity	Total acidity of plot soil (meq 100 cc^{-1})[h]

[a] Applied as ammonium nitrate, urea, compost, or manure.
[b] Determined in 0.01 M $CaCl_2$ solution using a potenciometer.
[c] Keldal method using distillation and digestion with sulfuric acid.
[d] North Carolina Mehlich method using molybdenum blue clorometric.
[e] North Carolina Mehlich method using a photometer.
[f] Extracted in 1 N KCl solution (Ca and Mg using an atomic absorbtion spectrophotometer; Al using titration).
[g] Walkley Black method.
[h] Indirect SMP method using a potenciometer.

Table 2
Maize types planted in *milpa* plots ($n = 42$ plots). Some plots were planted with more than one type of seed.

Maize type	Number of plots	Percent of plots (%)
Criollo		
Julupilse	19	35
Mexicano	9	16
Santa rosa	4	7
Unspecified criollo	4	7
Amarillo	1	2
Negrito	1	2
Certificado		
H-59	13	24
Seed type unknown	4	7

Because of the large number of variables compared, and in order to reduce the likelihood of Type I error, we first performed multivariate analysis of variance (MANOVA) with all predictor variables before analyzing each variable separately. Variables that were significantly related ($p \leqslant 0.05$) to maize seed choice in univariate analysis (ANOVA or Chi-square test) were then included in the logistic regression model.

2.4.2. Management differences between seed types

To investigate differences in fertilizer and pesticide use between plots planted with *criollo* and *certificado* seed, we used ANOVA (continuous variables) and Pearson's chi-square test. We analyzed relationships between management variables, including seed type, and maize yields using univariate correlations (Pearson's *r*) and ANOVA (Table 6). All analyses were performed in SPSS version 20.

2.4.3. Maize yields

We calculated maize yields per hectare for each plot for 2009 and analyzed this data (log-transformed for normality) for univariate correlations with agroecological and management variables. We then compared yields between plots planted with *criollo* seed and those planted with *certificado* seed. As yield was strongly negatively correlated with slope and *certificado* seed was not planted on steeply sloped plots, we also conducted the yield comparison with a subsample of plots with slope less than 25% ($N = 27$).

3. Results

3.1. Maize seed types

The farmers in this study reported obtaining seed from a number of sources, including seed saved from their own *milpa* plots, exchanges with friends, family, and neighbors, purchases from agricultural supply stores, and seed donations from the government. Farmers distinguished between two types of seed: *criollo* and *certificado* (also referred to more specifically as "hybrid" or "H-59" for its formal variety name). *Criollo* seed was either maintained by the farmers themselves, exchanged with other farmers, or occasionally purchased from local supply stores.The farmers involved in this research did not know the ultimate origin of most of the landraces of maize and beans that they planted, suggesting that the names and classifications assigned to these landraces were older than the farmers themselves. One farmer commented, "They are just old varieties. We do not know where they came from." Other studies (Almekinders et al., 1994; Bellon and Risopoulos, 2001; Bellon et al., 2003a, 2006) have documented that farmers "creolize" improved maize by replanting improved seed year after year or by deliberately or inadvertently crossing it with landraces; some have argued that this process simply introduces more diversity into landrace populations (Bellon and Risopoulos, 2001). As maize is open-pollinated, there may have been some genetic material from *certificado* maize varieties in the maize that the farmers in this study referred to as *criollo*. However, unlike in studies documenting creolization, the farmers in this study did not report deliberately adapting improved seed, nor did they refer to any of their *criollo* varieties by names that matched previously release improved varieties.

The Presidential Productivity Support Program was the primary source of *certificado* seed for the farmers in this study, all of whom reported that this was the only government support that they received for staple crop production. The only *certificado* seed variety used by the farmers in this study was H-59 maize, a triple-cross hybrid white maize variety. There was no evidence that the seed which the farmers referred to as *certificado* was creolized (i.e. second or third generation) improved seed, as the farmers described receiving it every year from the government, showed us the bags in which it was distributed, and noted that it was pre-treated with a fungicide. They also reported that the Presidential Productivity Support Program would be ceasing to distribute seed in the coming years and they expected to have to buy *certificado* seed yearly in the future if they were to continue planting it.

Table 3
Descriptive statistics and significance of continuous explanatory variables used in the comparison of plots planted with *criollo* seed and plots planted with *certificado* seed. Variables for which there were significant differences are in bold.

	Criollo			*Certificado*			Statistical results
	Mean	*n*	S.D.	Mean	*n*	S.D.	
Income	436	29	360	209	11	166	$F = 14.817$, $df = 36$, $p \leqslant 0.000$**
HH size	7	29	4	7	11	3	$F = 0.040$, $df = 38$, $p \leqslant 0.843$
Education	2	31	1	3	11	1	$F = 0.412$, $df = 40$, $p \leqslant 0.525$
Age	58	31	11.2	52	11	5.1	$F = 2.435$, $df = 40$, $p \leqslant 0.127$
Land	0.63	31	0.52	0.42	11	0.31	$F = 2.111$, $df = 40$, $p \leqslant 0.244$
Distance	639	30	111.7	278	11	66.4	$F = 1.848$, $df = 39$, $p \leqslant 0.182$
Elevation	879	31	52.1	818	11	53.3	$F = 10.953$, $df = 39$, $p \leqslant 0.002$**
Slope	22.5	31	6.7	14.4	11	4.7	$F = 13.547$, $df = 39$, $p \leqslant 0.001$**
pH	3.9	31	0.3	4.0	10	0.4	$F = 0.579$, $df = 39$, $p \leqslant 0.451$
N	0.21	31	0.04	0.17	10	0.0	$F = 6.115$, $df = 39$, $p \leqslant 0.018$*
P	26.5	31	21.6	18.1	10	9.6	$F = 1.422$, $df = 39$, $p \leqslant 0.240$
K	127.9	31	87.2	253.7	10	104.9	$F = 14.240$, $df = 39$, $p \leqslant 0.001$**
Ca	13.1	31	4.5	10.7	10	6.1	$F = 1.711$, $df = 39$, $p \leqslant 0.198$
Mg	3.5	31	1.5	3.0	10	1.7	$F = 1.076$, $df = 39$, $p \leqslant 0.306$
Al	1.1	31	1.0	1.0	10	0.9	$F = 0.046$, $df = 39$, $p \leqslant 0.831$
SOM	5.1	31	1.4	4.4	10	1.5	$F = 1.555$, $df = 39$, $p \leqslant 0.220$
Acidity	7.1	31	2.6	6.9	10	2.8	$F = 0.077$, $df = 39$, $p \leqslant 0.782$

* Significant at the 0.05 level.
** Significant at the 0.01 level.

Table 4
Frequencies (%) and significance of categorical variables in the comparison of plots planted with *criollo* seed and plots planted with *certificado* seed. None were significantly ($p \leqslant 0.05$) associated with seed type.

Variable	Category 1	Category 2	Statistical result
Migration	Migration	No migration	Pearson's $\chi^2 = 0.985$, $df = 1$, $p \leqslant 0.321$
Criollo	70%	30%	
Certificado	50%	50%	
Ag support	Participated	Not participated	Pearson's $\chi^2 = 1.942$, $df = 1$, $p \leqslant 0.163$
Criollo	50%	50%	
Certificado	70%	30%	
Other support	Participated	Not participated	Pearson's $\chi^2 = 3.507$, $df = 1$, $p \leqslant 0.061$
Criollo	70%	30%	
Certificado	100%	0%	
Barriers	Has	Does not have	Pearson's $\chi^2 = 0.010$, $df = 1$, $p \leqslant 0.922$
Criollo	79%	21%	
Certificado	78%	22%	
Tenure	Rented	Owned	Pearson's $\chi^2 = 0.443$, $df = 1$, $p \leqslant 0.505$
Criollo	70%	30%	
Certificado	60%	40%	

3.2. Predictors of maize seed choice

Of the 42 plots studied, 73% were planted with primarily *criollo* maize varieties. Five named varieties of *criollo* maize seed were reported, along with some seed that the farmers referred to as simply "criollo" without a specific landrace name (Table 2). A plot was defined as planted with *criollo* maize seed if more than 50% of the seed (by kg of seed) planted in the plot was *criollo*. The remaining 27% of plots were planted with primarily *certificado* seed. While the farmers generally planted either *criollo* or *certificado* seed in each plot (rather than mixing *criollo* and *certificado* seed in the same plot), the majority of farmers with more than one *milpa* plot made use of both kinds of seed, planting *criollo* varieties in certain plots and *certificado* seed in other plots. Only four of the 42 plots were planted with both *criollo* and *certificado* seed in the study year; of these, three were classified as *certificado* based on the above criteria, and one was classified as *criollo*.

MANOVA analysis confirmed that there were significant overall differences between plots planted with *criollo* and *certificado* seed (Wilks' Lambda $F = 2.927$, $p \leqslant 0.042$). Plots planted with *criollo* maize seed were significantly steeper and higher in elevation than plots planted to *certificado* seed. The mean per capita income of the household managing the plot was significantly higher for *criollo*-planted plots than for *certificado*-planted plots. (Table 3). Farmer age, educational level, total hectares of *milpa* cultivated by the household, size of the household managing the plot and distance from plot to homestead were not significantly different between plots planted to *criollo* seed and those planted to *certificado* seed. The type of maize seed used was not significantly associated with plot tenure structure or the managing household having received agricultural training or other training or support (Table 4). Nor was maize seed type associated with the managing household having had a member migrate away from the community (Table 4).

Some soil characteristics differed between plots planted with *criollo* seed and those planted with *certificado* seed. Total nitrogen was significantly higher and potassium was significantly lower in *criollo* plots than in *certificado* plots (Table 3). This was likely due to the elevation and slope differences between the plots, not due to any effect of the seed type itself. Total nitrogen was strongly positively correlated with elevation (Pearson's $r = 0.572$, $n = 41$, $p \leqslant 0.000$) because of the slower decomposition of organic matter in the cooler, wetter conditions at higher elevations. Potassium was negatively correlated with both elevation (Pearson's $r = -0.345$, $n = 41$, $p \leqslant 0.027$) and slope (Pearson's $r = -0.451$, $n = 41$, $p \leqslant 0.027$).

Variables that were significantly different between plots planted to *criollo* and *certificado* seed (continuous variables) or significantly associated with the type of seed used (categorical variables) in univariate analysis were included in a logistic regression to model the probabilities of using primarily *criollo* or *certificado* maize seed. Seed type was assigned a value of 0 if primarily *criollo* seed was used and a value of 1 if primarily *certificado* seed was used. Soil characteristics were not included in the logistic regression because they were correlated with elevation and slope. Additionally, the farmers in this study did not test their soil regularly, so we did not expect soil nutrient contents to influence seed choice as much as elevation and slope, which are readily observable characteristics. A logistic regression model using plot slope and household income accurately predicted 92.1% of cases, with the log odds of using primarily *certificado* seed increasing 0.36 units for each 1% decrease in slope and 3.81 units for each unit decrease in the natural log of income (see Table 5). Thus, more gently sloped plots that were also managed by households with lower income had a higher probability of being planted with *certificado* maize seed. This does not imply a relationship between plot slope and income, which were independent in our data, but does imply that both were significant predictors of maize seed choice. Plot eleva-

Table 5
Logistic regression model for prediction of use of *certificado* seed.

Variable name	Description	Estimated coefficient	S.E.	Odds ratio	Wald's χ^2	*p*
Constant		26.85	9.69	4.59E+11	7.30	0.006**
Income	Natural log of annual household income per person	−3.81	1.41	0.02	6.22	0.007**
Slope	Slope of plot	−0.36	0.14	0.70	7.68	0.013*

* Significant at the 0.05 level.
** Significant at the 0.01 level.

Table 6
Variables analyzed for interaction between management and seed type. Variables for which there were significant differences between seed types (continuous variables) or associations with seed type (categorical variables) are in bold.

Variable	Criollo			Certificado			Statistical result
	Mean	*n*	S.D.	Mean	*n*	S.D.	
Continuous variables							
Fertilizer	106.8	31	105.8	137.9	11	105.8	$F = 0.690$, $df = 40$, $p \leqslant 0.411$
Synth insect	**2.1**	**31**	**1.3**	**1.0**	**11**	**1.2**	$\mathbf{F = 5.856, df = 40, p \leqslant 0.020}$*
Herbicide	2.0	31	1.1	2.1	11	1.0	$F = 1.173$, $df = 40$, $p \leqslant 0.812$

Variable	Category 1	Category 2	Statistical result
Categorical variables			
Compost	Applied	Not applied	Pearson's $\chi^2 = 0.012$, $df = 1$, $p \leqslant 0.910$
Criollo	29%	61%	
Certificado	27%	63%	
Org insect	Applied	Not applied	Pearson's $\chi^2 = 0.654$, $df = 1$, $p \leqslant 0.419$
Criollo	16%	84%	
Certificado	27%	63%	

* Significant at the 0.05 level.

tion was not a significant predictor of seed choice when slope was also included in the model, likely because of its correlation with plot slope (Pearson's $r = 0.489$, $n = 42$, $p \leqslant 0.001$).

This model agrees with farmers' explanations of their own reasons for using *criollo* seed. In focus groups, farmers reported that the *certificado* seed provided to them by the government was suited only for warmer, drier, lower-elevation areas, and performed unreliably in their higher-elevation plots. *Criollo* seed was preferred for higher-elevation plots. It appears, however, that farmers may be using slope as a proxy measurement for elevation, as slope is easier to perceive on the ground than absolute elevation.

3.3. Interactions between management and seed type

3.3.1. Fertility management

The households in this study used a mixture of nutrient management techniques in their *milpa* plots. In all but one plot, plant residues were left in the field after harvest, which builds organic matter, returns nutrients to the soil and helps protect against soil erosion (Gliessman, 2007; Paliwal et al., 2000). In the one plot where plant residues were harvested, they were used as horse feed and then reapplied to the plot as manure. Nearly all plots (90%) received at least one application of synthetic fertilizer during the 2009 growing season. In 12 of the 42 plots (29%), some form of compost or manure was also applied, but in only one plot was this used exclusive of other synthetic fertilizers. We hypothesized that farmers would use higher levels of synthetic fertilizers in plots planted primarily to *certificado* seed, due to government fertilization recommendations for *certificado* varieties and the fact that improved seed varieties generally require more inputs to attain their yield potential (Hult et al., 1995). Additionally, we theorized that farmers would be more likely to use compost on plots planted with *criollo* seed.

Plots planted with *certificado* seed did have a higher total rate of fertilizer application—measured as nitrogen per hectare applied over the growing season—than those planted with *criollo* seed; however, the difference was not statistically significant (Table 6). On average, farmers applied 107 kg ha^{-1} of nitrogen to hybrid-planted plots and 83 kg ha^{-1} to *criollo*-planted plots. Farmer extension documents from CENTA recommend that farmers apply 105 kg ha^{-1} of nitrogen over the growing season (Guerra and Osorio, 2002), and most farmers in this study reported that they try to follow these recommendations, but they often cannot afford the recommended application rates.

Seed type was not associated with use of compost or other organic fertilizers (Table 4). The form of compost most frequently applied was bokashi, a type of compost developed by Japanese farmers and characterized by the addition of microorganisms to organic material to facilitate rapid decomposition (Nishio, 1996). Bokashi can be made from a variety of materials, usually including manure and some form of plant residue such as rice hulls or coffee pulp, and can be composted under aerobic or anaerobic conditions (Formowitz et al., 2007). The farmers in this study used coffee pulp (the remnants of the coffee cherry after the coffee has been processed) and chicken manure as the primary materials for bokashi production, with the addition of soil "from the mountains" (likely referring to soil from the protected forest area of the adjacent El Imposible National Park) to inoculate the mixture with microorganisms. Their initial training in bokashi production came from a project run by the Cooperative League of the United States of America (CLUSA) International, in which many of the farmers participated. Originally, the farmers used bokashi only to replace synthetic fertilizers in their coffee plantations so that they could be certified organic. The coffee cooperative has constructed a large patio for the production of bokashi. However, some then began adopting it for use in their *milpa* as well, and in 2009, a group of six farmers began a smaller-scale bokashi production area—separate from that operated by the cooperative—to produce bokashi for their *milpa*.

3.3.2. Use of pesticides

The majority of the plots (79%) were managed using synthetic insecticides. Methyl parathion (brand name Folidol) was the most commonly used insecticide, applied to 13 of the 42 plots (31%) during the 2009 growing season. In 7 of the 42 plots (17%), an organic insecticide solution was applied. This solution is referred to as "M5" and is made by mixing hot pepper, onion, garlic, and various other plants in water and vinegar and allowing the solution to ferment for 15–20 days. Some farmers also added other ingredients with pest-repellent properties, such as papaya bark or neem seed. The farmers reported that these insecticides were far less expensive than synthetic insecticides, and some used them as replacements when they could not afford synthetic insecticides.

There was a significant relationship between use of *criollo* seed and use of synthetic insecticide; *criollo* plots had a higher mean number of insecticide applications (Table 6). This is likely explained by the confounding between plot elevation and insecticide use. Plots where insecticides were applied tended to be at higher elevation (Students $t = -2.303$, $df = 40$, $p \leqslant 0.027$), where farmers reported that wetter conditions attracted certain pests. As *criollo* seed was also used in higher-elevation plots, this would lead to statistically higher insecticide use in plots planted with *criollo* seed.

Farmers' perceptions are that *criollo* seed is more pest resistant. In focus groups, they described *criollo* seed as "stronger," having "stronger roots" and hybrid seed as "more prone to rotting" and "less resistant to rain." During the growing season, when these focus groups were conducted, the rains had been particularly heavy, and problems with pests and diseases favored by moisture were particularly prevalent.

There was no relationship between use of organic insecticides and the type of seed planted (Table 6), nor was there a difference in herbicide applications between plots planted with *criollo* and *certificado* seed. Herbicides were applied in all but four plots; most commonly, farmers applied some combination of 2,4-D, atrazine, and/or paraquat.

3.4. Maize yields

Yields of maize averaged 1313 kg ha^{-1}, ranging from no yield at all—in several plots the entire maize crop was lost in late-season storms—to a maximum of 5853 kg ha^{-1}. This average is lower than the regional average of 2630 kg ha^{-1} in Central America for 2004–2009 (Ferrufino, 2009).

In univariate analysis, maize yield (log transformed for normality) was positively correlated with fertilizer application, measured on a per-kilogram of nitrogen basis (Pearson's $r = 0.371$, $df = 31$, $p \leqslant 0.034$) and strongly negatively correlated with the slope of the plot (Pearson's $r = -0.612$, $df = 33$, $p \leqslant 0.000$). Yield was not significantly correlated with plot elevation (Pearson's $r = -0.091$, $df = 33$, $p \leqslant 0.605$), number of weedings (Pearson's $r = -0.068$, $df = 32$, $p \leqslant 0.704$), number of applications of herbicides (Pearson's $r = -0.274$, $df = 33$, $p \leqslant 0.112$) or insecticides (Pearson's $r = -0.332$, $df = 33$, $p \leqslant 0.052$), or any soil characteristics other than phosphorus content, for which there was a weak negative correlation ($r = -0.342$, $df = 32$, $p \leqslant 0.048$).

Yield in plots planted with primarily *certificado* seed was significantly higher than yield in plots planted with *criollo* seed ($F = 4.599$, $df = 33$, $p \leqslant 0.040$). However, because *criollo* seed was more commonly planted in more steeply sloped plots and certified seed was not planted in any plots with slope greater than 25%, it may have been slope rather than seed type that was driving the yield differences, as slope was negatively correlated with yield

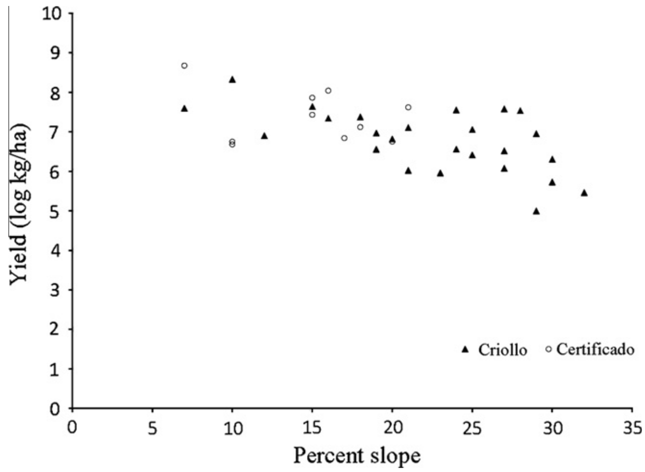

Fig. 3. Relationship between slope and maize yield (Pearson's $r = -0.612$).

for both seed types (Fig. 3). To investigate this, we conducted the same analysis with a subsample of plots with slope less than 25% ($N = 27$). With this subsample, there was no significant difference in yield between plots planted with certified and *criollo* seed (Students $t = 1.428$, $df = 22$, $p \leqslant 0.245$), though there was still a significant negative correlation between plot slope and yield (Pearson's $r = -0.504$, $df = 23$, $p \leqslant 0.012$).

The challenge of growing maize and beans on steep slopes at high elevations was a common topic in interviews with farmers. The growing season corresponds with the rainy season, which often brings more rain than the shallow soils of western El Salvador can handle. Steep slopes frequently suffer landslides, which may bring the entire crop with them; even the usual rainstorms of the rainy season can cause significant erosion (Buckles et al., 1998). Citing encouragement from NGO agricultural training projects, the majority of farmers in this study left corn plant residues in the field following harvest and cultivated live barriers of izote (*Yucca elephantipes*) plants perpendicular to the slope of the plot. Plots that were owned by the farmer rather than rented were significantly more likely to have live barriers planted (Pearson's $\chi^2 = 6.842$, $df = 1$, $p \leqslant 0.009$), as farmers explained that if they made improvements to a rented plot, the owner would likely take it away from them the next year because it would be worth more.

In 11 of the plots in this study, farmers cited lodging of maize plants as a detriment to the productivity of the plot. Lodging generally results from the strong winds that accompany rainstorms in El Salvador, with the steep slope of the land and thin, clayey soils of western El Salvador combining to prevent plants from developing strong root systems (Norman et al., 1995). Farmers did not specifically mention that *criollo* seed was more resistant to lodging, though some did mention that it developed a stronger root system. While improved varieties have generally been bred for short stature in order to resist lodging (Bellon et al., 2006), this does not appear to be providing a significant yield advantage in this environment.

4. Discussion

Despite integration into the global economy via coffee sales, small-scale coffee farmers in the highlands of El Salvador continue to grow basic grains for subsistence production. This is consistent with research in coffee landscapes elsewhere in Mesoamerica, which has found that basic grain production continues to be an important livelihood strategy for small-scale coffee farmers, particularly those who are spatially and economically marginalized (Jaffee, 2007; Trujillo, 2008). In our study, even those farmers who claimed that they prioritized coffee production over other livelihood strategies still continued to produce basic grains, indicating that this activity is considered necessary to ensure family food security. One participant summed up her perception of basic grain production as follows: "If I had to buy all of my maize and beans, I would not be able to eat."

In their dual roles as coffee and grain producers, these farmers face a number of challenges. The hilly areas that are well-suited to growing high-quality coffee are not ideal for production of grains, particularly maize. The cool, wet conditions at high altitudes slow the growth of maize and favor certain pests and fungal diseases, and steep slopes are prone to erosion (Buckles et al., 1998) that contributes to lodging. As a result, maize yields tend to be low in these environments. Climate change is likely to exacerbate the already erratic environmental conditions in this area, increasing the intensity of temperature and precipitation extremes and the interannual variability in climate (Solomon et al., 2007).

Local maize landraces appear to meet some of those challenges. Farmers in this study had a clear preference for local landraces in higher-altitude and more steeply sloped plots, which confirms findings by Keleman et al. (2009) that landraces tend to be planted on more marginal lands. There was no significant yield advantage for improved maize over landraces, despite claims by national breeding programs that it has higher yield and is more pest and disease-resistant than landraces (CENTA, 2002). Additionally, the higher genetic variation in landrace populations could give them an advantage over improved varieties in adapting to the effects of climate change, albeit with variation in adaptation capacity between specific landraces (Mercer and Perales, 2010). Vigouroux et al. (2011), for example, found that phenotypic adaptation of landraces via human and natural selection have played a significant part in crop adaptation to climate change in the Sahel. This may be occurring with maize landraces in Mesoamerica as well.

Interestingly, though research elsewhere in Mesoamerica has found that improved seed varieties are (accurately) viewed by farmers as more input-intensive (Bellon and Hellin, 2011), the farmers in this study managed landraces and improved varieties with similar input levels. There were no significant differences in fertilizer application or use of compost, organic insecticides, or herbicides between plots planted to *criollo* and *certificado* seed. There was, however, a positive association between synthetic insecticide use and *criollo* seed use, though this was likely due to the higher elevation of *criollo*-planted plots. Thus, farmers who chose local seed landraces were not necessarily rejecting Green Revolution technologies altogether, but instead mixing traditional seed landraces with "technified" management methods.

There are two interacting explanations for the strong relationship between higher income and use of *criollo* seed. First, in focus groups, most farmers expressed a preference for *criollo* seed, with *certificado* seed used primarily because the farmers received it for free from the government. They described *criollo* maize as having "stronger roots" and being more disease-resistant. Farmers with higher income may have had a higher capacity to act on this preference, either by saving more of their maize crop for seed or purchasing preferred *criollo* seed. Second, the relationship between income and seed choice may have been partly an effect of the relationship between income and the number of plots managed by a household. Using the household as the unit of analysis, households managing more than one *milpa* plot had higher per capita incomes than households managing only one plot ($F = 6.864$, $df = 24$, $p \leqslant 0.016$). Because farmers generally only received enough *certificado* seed through the government distribution program to plant one plot (or most of one plot), farmers who planted more than one plot (those with higher incomes) were therefore less likely to use government-distributed *certificado* seed in their remaining plots.

These findings have several implications. For one, despite a robust government seed provisioning program, improved varieties do not appear to be meeting the needs of subsistence *milpa* farmers with marginal land. While improved seed varieties may have substantial benefits for farmers growing maize commercially and those in the flatter lowlands, the major seed producers do not tend to cater to the need of small-scale hillside farmers for maize varieties that give stable yields on wet, highly sloped land without high levels of inputs. Research has documented this dynamic in Mexican agriculture as well, where large-scale commercial farms were the primary focus for improved maize seed (Bellon and Berthaud, 2004) and local landraces better met smallholder farmers' preferences for production and consumption (Badstue et al., 2007). As the responsibility for seed production shifts more from the state to the private sector (Ferrufino, 2009), it will become increasingly unlikely that maize breeding efforts will be geared towards the needs of small-scale, resource-poor farmers, who do not have the political-economic power to influence corporate breeding programs. This makes it all the more important to support small-scale famers in the maintenance of locally-adapted seed.

Second, the results from this study suggest that coffee regions may be areas of conservation of crop genetic diversity in addition to wild plant and animal biodiversity. Shade coffee landscapes have been recognized for over a decade as sites of high conservation value for plant and animal biodiversity (Méndez et al., 2010a,b; Moguel and Toledo, 1999; Perfecto et al., 1996; Perfecto and Vandermeer, 2002, 2008a; Soto-Pinto et al., 2010). This research has focused primarily on wild agrobiodiversity, defined as those species that colonize an agroecosystem without direct intervention by the farmer. However, only recently have researchers begun to realize the conservation potential of non-coffee areas managed by coffee farmers, as well as their importance to farmers' livelihoods (Méndez et al., 2010a). This is of particular relevance in countries like El Salvador where the seed market is dominated by improved varieties produced by multinational corporations, and where small-scale hillside farmers may be some of the only farmers still maintaining landraces of maize seed. Farmers benefit from this diversity in the form of better-adapted maize, but this on-farm conservation of crop diversity may also have global impact as a source of genetic variety for future maize breeding (Smale et al., 2001). *In situ* conservation of genetic resources has been recognized as a key strategy for conserving crop genetic resources (Bellon et al., 2003b; Isakson, 2011). The importance of these landraces may become even more apparent as we begin to see the effects of climate change in the tropics, which is predicted to cause more erratic precipitation of greater intensity (Solomon et al., 2007). As supported by this study, landraces tend to be better adapted for more marginal farming environments, and climate change is likely to expand the area considered "marginal" for agriculture.

While *milpa* plots embedded in shade coffee landscapes enhance conservation potential for crop genetic diversity, the use of synthetic fertilizers and pesticides in the *milpa* can compromise the landscape's potential as habitat for wild biodiversity. A new paradigm is emerging in conservation biology that recognizes the reality that wild plant and animal species in the tropics often exist in a fragmented landscape of patches of forest habitat surrounded by agriculture. In this fragmented landscape, habitat patches that are biodiversity-poor (e.g. cultivated fields, called "matrix") serve as important passageways between patches that are biodiversity-rich (e.g. reserves or forests). The quality of the agricultural "matrix" thus plays an important role in the maintenance of species populations (Anderson et al., 2007; Perfecto and Vandermeer, 2008b, 2010; Philpott et al., 2008). In coffee landscapes, this paradigm has generally been applied to emphasize the importance of shade coffee agroecosystems as a high-quality matrix between patches of conserved forest. However, shade coffee agroecosystems, particularly those managed by smallholders, are often themselves further separated by patches of cultivated crops that coffee farmers manage for subsistence, as is the case with the landscape in this study. While the plots managed by the farmers in this study comprise a relatively small portion of the landscape, *milpa* cultivation covers 24% of the land within a one-kilometer radius of the study plots (Fig. 2). It is likely that most of this cultivation is carried out using similar, if not more intensive, use of synthetic fertilizers and pesticides. The quality of shade coffee forest as habitat for wild biodiversity may thus be highly influenced by the management of the surrounding maize and bean plots. In this study for example, the use of methyl parathion is of particular concern as it is one of the most highly toxic organophosphate insecticides, posing high risks to human health, especially in children (Eskenazi et al., 2007), as well as to birds and aquatic invertebrates (Kalipci et al., 2010).

Unlike with coffee, there is no market incentive to grow maize or other food crops organically, as nearly all such products are consumed locally. Furthermore, national extension agencies continue to advise more conventional, chemically-intensive methods. Despite this, some organic coffee growers are already taking the growing methods that they use for their coffee and applying them to their maize and bean production as a way of saving money on inputs (Bray et al., 2002; Jaffee, 2007), and NGOs are providing support for more agroecological growing methods. For example, several participants in this research were members of a project sponsored by The Foundation for Socioeconomic Development and Environmental Restoration (FUNDESYRAM) to produce organic compost for their corn and bean plots. Also, hillside farmers in Honduras have had great success increasing soil quality and yields by using velvetbean (*Mucuna pruriens*) as a cover crop (Buckles et al., 1998). Other NGOs and farmer movements are providing support for *in situ* conservation of crop genetic diversity. The *Campesino a Campesino* (Farmer to Farmer) movement in Latin America, for example, has prioritized recognition and conservation of local seed landraces among its objectives (Holt-Giménez et al., 2010). In the municipality of San Ramon in Matagalpa, Nicaragua, NGOs and unions allied with the *Campesino a Campesino* movement carried out a study in 2008 to recognize and conserve local seed landraces. Based on this work, the organizations then established a set of local seed banks and a municipal seed bank, with the eventual goal of expanding to nearby municipalities and increasing reproduction of local landraces (Holt-Giménez et al., 2010). Programs such as FUNDESYRAM's and *Campesino a Campesino*'s, when combined with enabling policies such as access to credit and land (Buckles et al., 1998), have the potential to positively impact water quality, biodiversity, and carbon sequestration in coffee landscapes while supporting farmers' control over their own food supply. Support for agroecological methods and landrace conservation will also be critical to help small-scale farmers meet the challenges of climate change.

5. Conclusion

The important role that local landraces play in the *milpa* farming of small-scale coffee producers of western El Salvador suggests that government spending to support small-scale agriculture might be better focused on maintaining and improving landraces than distributing free hybrid seed. As farmers prefer landraces and there is evidence that they perform at least as well as improved varieties under local conditions, we suggest that participatory approaches to strengthen farmers' own practices of seed saving and exchange may be a better approach, particularly in light of increasing corporate control of seed supply systems. Programs that support existing informal seed markets, exchange networks, and farmer seed saving can provide farmers with high-quality, locally adapted seed (Sperling and McGuire, 2010) while conserving crop genetic diversity and strengthening local livelihoods.

Our research also demonstrated that despite some advances by NGOs to support agroecological technical assistance, the national extension service remains fixed in disseminating green revolution technology packages, which are not well adapted to the context of smallholders in marginal environments. Our findings highlight the need for a redirection of support towards agroecological methods of food crop production in coffee landscapes, particularly those with steep slopes. Despite the crop biodiversity conservation potential of *milpa* plots in coffee agroecosystems, the erosion potential of such plots coupled with the use of herbicides and synthetic insecticides can compromise the conservation value and ecological functioning of the agroecosystem as a whole. This calls for an integrated approach the brings together national agricultural agencies, NGOs, and farmers to develop agroecologically-based approaches for seed and *milpa* management that are better adapted to the realities of small-scale coffee farmers.

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