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Explaining the 'hungry farmer paradox': Smallholders and fair trade cooperatives navigate seasonality and change in Nicaragua's corn and coffee markets

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ABSTRACT

Latin American smallholder coffee farmers linked with fair trade and organic markets are frequently cited as models for sustainable food systems. Yet many experience seasonal hunger, which is a very common, but understudied, form of food insecurity. Northern Nicaragua's highlands include well-organized cooperatives, high rural poverty rates, and rain dependent farms, offering a compelling study area to understand what factors are associated with seasonal hunger. This participatory mixed methods study combines data from observations, interviews and focus groups with results from a survey of 244 cooperative members. It finds that seasonal hunger is influenced by multiple factors, including: (1) annual cycles of precipitation and rising maize prices during the lean months; (2) inter annual droughts and periodic storms; and (3) the long-term inability of coffee harvests and prices to provide sufficient income. Sampled households experienced an average of about 3 months of seasonal hunger in 2009. A series of five least squares regression models find the expected significant impacts of corn harvest quantity, farm area, improved grain storage, and household incomes, all inversely correlated with lean months. Unanticipated results include the finding that households with more fruit trees reported fewer lean months, while the predominant environmentally friendly farming practices had no discernable impacts. The presence of hunger among producers challenges sustainable coffee marketing claims. We describe one example of a partnership-based response that integrates agroecological farm management with the use of fair trade cooperative institutions to re-localize the corn distribution system. Increased investments and integrated strategies will be needed to reduce threats to food security, livelihoods, and biodiversity associated with the rapid spread of coffee leaf rust and falling commodity prices.

1. Introduction

Although the global food system currently produces enough food to feed more than 9 billion people, hunger persists among more than 870 million (FAO, 2012; Godfray et al., 2010). An estimated 2.5 billion worldwide depend upon harvests from about 500 million smallholder farms (FAO, 2013; IFAD-UNEP, 2013, p. 8). Approximately 80% of those facing food insecurity live in rural areas, and half are small-scale farmers, often managing marginal lands (FAO, 2012; Sanchez and Swaminathan, 2005). This "hungry farmer paradox" illustrates the vast inequalities in a global food system that also generates damage to the environment and human health (Gottlieb and Joshi, 2010).

Intense environmental and food policy debates persist about production- versus distribution-oriented approaches to improving food security and about the degree to which solutions should contribute to broader environmental and social goals (IAASTD, 2009; Wittman, 2011; Maxwell and Slater, 2003). Sustainable intensification and diversification are both potentially effective

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strategies (Ellis, 2000; Pretty et al., 2011), but remain production-oriented and fail to consider questions about uneven food distribution (Horlings and Marsden, 2011). Government sponsored food assistance strategies are often effective and could develop more innovative approaches (Lentz et al., 2013), but they historically have focused on immediate needs, typically addressing neither structural causes of hunger nor broader sustainability goals. A fourth strategy is the creation of sustainable agrifood systems, which can address production as well as distribution, consumption, and environmental, socio-economic and cultural factors (Goodman et al., 2011). Although this strategy holds significant potential, few studies have assessed links between "sustainable" global food systems and farmer food security.

This article analyzes seasonal hunger as an understudied aspect of food security in certified sustainable commodity chains, interrogating the case of fair trade/organic coffee farmers in northern Nicaragua. It documents the extent of seasonal hunger and key contributing factors among smallholder coffee producers. It also describes household, cooperative, and NGO responses to food insecurity and analyzes the relationship between sustainable agricultural practices and seasonal hunger. We integrate qualitative field research with the existing studies on rural food security, agroecology, certified sustainable coffee, and rural institutions to develop the following research questions and hypotheses:

(1) What factors are associated with seasonal hunger among smallholder coffee producers?

   Based on a large theoretical and empirical literature as well as interviews and focus groups with farmers, we predict that households with higher incomes, access to more favorable terms of exchange in markets, and larger agricultural harvests will tend to report shorter periods of seasonal hunger, other things equal. On the other hand, the occurrence and intensity of natural hazards—such as droughts or storms—and economic shocks—such as falling coffee prices—will adversely impact household food security.

(2) Do coffee smallholders selling to fair trade markets and using more environmentally friendly farming practices experience shorter periods of seasonal hunger?

   The literature studying the impact of environmentally friendly farming and certified organic production on agricultural yields, income, and poverty among smallholder farmers is mixed. Certification is associated with favorable market access, prices and farming practices, such as the elimination of toxic chemicals and resource conservation, which may enhance incomes and mitigate risk. However, short-term yields may fall and production costs rise, offsetting these gains. We posit that many of the same tradeoffs will affect the impact of certification on exposure to seasonal hunger.

(3) How have coffee smallholders, cooperatives, and other stakeholders responded to the challenge of seasonal hunger?

   Through decades of navigating predictable seasonal dynamics related to the timing of rain, agricultural harvests, the availability of off-farm employment, and periods of food scarcity, smallholders and local communities have developed various coping strategies, at times augmented by mainstream food assistance programs, while stakeholders in the coffee value chain (sometimes including cooperatives) have historically ignored rural hunger. Based on survey evidence, interviews and participant observation, we identify and describe these household and community responses in the Nicaraguan context.

This article also describes a partnership launched by several of the coauthors linking a sustainable agriculture NGO to cooperatives through a community-based participatory action research initiative that holds the potential to develop more effective strategies to reduce seasonal hunger, while empowering farmers, and conserving agricultural biodiversity.

1.1. Smallholder food security, seasonal hunger and livelihood vulnerability

Seasonal hunger, a predictable and cyclical pattern of reduced food availability and access, is the most common form of food insecurity that smallholders face. Influenced by annual cycles of work, weather, and changing markets, seasonal hunger is often exacerbated by natural hazards and political economic trends and shocks (Chambers, 1982; Vaitla et al., 2009; Barrett, 2010). It also correlates with fluctuations in climate, cropping patterns, and human disease (Vaitla et al., 2009). Smallholders often do not produce enough food to last their household the full year and/or sell a portion of their subsistence crops after the harvest, when market prices are low and cash demands are pressing, and then cannot afford to buy food during the subsequent lean months when crop prices are typically higher (Devereux et al., 2008). The timing of income from off-farm employment, remittances, and cash crops can further affect the duration and intensity of the lean months.

An emphasis on how households access food, rather than on aggregate food availability, is a hallmark of Amartya Sen's entitlement approach to poverty and famines (Sen, 1981; Scoones, 2009; Adger, 2006). In this spirit, the World Food Summit of 1996 moved analytic focus away from narrow measurements of food availability to questions about food access, initiating greater official consideration of food distribution and socioeconomic inequality (Sen, 1981; Devereux et al., 2008; Pinstrup-Andersen, 2009): "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996).

Access to natural resources, markets, and support networks gradually became a central theme for studying rural development and change (Ribot and Peluso, 2003). Questions about food access through time suggest consideration of household livelihood vulnerabilities, which encompass exposure and sensitivity to annual climate variability, natural hazards, such as droughts and storms, and economic trends, such as rising input costs and changing commodity prices (Adger, 2006, p. 268; Eakin and Luers, 2006, p. 366; Scoones, 1998). Thus, hunger is causally linked to vulnerability, poverty and ultimately powerlessness as manifested in the inability of households to access sufficient food through production, exchange, or other means (Watts and Bohle, 1993).

From this perspective, seasonal hunger arises not only from chronic shortfalls in production, but also from annual and trend fluctuations in the terms of trade between food and nonfood commodities, limited access to self-insurance (such as storage and precautionary savings), and inadequate collective (institutional) mechanisms for pooling risk, providing access to short-term credit, etc. Accordingly, strategies that use this theory to address rural hunger seek to change the institutions (i.e., laws, informal norms, local associations, market channels, agricultural ministries, etc.) that shape the terms of exchange (Ostrom, 2005; Sen and Drèze, 1989).

1.2. Environmentally friendly farming practices, agroecology, and smallholder food security

An open scientific and agricultural development policy question concerns the extent to which environmentally friendly farming practices can meet the challenge of improving smallholder food security while reducing negative environmental impacts, and the extent to which this issue can—or should—be linked to broader questions about justice and democratic participation throughout the food system (Foley et al., 2011; Seufert et al., 2012; Kremen and Miles, 2012; Pretty et al., 2011; Goodman et al., 2011). One of the many methodological challenges here is that there is no consensus on what counts as an 'environmentally friendly farming practice'. Many approaches exist, ranging from the most commonly known certified organic systems to less-understood perspectives such as biodynamic farming, and these approaches generate smaller negative environmental impacts than industrialized monoculture production (Kremen et al., 2012; Pimentel et al., 2005; Gomiero and Pimentel, 2011; Carlisle and Miles, 2013).

Most of the research on environmentally friendly agriculture has focused on yield performance of organic vs. conventional production systems (Seufert et al., 2012; Badgley et al., 2007). Fair trade standards require several environmentally friendly farming practices, such as prohibiting the use of highly toxic agrochemicals (Fairtrade International, 2012). However, these are minor adjustments compared to the elimination of synthetic agrochemicals and the soil fertility management required by certified organic production. Recent review articles using meta-analysis approaches broadly converge on the conclusion that industrialized agriculture often generates higher yields for a single crop, but there are additional considerations (Kremen and Miles, 2012; Seufert et al., 2012). Seufert and colleagues (2012) found that conventional systems averaged 25% higher yield, but there were important context-dependent differences related to crop type (e.g. gaps were lower for perennial crops), experience with organic agriculture, and the use of best management practices (Seufert et al., 2012, p 229; see also Kremen et al., 2012). In low intensity smallholder farming systems in which few recommended management practices are implemented, sustainable agriculture methods can increase yields and incomes (Altieri, 2002; Asaah et al., 2011) while avoiding several costs associated with agrochemical-based intensification (Tilman et al., 2002; Noltze et al., 2013). Studies that extend the organic vs. conventional comparison to measure ecosystem services found "substantial evidence" that organic systems outperform conventional systems in most areas, including biodiversity conservation, control of arthropod pests, weeds and diseases, pollination services, soil quality maintenance, energy efficiency and reduction of global-warming potential, resistance and resilience to extreme weather events, and enhanced carbon sequestration and water-holding capacity in surface soils (Kremen and Miles, 2012; Gomiero and Pimentel, 2011). Farmers are not typically compensated for the full value of these contributions to the environmental commons.

Although the adoption of environmentally friendly agriculture may entail short-term tradeoffs between yields and environmental impact in specific contexts, a complete assessment of the implications for food security would require comparing the total human-edible calorie yield of all crops produced over a complete rotation, rather than the yield ratios for single crops, and comparing the variance in incomes and yields (risk), not just the mean (Foley et al., 2011; Kremen et al., 2012).

Agroecology is an approach that smallholders often use to increase yields, generate environmental benefits, contribute to household food security, and advance farmer autonomy (Altieri et al., 2012; Kremen et al., 2012; Tscharntke et al., 2012). This approach seeks to manage whole systems, integrate high levels of agrobiodiversity, improve soil fertility, and dramatically reduce synthetic and fossil fuel inputs (Gliessman, 2007). Agroecology contributed to creating the system of rice intensification (SRI) in Asia, and farmers that adopted it reported increased yields, reduced seed costs, water conservation, and, in some cases, higher incomes (Styger et al., 2011; Noltze et al., 2013). In Malawi, farmers used inter-cropping to reduce synthetic fertilizer use and increase protein yield values (Snapp et al., 2010). Agroecology-based strategies also fit well with institutional efforts to create more sustainable food systems and advance *food sovereignty* (De Schutter, 2011; Wittman, 2011).

1.3. Sustainable food systems, eco-labeled coffee and cooperatives

The model of an agrifood system depicts the processes and interactions that determine what, how much, by what method, and for whom food is produced, processed, distributed, and consumed (Ericksen, >2008; Pimbert et al., 2001). A sustainable agrifood system targets multiple goals, including meeting basic human needs in current and future generations; enhancing a community's environmental, economic, and social well-being; and resisting damages from economic hazards and shocks (Ericksen, 2008). Eliminating seasonal hunger is an essential step in creating a more sustainable agrifood system.

Sustainable agrifood systems oriented researchers often study the relationships linking certified fair trade, shade grown, and organic coffee markets to Latin American landscapes and communities (Rice, 2001; Raynolds, 2000; Mutersbaugh, 2004; Eakin et al., 2006; Giovannucci and Ponte, 2005; Goodman, 2004). Mesoamerican coffee smallholders reproduce indigenous cultures (Altieri and Toledo, 2011), manage high levels of biodiversity (Perfecto et al., 1996), and generate many ecosystem services (Jha et al., 2011; Vandermeer et al., 2010). Organized smallholder cooperatives have partnered with religious groups, development agencies, and businesses to create organic and fair trade networks as an alternative to the global commodity markets (Bacon et al., 2008).

The rapid expansion of fair trade coffee value chains offered increased market access and price premiums that partially invigorated secondary cooperatives in Latin America (Raynolds et al., 2007). The initial goals of fair trade were to create a "different" type of market rooted in values of North-South solidarity, reciprocal exchange, smallholder and worker empowerment, and environmental sustainability (Reed, 2009). Core criteria for the international fair trade coffee labeling system include: a minimum price floor (currently at $1.50/lb for Arabica coffees), prioritization of smallholder cooperatives, a price premium for social development (currently $0.20/lb) (Fairtrade International, 2011), a set price differential for certified organic production, annual audits to ensure transparency and accountability within the cooperatives, and selected standards for environmentally sustainable production (Jaffee, 2012). Furthermore, there is a loose network of international development agencies that frequently partner with NGOs and fair trade certified producer associations to fund projects focused on marketing, agricultural productivity, diversification and to a lesser extent environmental management and social development.

Smallholder cooperative institutions can coordinate collective action to govern natural resources, manage risk, and broker access to markets, development projects, and government agencies (Agrawal, 2010; Tucker et al., 2010). Coffee marketing cooperatives in Mexico also help farmers navigate market risks and vulnerability to climate events, such as drought (Frank et al., 2011). Several studies have considered the effectiveness of co-ops and associations in creating sustainable food systems that meet urban food security goals (Allen, 1999; Guthman et al., 2006; Rosset et al., 2011) and assessed co-op impacts on rural livelihoods (Raynolds, 2002; Méndez et al., 2010; Francesconi and Heerink, 2011). However, few have probed how, if, and under what circumstances agricultural marketing cooperatives address farmer food security.

1.4. Certified sustainable coffee and the challenge of rural food security in Latin America

An expanding literature studies the influence of organic and fair trade coffee markets upon farmer livelihoods (Wilson, 2010;

Mutersbaugh, 2002; Raynolds et al., 2007; Bacon et al., 2008; Jaffee, 2007; Valkila, 2009). Smallholders linked to cooperatives and fair trade organic markets generally receive higher farm gate prices, improved access to credit, enjoy more social ties to outside organizations, and, in some cases, have higher levels of educational attainment (Raynolds, 2009; Méndez et al., 2010; Bacon et al., 2008; Arnould et al., 2009). Case study evidence further suggests that farmers with diverse shade coffee production systems are less vulnerable to hurricanes (Philpott et al., 2008), and that those linked to fair trade markets have lower exposure to coffee market price crashes (Bacon, 2005). However, research also shows that the higher prices associated with fair trade and organic markets, even when coupled with international development funding to fair trade co-ops, do not necessarily cover additional costs (Barham and Weber, 2012), and as a single strategy are insufficient to ensure sustainable livelihoods (Bacon et al., 2008; Barham et al., 2011; Fraser et al., 2014; Calo and Wise, 2005; Valkila, 2009). Previous research in Nicaragua and Latin America finds that smallholder poverty and farmer debt persist, though debates about causes remain (Bacon et al., 2008; Wilson, 2010; Beuchelt and Zeller, 2011). Ethnographic research has revealed that while certification requirements can sometimes complement indigenous organizations (Castillo and Nigh, 1998), they can also disrupt community labor routines and perpetuate uneven gender relations (Mutersbaugh, 2004; Lyon et al., 2010).

Farmer food insecurity is a fundamental challenge to the goals of fair trade coffee and other sustainable coffee certification programs (Bacon et al., 2008), and its presence among participating households raises concerns about "greenwashing" (Howard and Jaffee, 2013). In the mid-2000s, marketing campaigns from coffee certification organizations often implied that certified farmers were experiencing considerably improved livelihoods (including food security), due to their participation in these fair trade markets (Goodman, 2004). The field research conducted at this time showed several livelihood and organizational benefits but identified potential limits (Raynolds, 2002; Jaffee, 2007; Bacon, 2005). It also showed little household level evidence for the elimination of poverty and identified food security as a challenge for all producers including those linked to sustainable markets (Bacon, 2005). These findings, growing interest, and expanding markets spurred additional impact assessment research. Projects included a survey of farmers in Mexico and Central America by the International Center for Tropical Agriculture (CIAT), funded by Green Mountain Coffee Roasters (Fujisaka, 2007); a similar study funded by Oxfam America also in Mesoamerica (Méndez et al., 2010; Bacon et al., 2008); and a study funded through Transfair USA (now Fair Trade USA) in Nicaragua, Peru and Guatemala (Arnould et al., 2009). The CIAT and Oxfam America studies explicitly addressed food security, finding that households frequently experienced challenges in meeting their basic food needs. Both studies also noted that certifications (fair trade and organic) alone were insufficient for farmers to attain food security goals. Partly motivated by these studies, both researchers and coffee industry actors have continued raising awareness of the situation and responded through an expansion and deepening of research, as well as by funding projects in coffee communities (Caswell et al., 2012). More recently, several larger specialty coffee firms and non-governmental organizations initiated coordinated efforts to address hunger in the coffee lands (e.g. After the Harvest). Nicaragua has emerged as a key place to develop potentially innovative approaches to reduce seasonal hunger, largely due to its capable smallholder fair trade cooperatives and the relative safety of working in rural environments.

2. Study area, approach, and methods

2.1. Description of study area

The research site is located in the northern Nicaraguan departments of Estelí, Madriz, and Nueva Segovia (Fig. 1). The physical geography of north central Nicaragua includes plateaus, low mountains and hills. The altitudes of coffee production generally range from 700 to 1550 masl. Maps using the Holdridge Life Zone system classify the lower altitudes as Premontane tropical dry forest and the higher altitude coffee regions as Premontane moist forests (Khatun et al., 2013, p. 186). Annual precipitation varies; on average the study area receives 1357 mm, with the upper coffee growing altitudes receiving more (INETER, 2012). Seasonal patterns in this region divide the climate into a rainy season (May through November) and a dry season. Since 1950, deforestation in the northern mountains and Atlantic coastal plains has averaged 1500–2000 square kilometers per year, degrading soil quality, water, and biodiversity and altering local precipitation patterns (Tarrasón et al., 2010, pp. 814–815). Smallholders conserve much of the remaining tree cover through their shade coffee agroforestry systems and small forest patches (Jha et al., 2011).

In 2005, these departments were primarily rural, except for the city of Estelí, the largest in the northern region and the seventh most populous in the country (INIDE-MINSA, 2008). Table 1 summarizes the socio-demographic indicators of the study area. Population densities are relatively low compared with other Central American countries, ranging from 67 to 90 inhabitants per square kilometer (INIDE-MINSA, 2008, p. 8). Rural poverty rates are above national averages for Madriz and Nueva Segovia; childhood malnourishment was 34% in Madriz (MINSA, 2007). Although Nicaragua's per capita GNP has rapidly increased in the past five years, poverty persists, with 68% of rural households living on less than $1.88 a day (FIDEG, 2009).

2.2. Participatory action research and partnership-based approach

This study emerged in the context of the lead author's ongoing research on the impacts of fair trade and organic coffee among smallholders in northern Nicaragua and an internationally funded sustainable community development project with the goal of reducing seasonal hunger in coffee-growing communities. The project was based on a partnership model that links five organizations and multiple individuals: the California-based Community Agroecology Network (CAN), a non-profit international development and education organization; PRODECOOP, a leading fair trade smallholder cooperative in the Segovias (Denaux and Valdivia, 2012); CII-ASDENIC, a Nicaragua-based local development NGO focused on communications technology and research assistance; Santa Clara University professors; and Green Mountain Coffee Roasters. After the lead author drafted the initial project proposal with input from PRODECOOP's rural development team, a CAN hired consultant has coordinated the overall project implementation monitoring, and training programs. PRODECOOP, which has 2400 member families, including more than 1000 certified organic farms, provided the critical local institutional and administrative infrastructure, enabling the project to work with 18 of its 38 primary cooperatives. Santa Clara University and University of Vermont faculty collaborated with researchers to provide scientific advice for research design, farmer experimentation, monitoring methods, and statistical analysis. The coffee roaster provided funding and strategic advice. CII-ASDENIC contributed to the conduct of field research and project monitoring.

Through community-based participatory action research (CB-PAR), this partnership sought a democratic approach to knowledge

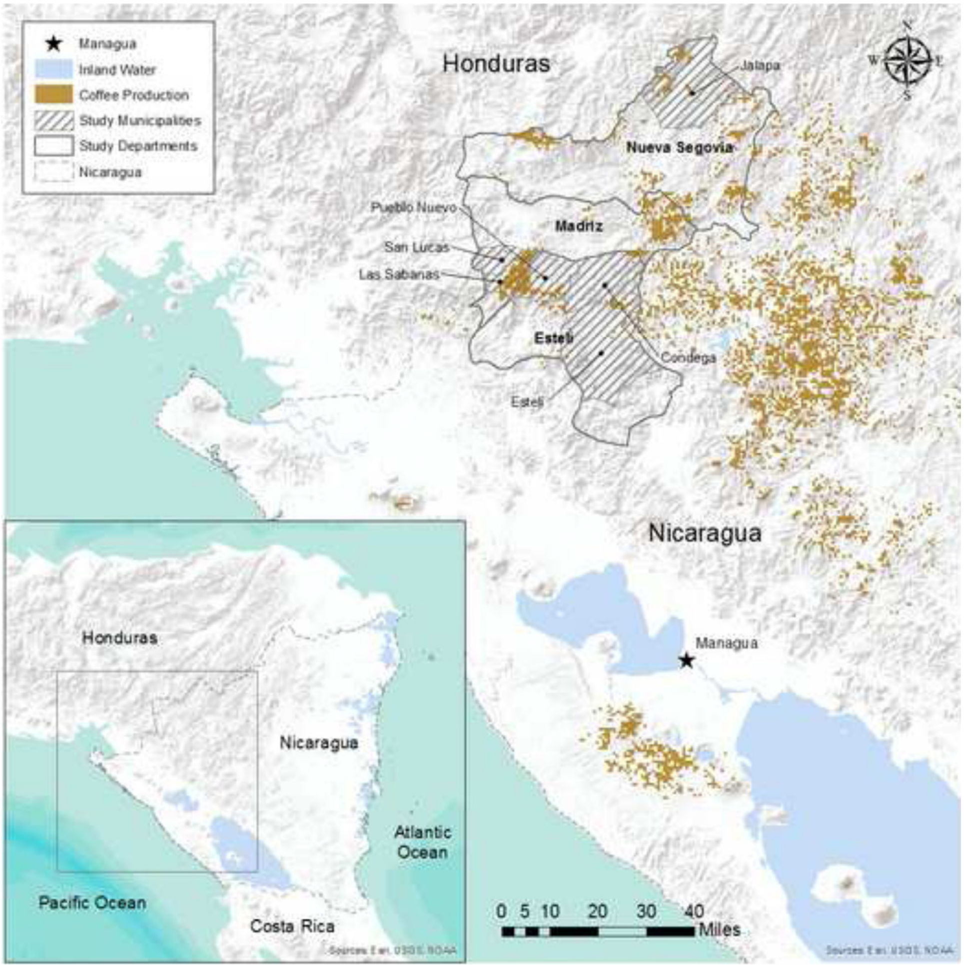


Fig. 1. Map of the study area.

Table 1
Socio-demographic, economic and agricultural indicators by department and municipality (HH).

Departmen	Population from census	% Rural Pop.	No. people/ HH	% Of rural employment in agriculture	% Rural HH insufficient basic services	Poverty rate in rural areas	Green coffee yields (kg/ha)	Corn yields (kg/ha)
National	5, 142, 098	45%	5	72%	25%	68%	269	546
Nueva Segovia	201, 548	59%	4.8	–		Moderate to high	147	762
Madriz	132, 459	69%	5.1	–	46% in rural communities of central north region	Moderate to high	298	627
Estelí	208, 523	41%	4.5	–		Low to moderate	133	798

Source for populations: VIII Censo Nacional de Poblacion y IV de Vivienda, 2005, p. 284.
Source for poverty levels: Instituto Nacional de Informacion de Desarrollo (INIDE), 2005.
Source for malnutrition levels: INIDE, Encuesta Nicaraguenese de Demografía y Salud 2006/07.
Source for coffee yields: Instituto Nacional de Informacion de Desarrollo (INIDE), Anuario Estdistica 2009, p. 266. Data for 2008/2009.

production and community change (Minkler and Wallerstein, 2010; Hacker, 2013). CB-PAR aims to link farmers' local and experiential knowledge with agronomists' technical skills and university researchers' theoretical knowledge and cross-case expertise. To enable this dialog among knowledge systems and create a shared vision, we used participatory facilitation techniques from the *campesino-a-compesino* movement (Holt-Giménez, 2006).

The local research team consisted of PRODECOOP's agronomists working from the co-op's central offices in the city of Estelí and a network of 24 primary co-op level promoters (farmers who receive a small monthly stipend from CAN and PRODECOOP to coordinate a wide range of activities). CII-ASDENIC staff with training in field research methods, information technologies, and local development coordinated the reception and initial data capture from surveys. CAN and ASDENIC staff drew from researcher recommendations, GMCR guidelines, and PRODECOOP interest to develop indicators for project monitoring and evaluation.

2.3. Study population and sample

PRODECOOP's general manager, rural development director, and board of directors identified, from the 38 primary cooperative members, 18 cooperatives and 854 affiliated households as the most food insecure. The criteria used by PRODECOOP to select co-ops and farmers for participation in this study and the subsequent intervention included: poverty levels, the severity of current food insecurity, high density of very small farms, small coffee harvests, and regions highly vulnerable to drought and climatic change. Primary level co-ops were geographically clustered, including all co-ops in several locations and none in others. The households in the selected co-ops constituted the research population. We stratified the population by local cooperative and used a random numbers table to select the names of 31% of the active members in each cooperative. All households in the sample were surveyed. We recruited focus group and interview participants from the sampled population but also included the purposeful recruitment of experienced cooperative leaders.

2.4. Mixed methods for data collection

We combined the participatory action research approach with a mixed methods strategy. Similar to other studies that integrate development work, reflexive ethnography and mixed methods (Below et al., 2012; Mikkelsen, 2005; O'Reilly, 2004), we used participant observation, key informant interviews, focus groups, workshops, a household survey, and document review (see Fig. 2). We replicated several data analysis strategies used by a recently published mixed methods study (Galt, 2013), using qualitative data to inform the hypotheses, identify variables to include in the regression analysis, generate the agricultural calendar and inform our analysis of the links connecting predictable seasonal dynamics of livelihoods, climates, and lean months. They also documented farmer concerns about the drought and irregular rainfall, prices received when selling forward their corn and bean harvests, coffee prices, and low wage compensation, confirming the relevance of Sen's exchange entitlement approach in this context. The use of mixed methods also enabled data triangulation. For example, we crosschecked the size of the coffee farm reported in the surveys with the interview results and records held by the cooperative's staff.

Qualitative methods were grounded in participant observation, which included attending food security project meetings, group conversations and two field visits per year for the previous three years (Miles and Huberman, 1994). Focus groups generally consisted of 5–7 male and female farmers. Questions addressed the topics summarized in Fig. 2, and methods were also drawn from participatory development handbooks (Gonsalves et al., 2005). Interview questions were semi structured and thematic. All 2013 interviews and focus groups were recorded and transcribed; others were selectively recorded or based on hand written notes.

The survey, conducted orally in Spanish with individuals in their homes, generally lasted 70–90 min. The lead author led the research team in the design of the survey through an iterative process that involved all partners and included field tests (see Fig. 2). Survey questions elicited livelihood, agricultural and food security data. Questions were drawn from past coffee smallholder household and agricultural surveys addressing similar topics (Arnould et al., 2009; Méndez et al., 2010; Bacon et al., 2008), including a Nicaraguan demography and health survey (INEC-MINSA, 2001). We also included several questions that serve as indicators for environmentally friendly farming, such as the use of cover crops, the number of crops and seed varieties, certified organic production, fertilizer use, and soil conservation (Piorr, 2003). In addition to these questions, PRODECOOP staff added several questions about coffee yields and management, and CII-ASDENIC staff added questions about technology and water use.

2.5. Measures of seasonal hunger

There is no single indicator for household food insecurity and very few that specifically target seasonal hunger (Webb et al.,

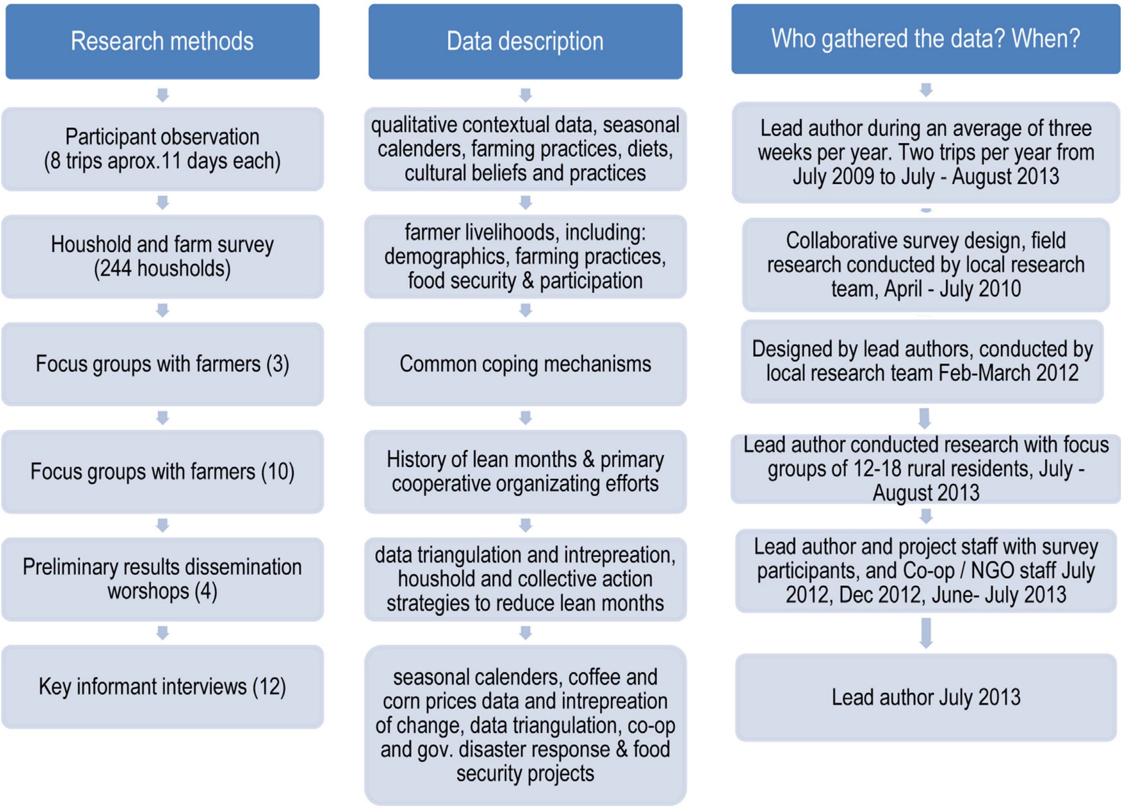


Fig. 2. Concept of field research methods and data collection activities.

2006; Barrett, 2010). Cyclical hunger can be overlooked by 24-h dietary recall studies, which focus on a limited period of time. To measure household food insecurity, the survey included multiple questions about food production and agricultural practices, and several that directly addressed seasonal food insecurity. A key sequence of questions started with one that asked the percent of foods consumed in the household that were grown on the farm. The second question asked if there was a moment in which they could not meet their basic food needs, and, if so, why not. The next question asked which months are the most difficult for their family [to meet basic food needs]. Based on follow-up conversations and data, we are confident that households answered this question based on their perceptions of the previous year (i.e. from April 2009 to April 2010). These self-reported "lean months" form the basis of the dependent variable in our regressions (see below). The following question asked where the household accesses food during the times of scarcity. Livelihood surveys that addressed food security among smallholder coffee farmers and rural residents in Nicaragua, El Salvador and Guatemala used similar questions (Morris et al., 2013b; Hahn et al., 2009; Fujisaka, 2007). Measures of food insecurity based on household self-reporting offer the advantages of including an overall assessment and the possibility of identifying "hidden" hunger that could be missed by other measures; however, they are limited by the subjective perceptions of what counts as a difficult month and the possibility of over-reporting (Maxwell et al., 1999).

We identified common food insecurity coping mechanisms from survey responses to an open-ended question about what households do to navigate the lean months, as well as answers to a series of commonly used questions that we adapted to reflect local cultures, which we asked in interviews and first focus groups (Maxwell et al., 1999; Morris et al., 2013a).

2.6. Data analysis: regressions

Our quantitative analysis of the survey data employs regression models to predict the incidence of seasonal hunger among smallholder households. The dependent variable is the number of lean months reported by the household. In our sample, this variable takes discrete values ranging from 1 to 7, with 96% of values in the range 2–5. We focus on the results of ordinary least squares (OLS) regression, given their ease of interpretation, but the results are qualitatively similar when Poisson regression is used to account for the count nature of the dependent variable. As regressors, we selected variables that were likely to play an important causal role in seasonal hunger, as suggested by our first and second research questions and hypotheses, and by information obtained from our qualitative methods. The exchange entitlement approach posits that access to food is influenced by food production, crops sales, and income sources. The capacity to secure adequate food between harvests and during high purchase price periods may also depend on buffer stocks of wealth, including, for example, animals and fruit tree. Farmers themselves frequently identified corn yields, farm size, and the number of family members as factors that explain the length of hungry periods. We are also particularly interested in the potential role of environmentally friendly farming practices in reducing seasonal hunger (question 2). The survey data include several sustainable farming practices, which we employ as regressors in selected models. We also explore the potential impact of social capital related indicators.

We start with a relatively simple baseline model, which uses indicators of household production, income, and food demand—the variables most closely related to our first research question. We then contrast this with alternative specifications that include indicators of sustainable agricultural practices as well as a several socioeconomic households characteristics. We also summarize various robustness checks and alternative specifications. Given the observational nature of our data and the absence of a randomized trial or natural experiment, the regression results cannot establish causality, but do reveal important correlations and provide evidence bearing on our key research questions.

3. Findings

3.1. The extent of seasonal hunger

Our main measure of seasonal hunger is the number of thin months that households reported for the previous year. The length of seasonal hunger was 3.15 months (SD = 1.06), or three months and 4.5 days.

A description of the common diets provides context to interpret the lean months. One person summarized her diet as such: "Corn we eat all year round, and tortillas, too. Tamales only when there is fresh corn from the harvest in August, and the other tamales are during *Semana Santa* or Easter Week. We eat rice about three times a week, but not in June, July, August, and September, when there is not money to buy it." In the surveys, households were asked to list recipes they would like to share and what time of year they cooked them. The participants in the interviews reported total of 700 individual recipes representing 102 different dishes, the most frequently shared receipts were those with beans and rice, but the range spanned from tortillas and tamales to vegetable stews, meats, eggs, cassava, salads, and fruit marmalades. The breadth of recipes demonstrates the extent of existing gendered food preparation knowledge (only 3 of the 244 respondents to this question were male). Although reluctant to talk about it, individuals also depended on food donations often consisting of soybeans and lentils, which, although not culturally preferred, provide needed protein.

To assess the severity of the lean months, we examined additional indicators of food stress—in particular, reports of coping mechanisms from surveys, focus groups, and interviews. The frequencies of different coping mechanisms are likely to be underreported; first, survey responses were coded from an open-ended question; second, although focus groups used a set of common questions, poor households could be less likely to discuss several coping mechanisms in the presence of peers. A common household dietary change during the lean months involved replacing tortillas with bananas and plantains. In focus groups, household case studies, and survey responses, individuals identified food rationing, eating less preferred foods, and using credit to buy basic foods during the lean months. Frequently reported food-rationing practices include eating less of everything, and eating beans one day and the bean water as soup the next.

Common coping mechanisms reported in the household survey responses are summarized in Fig. 3. The most frequently cited response was use of credit for subsistence food purchases, which can contribute to debt accumulation and asset loss (Maxwell et al., 1999). Households also reported food rationing and the "*busqueda*," which represents a desperate search and especially begging.

We find that seasonal hunger coincided with the mid-season dry period, known as "los Julio" or the *canícula* throughout Mesoamerica, a finding consistent with past research (Appendini and Liverman, 1994). Our findings are similar to recent studies in coffee-growing regions documenting coping mechanisms in El Salvador (Morris et al., 2013a), and finding that 44% of coffee smallholders interviewed in Nicaragua, 31% of those in Mexico, and 61% in Guatemala suffered food scarcity that lasted from 3 to 4 months (Fujisaka, 2007).

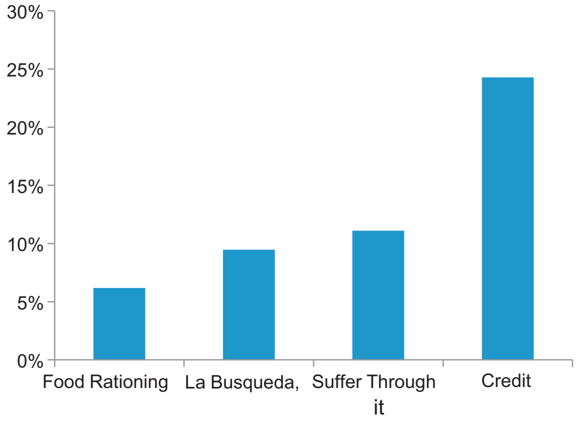


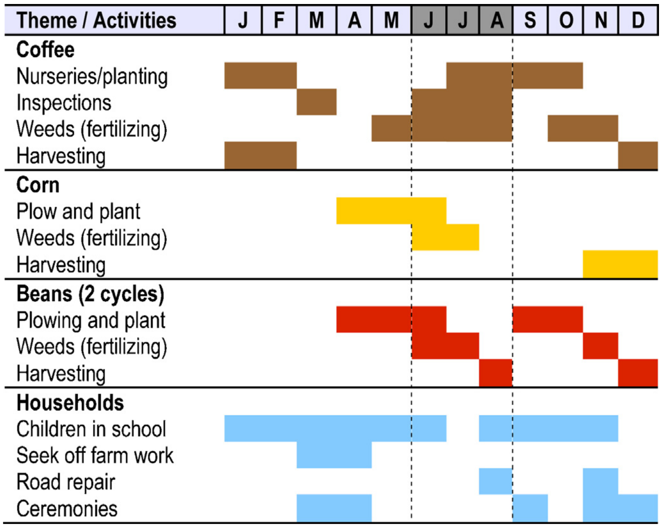
Fig. 3. Household coping mechanisms showing seasonal hunger severity ($n = 244$).

3.2. *The seasonality of coffee and corn farmer livelihoods*

Both coffee and subsistence crops are grown on steep slopes, often with thin soils, and are dependent on rain. During a regular year, the agricultural calendar starts with the anticipated *lluvias de Mayo*. Fig. 4 shows the seasonal calendar of agricultural and rural household activities, while Fig. 5 depicts the mutual correlations of lean months, seasonal agricultural activities, precipitation, and corn prices. Farmers prepare their fields and search for seeds in April. They may use saved seeds, borrow, trade, or buy seeds from neighbors, or receive donations.

The first sowing of corn and beans (*la primera*) generally starts in May, but sometimes as late as June, depending on precipitation, seed availability, and farmer decision-making. If they can afford them, most farmers use herbicides to control weeds in their corn and bean crop. Both organic and conventional farmers apply little to no fertilizer.

Figs. 4 and 5 show that the most frequently reported lean months of June, July and August are associated with a lack of income generating activities. The revenues from the coffee harvest are spent by May, and the previous season's corn and bean harvests are often depleted. At the same time, the market price of corn increases to reflect seasonal scarcity. This is a period when farmers may "look for work on the rich people's farms," and/or seek other forms of off-farm employment. Individuals may also participate in food-for-work programs, such as the World Food Program's rural road repair projects. Household food insecurity is exacerbated during the July break from school because students miss school feeding programs.



Theme / Activities	J	F	M	A	M	J	J	A	S	O	N	D
Coffee												
Nurseries/planting	🟫	🟫					🟫	🟫	🟫	🟫		
Inspections			🟫			🟫	🟫	🟫				
Weeds (fertilizing)					🟫	🟫	🟫	🟫		🟫	🟫	
Harvesting	🟫	🟫										🟫
Corn												
Plow and plant				🟨	🟨	🟨						
Weeds (fertilizing)						🟨	🟨					
Harvesting											🟨	🟨
Beans (2 cycles)												
Plowing and plant				🟥	🟥	🟥			🟥	🟥		
Weeds (fertilizing)						🟥	🟥				🟥	
Harvesting								🟥				🟥
Households												
Children in school	🟦	🟦	🟦	🟦	🟦	🟦		🟦	🟦	🟦	🟦	
Seek off farm work			🟦	🟦								
Road repair								🟦			🟦	
Ceremonies			🟦	🟦					🟦		🟦	🟦

Fig. 4. Summary of Nicaraguan coffee smallholder seasonal calendar.

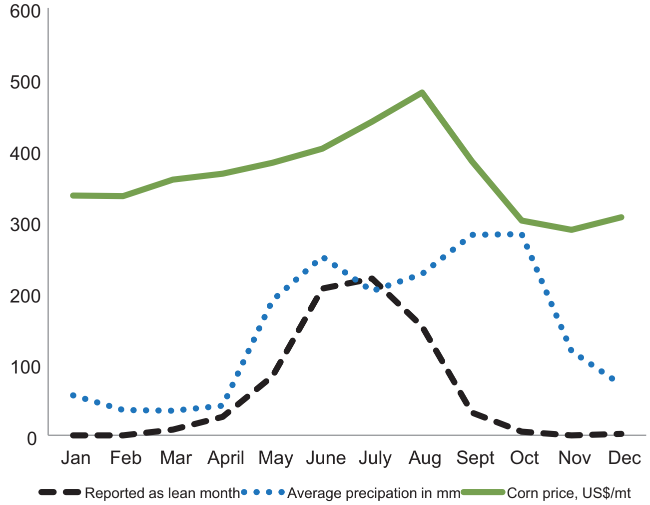


Fig. 5. Seasonal patterns of hunger, rain, and maize prices. *Notes and Sources*: Number of households ($n = 233$) reporting month as lean month. Average monthly precipitation, INETER, 2012; average monthly corn price ($/metric ton) predicted from linear regression using monthly dummy variables and linear time trend, 8/2007–12/2012. MAGFOR (2012).

Most farmers pick fresh corn to eat as early as September; however, they leave the majority to dry on the stalk until the *tapisque* or dry corn harvest in November. Dried white maize is *the staple food*—it is used to make tortillas and often to feed chickens, pigs and even pets. In August and September, households use the fresh corn or *maiz nuevo* to eat on the cob or prepare tamales and a different, sweeter type of tortilla. Although these foods are consumed or given as gifts, they are not a substitute for daily tortillas made from dried white corn.

The seasonal fluctuation of corn prices is a key factor in the food security outlook for farmers whose production or storage capacity of subsistence foods is insufficient. The pattern of corn prices reported in Fig. 5 shows average wholesale maize prices in Nicaragua from 2007 to 2012. Prices rise steadily until reaching their maximum in August and dropping rapidly to their minimum in November, coinciding with the peak harvest season of dried maize. Such a relationship between seasonal food prices and the annual harvest cycles has been observed in many developing economies with weak access to wider food markets (Devereux, 2010).

Fewer households report September as a lean month for several reasons, including falling corn prices, access to beans and fresh corn harvests, the availability of credit from cooperatives for coffee production. Farmers who sell to fair trade markets often receive the final part of the payment in September or October (the cooperative initially pays slightly above "local market prices" during the harvest months). This adjustment payment is based on the final price that PRODECOOP received after drying, sorting and exporting their beans.

Workloads tend to increase September through December as both subsistence and cash crops need pest control and fertilization. In late August and early September, farmers continue tending their perennial coffee and fruit trees, and seek seeds to plant the second cycle (*postrera*) of their annual crops. A family member often sleeps in the fields to protect the drying corn from theft. They also weed and fertilize coffee plots and transplant new coffee bushes and trees for both fruit and reforestation. However, some of these tasks, such as pruning coffee and shade trees, and applying sufficient organic or conventional fertilizers, are not performed consistently (Morris et al., 2013a; Guadarrama-Zugasti, 2008; Valkila, 2009).

In November and December, farmers harvest the dried maize and the second crop of dry beans (see Fig. 4). They also start several weeks of picking coffee cherries as they ripen. The coffee harvest timing depends on altitude as well as precipitation and temperatures during previous months. The coffee sales, harvests, and additional income from fruit sales (especially for the December holidays) increase food supplies and cash flows in rural economies.

The rainy season generally ends in November, and the coffee harvest continues into February. March and April are perceived to be the warmest and driest months. Although there is less agricultural work, the harvests and revenues from the previous two crop cycles usually last through May or June.

3.3. What factors are associated with the lean months among coffee smallholders?

We use regression analysis of the survey data to complement the qualitative findings reported above and assess in a multivariate setting the hypotheses associated with our first and second research questions. Table 2 provides sample statistics for all the variables used in our regressions. Most variables have responses for a large majority of the households. For the variables with missing values, we impute the missing value as the sample mean. This imputation had little effect on our core regression results (see below).

Table 3 presents the ordinary least squares regression coefficients, with heteroskedasticity-robust standard errors in parentheses. Column (1) is our baseline model, using core production, income and demand-related variables as regressors. Income per person in the household (logged) is included to capture the household's basic command over (entitlement to) purchased food. Income encompasses all sources of cash income reported by households, including sales of cash crops, earnings from off-farm wage labor, and remittances (less than 10% of surveyed households reported receiving remittances). The natural log transformation mitigates skewness and influence of outliers in the income variable. The estimated coefficient on log income can be interpreted as approximately the change in thin months for a proportional increase in income per person, other things equal. The production measures include corn, beans and coffee. We also include four key indicators of agricultural production capacity or wealth: the land area of the farm, the number of fruit trees, the number of chickens, and quantity of chemical fertilizer applied to grain production. We use individuals per household as a proxy for food demand. Finally, we include one variable for food security

Table 2
Summary statistics for variables used in regressions.

Variable	Units	Mean	SD	Min	Max	*N*
Dependent variable Number of thin months	Months	3.16	1.06	1	7	233
Baseline variables: Production, income, and capital						
Quantity corn harvested	Quintales (100 lbs.)	5.09	3.54	0	15	232
Quantity beans harvested	Quintales	4.75	3.93	0	12	233
Quantity coffee harvested	Quintales	26.95	28.80	0.5	200	233
Total land area	hectares	4.93	3.99	0.35	28.86	233
Number of fruit trees on farm	number	31.91	86.04	0	922	233
Number of chickens	number	6.70	7.31	0	50	233
Improved storage for corn and beans	binary	0.32	0.47	0	1	233
Quantity chemical fertilizer applied per ha to basic grain crops	Quintales/ha	0.30	1.27	0	14.2	233
Number of persons in HH	Number	5.67	2.41	1	13	233
Natural log of household income per person	U.S. dollars	3.86	1.55	0.55	7.35	233
Environmentally friendly farming practices						
Number varieties basic grains produced	Number	1.67	1.31	0	6	233
Number of fruit species produced	Number	2.49	2.03	0	10	233
Number of animal species raised	Number	1.74	1.20	0	6	233
Produce organic coffee	Binary	0.73	0.44	0	1	233
Use soil conservation for basic grains	Binary	0.48	0.50	0	1	233
Number of types of fertilizer used	Number	1.06	1.11	0	5.	233
Organic fertilizer applied per ha to coffee	Quintales/ha	3.39	6.73	0	56.82	232
Location (binary variables)						
Jalapa Municipality	Binary	0.20	0.40	0	1	233
Las Sabanas Municipality	Binary	0.11	0.31	0	1	233
Miraflor Municipality	Binary	0.06	0.25	0	1	233
Pueblo Nuevo Municipality	Binary	0.13	0.34	0	1	233
San Lucas Municipality	Binary	0.23	0.42	0	1	233
Household demographics						
HH members contributing income	Number	1.32	0.61	1	4	233
Number of families in HH	Number	2.25	1.28	1	4	233
Average age of HH heads	Years	48.57	13.09	20	83	233
Primary aged children attend class	Binary	0.41	0.49	0	1	233
Community and cooperative involvement						
Participate in community decisions	Binary	0.85	0.36	0	1	233
Hold leadership position in coop	Binary	0.32	0.47	0	1	233
Years of membership in coop	Years	16.53	12.07	0	140	233
Coping mechanisms						
Percent of basic food needs bought	Ordinal: <25%, 25–50, 50–75, 75–100%	1.77	0.79	0	3	233
Have access to credit	Binary	0.79	0.41	0	1	233
Distance to nearest health center	km	5.70	21.03	0	200	233
Receive help from NGO, etc.	Binary	0.19	0.39	0	1	233

Source: Household survey (see text).

"best practices," namely a binary variable for the use of improved storage methods (silos or metal barrels) for corn and beans.

The estimated coefficients in column (1) generally have the anticipated signs, with a negative number suggesting a correlation with fewer lean months. The negative coefficients on corn production, farm size, fruit trees, and income are all statistically significant ($p < 0.05$), suggesting an association with reduced seasonal hunger. In terms of the magnitudes of these effects, the size of the corn crop appears to have the greatest impact, with a beta coefficient of −0.26; the harvest of an additional 350 lbs of corn (a one standard deviation increase) is associated with families reporting seasonal hunger periods that are roughly eight and a half days shorter, other things equal. The number of fruit trees and income per person are the other variables with the largest marginal effects (beta coefficients are −0.19 and −0.16, respectively).

The coefficient on coffee production is positive and weakly significant at 10%. Although this is suggestive of a possible tradeoff between cash crop production and food security, it should be remembered that this regression controls for income. Coffee production could be expected to mitigate seasonal hunger by increasing household income. When income is dropped from the regression (results not reported here), the coefficient on coffee production is not significantly different from zero in any specification. Furthermore, the coffee coefficient loses its statistical significance when additional controls are included in the regression, even when income is included (columns 3–5). These results suggest that, for the coffee harvest sizes, prices, and costs of production in this sample, greater coffee production is neither enhancing nor detracting from seasonal food security. Our qualitative research suggests several additional considerations. Rural credit is generally based on the anticipated coffee harvest. Many households divert credit for coffee production activities to purchase inputs for their corn and bean production systems and to buy household food supplies. However, the corn yield benefits associated with these investments in basic grain production were not evident in our findings. This could be based on the production practices used and/or the corn and bean crop failures during the study period. The interest rates for rural loans are also significant, they are often 15–18% annually from cooperatives, but other sources, like local grain traders, can charge the equivalent of 36–60%. Farmers often do not have a clear idea of these finance costs. In El Salvador, a study with coffee smallholders found that farmers exacerbated the lean months by using money to buy chemical inputs for corn and beans production instead of food (Morris et al., 2013a). We recommend additional research to understand the relationships connecting household food security to coffee production, corn production, costs, and the role of rural credit and debt.

Column (2) displays estimates for a regression of thin months on a set of variables indicating the environmentally friendly farming practices recorded in the survey. Initially, we do not include the variables from column (1) as controls; consequently, any effects identified in column (2) pick up all the direct and indirect effects of environmentally friendly farming practices on yields and income. The variables we are able to measure include indicators of crop diversification (e.g., number of varieties of grains produced) and other indicators of sustainable practices, such as organic coffee certification and use of organic fertilizers. None of the variables has a significant coefficient.

The results showing that environmentally friendly farming practices are not related to seasonal hunger in this sample could be interpreted in several ways. First, it may be that actual farming practices "on the ground" do not differ that much between organic and inorganic growers, in which case any effects would be correspondingly small. Second, small positive and negative impacts may roughly cancel each other out; for example, organic cultivation may result in somewhat lower yields but command somewhat higher prices. Third, measurement error in the environmentally friendly indicators may cause attenuation bias (bias toward zero) in the coefficients. Finally, to the extent that farmers select preferred (e.g., higher-yield) farming techniques, differences in outcomes may be canceled by sorting that reflects comparative advantage.

The third column in Table 3 combines the regressors from columns (1) and (2). This model examines the impact of environmentally friendly farming practices on seasonal hunger, adjusting for the baseline production, income, and household demand factors, and vice versa. Again, in this specification none of the environmentally friendly practice variables has a significant coefficient, nor are they significant as a group ($p = 0.351$). In column (4) we repeat column (3) but add dummy variables for location (municipality) to control for any systematic locational patterns in seasonal hunger not captured in the repressors. Condega is the excluded municipality. The coefficients on the municipality dummies variables suggest that there are locational differences, but the effects of the other variables are not qualitatively changed. In this specification, the coefficient on improved grain storage methods has a statistically significant effect, reducing seasonal hunger, with a beta coefficient of −0.14. In results not reported here, we replaced the locational effects with a set of fixed effects (dummies) for the cooperatives (18 cooperatives are represented in the data). The results were broadly similar.

Finally, in column (5) we add a variety of variables that capture additional features of household demographics, social and human capital (e.g. participation in cooperative leadership), and indicators of potential coping mechanisms. None of the new variables is statistically significant at conventional levels, and an *F*-test accepts the null hypothesis that all of the new coefficients are zero ($p = 0.946$).

In addition to running the alternative specifications discussed above, we conducted a number of robustness checks. We ran the main specifications excluding observations with missing values rather than imputing them. We also estimated Poisson regressions to take account of the count-variable nature of our dependent variable (thin months). These results are qualitatively quite similar to what we report above. Finally, given the large number of potential explanatory variables and no strong reasons for excluding any of them a priori, we experimented with replacing the raw variables with factors derived from principal-components analysis of the full set of regressors used in the specification reported in column (5) of Table 3. This procedure did not show much promise for substantially reducing the dimensionality of the regression. Some 13 components had eigenvalues exceeding 1.0. Results of the alternative regressions are available in a technical Appendix, along with Stata code and data.

We can draw two main conclusions from the regression analysis. First, the data exhibit the expected relationship between seasonal hunger on the one hand and food production, income, and wealth on the other, as we hypothesized in research question (1). Second, regarding research question (2), the environmentally friendly farming practices that we could measure did not have a significant relationship with short-run food security. There is no statistical evidence that farmers using these practices are suffering significant costs (or benefits) in terms of food security.

Our interpretation—based on direct observation, survey responses, and interviews with PRODECOOP agronomists—is that most producers in this population are relatively low intensity farmers who do not use the best management practices in all areas of their farms or coffee plots. For example, according to PRODECOOP's agronomists and our calculations based on survey data, the quantity of fertilizers applied to either organic or

Table 3
OLS regression results.

Dependent variable: Number of thin months	(1)	(2)	(3)	(4)	(5)
Baseline variables: Production, income, and capital					
Quantity corn harvested	−0.0781***		−0.0747***	−0.0445*	−0.0400
	(0.0260)		(0.0265)	(0.0249)	(0.0268)
Quantity beans harvested	−0.0226		−0.0278	−0.0335	−0.0339
	(0.0226)		(0.0236)	(0.0227)	(0.0229)
Quantity coffee harvested	0.00482*		0.00412	0.00356	0.00358
	(0.00266)		(0.00266)	(0.00290)	(0.00305)
Total land area	−0.0297**		−0.0337**	−0.0292**	−0.0245
	(0.0149)		(0.0155)	(0.0148)	(0.0172)
Number of fruit trees on farm	−0.00240***		−0.00233***	−0.00170***	−0.00180***
	(0.000442)		(0.000486)	(0.000503)	(0.000562)
Number of chickens	−0.000370		0.000423	0.00174	0.00369
	(0.00838)		(0.00806)	(0.00857)	(0.00931)
Improved storage for corn and beans	−0.113		−0.173	−0.319**	−0.351*
	(0.145)		(0.143)	(0.161)	(0.193)
Qty chemical fertilizer applied per ha grain	−0.0290		−0.0234	0.00734	0.0112
	(0.0363)		(0.0380)	(0.0421)	(0.0440)
Number of persons in HH	0.0504*		0.0346	0.0353	0.0259
	(0.0286)		(0.0301)	(0.0291)	(0.0333)
Log of household income per person	−0.108**		−0.148***	−0.109**	−0.117**
	(0.0508)		(0.0542)	(0.0550)	(0.0581)
Environmentally friendly farming practices					
Number varieties basic grains produced		0.0759	0.0781	0.0633	0.0598
		(0.0539)	(0.0486)	(0.0493)	(0.0512)
Number of fruit species produced		−0.0514	−0.0312	−0.0162	−0.0196
		(0.0344)	(0.0346)	(0.0366)	(0.0386)
Number of animal species raised		−0.000812	0.0558	0.0497	0.0404
		(0.0539)	(0.0605)	(0.0569)	(0.0621)
Produce organic coffee		−0.0922	−0.0889	0.203	0.218
		(0.170)	(0.163)	(0.197)	(0.197)
Use soil conservation for basic grains		−0.0335	0.0511	0.0319	0.0344
		(0.157)	(0.146)	(0.161)	(0.181)
Number of types of fertilizer used		−0.0380	0.0789	0.0408	0.0396
		(0.0653)	(0.0581)	(0.0579)	(0.0622)
Qty organic fertilizer applied per ha coffee		0.00963	0.00352	−0.000226	−0.000361
		(0.0115)	(0.00968)	(0.0107)	(0.0110)
Location (binary variables)					
Jalapa Municipality				0.844***	0.778***
				(0.245)	(0.261)
Las Sabanas Municipality				0.754**	0.702**
				(0.318)	(0.340)
Miraflor Municipality				0.260	0.235
				(0.290)	(0.307)
Pueblo Nuevo Municipality				0.387	0.349
				(0.289)	(0.305)
San Lucas Municipality				0.247	0.140
				(0.202)	(0.241)
Household structure					
Number HH members contributing income					0.0828
					(0.120)
Number of families in HH					0.0105
					(0.0740)
Average age of HH heads					0.00119
					(0.00537)
Primary aged children attend class					0.0698
					(0.143)
Community and cooperative involvement					
Participate in community decisions					0.0981
					(0.162)
Hold leadership position in coop					0.0638
					(0.169)
Years of membership in coop					−0.000607
					(0.00511)
Coping mechanisms					
Percent of basic food needs bought					0.0761
					(0.104)
Have access to credit					−0.0106
					(0.208)
Distance to nearest health center					0.00274
					(0.00213)
Receive help from NGO, etc.					0.184

Table 3 (*Continued*)

Dependent variable: Number of thin months	(1)	(2)	(3)	(4)	(5)
					(0.188)
Constant	3.925^{***}	3.245^{***}	4.024^{***}	3.225^{***}	2.839^{***}
	(0.330)	(0.236)	(0.400)	(0.468)	(0.498)
Observations	232	232	231	231	231
R-squared	0.201	0.023	0.231	0.287	0.302

Robust standard errors in parentheses.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

conventional production systems were generally only 10–20% of the recommended levels. These findings further suggest the potential benefits from integrating environmentally friendly practices into a broader agroecological intensification strategy that builds soil fertility.

3.4. Vulnerability to inter-annual climate variability and market trends

From 2007 to 2009, many Nicaraguan farming communities experienced a drought and irregular rain patterns that coincided with *El Niño-Southern Oscillation* (ENSO) (ACF, 2010). All farmers in this study depend on rain-fed agriculture and thus are highly exposed to droughts, extreme rain events, and precipitation variability within a single year. Approximately one million farm households in Central America's dry corridor were stressed by a drought coupled with high food prices (FAO, 2010a; ACF, 2010). The dry corridor includes the areas in our study site as part of the tropical dry forests and pre mountain highlands on the Pacific coasts and in the central regions of Nicaragua, Honduras, Guatemala, and the Guanacaste region of northwestern Costa Rica. The FAO's initially estimated that Central American countries collectively lost $70 million due to crop loss associated with 2009 *El Niño* events (FAO, 2010b).

In early 2010, PRODECOOP's rural extension team assessed crop loss with the farmers in this research population. After conducting field visits, they compared the anticipated harvests for areas planted against reported harvests and concluded that there was a 47% corn harvest loss and a 50% bean harvest loss during the *primera* and a 44% total loss during the *postrera*. International agencies reported similar results for the region (ACF, 2010). These damages presumably impacted the duration of seasonal hunger reported in surveys.

Although PRODECOOP lacks a comprehensive disaster management plan, the drought provoked demands from the primary cooperative members and a corresponding response. First, from 2007 to 2009, PRODECOOOP channeled a small quantity of donated food assistance to 1000 member families. Then, they coordinated with the state agricultural agencies to get donations of drought resistant corn and bean seed varieties.

Access to the corn and beans produced on their farms is only one way that households access food. The second approach is through purchasing or bartering for corn and beans. Survey results show that 97% households ($n = 229$) buy a portion of their basic grains. Coffee sales are reported as the most important source of cash, and farm gate coffee and corn prices are a key determinant of the household's exchange entitlement for food (Sen, 1981)—i.e., the quantity of corn received in exchange for coffee. The relative price of corn to coffee typically rises substantially during June, July and August, when corn prices reach a seasonal peak (see Figs. 5 and 6).

Although farmers are aware of market prices in their town and local municipalities, the lack of institutional access to preferred markets, coupled with unexpected expenses (e.g., a medical bill), can lead the household to accept highly unfavorable terms of exchange. Focus groups and interviews with two cooperatives in distinct communities revealed cases of farmers selling their future coffee harvest to intermediaries in exchange for corn and a small amount of cash. In one community, the farmers cited examples from previous years in which they received about 300 pounds of corn and a small amount of cash in July, in return providing the intermediary with 100 pounds of coffee in January. These cases are common. Meanwhile, international markets usually value coffee at 10 or more times the price of corn (see Fig. 6). In other cases, farmers reported selling their corn harvest to local grain traders in November and buying corn at two to three times this price in June through August.

Small-scale coffee farmers are also vulnerable to the sharper fluctuations in global coffee prices and the spread of disease contributing to crop loss. Although fair trade pricing agreements may serve to insure participating growers against the worst collapses in coffee prices, the average terms of trade of coffee against corn and other goods remain subject to dramatic fluctuations. As Fig. 6 indicates, coffee prices (including fair trade)

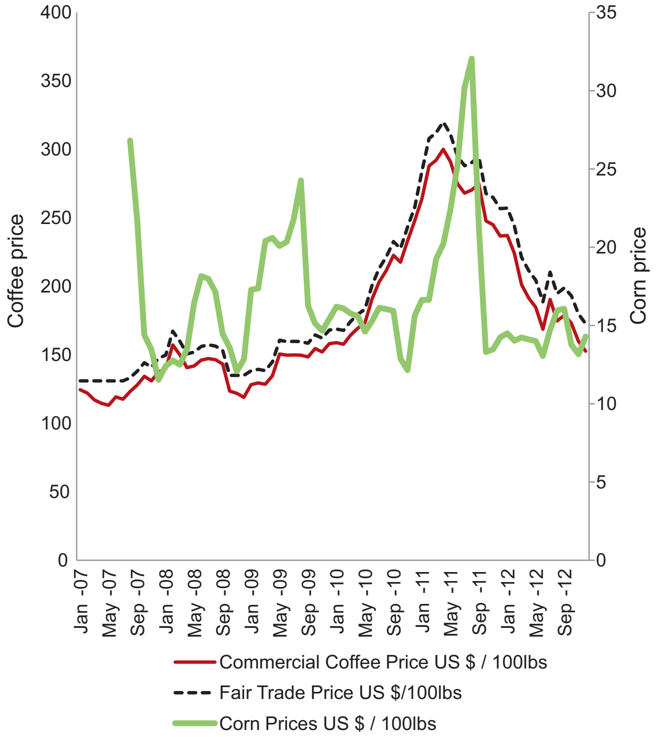


Fig. 6. Wholesale maize prices in Managua, international fair trade vs. commercial coffee prices for other washed Arabicas. *Sources*: ICO (2013a,b), MAGFOR (2012).

more than doubled between 2009 and early 2011, only to return almost to where they began by the end of 2012. When coffee prices collapse, coffee farmers are hit with a major reduction in purchasing power with which to respond to seasonal peaks in their demand and the price of corn for consumption. Fair trade offers a price floor that partially mitigates the crash in coffee prices (Bacon et al., 2008). PRODECOOP and CAN are now proposing a new type of local fair trade through changes to the local corn food system that will increase access and avoid seasonal price spikes.

Recent impacts due to the rapid spread of coffee disease and falling prices suggest that farmers' gross coffee revenues could fall by more than 50% from the 2010/11 to the 2013/14 harvest. Though definitive scientific evidence is pending, interviews with farmers and agronomists suggest that increasing frequency of irregular weather extremes (including rapid changes in temperature and changing precipitation patterns) have contributed to spreading the coffee leaf rust (*Hemileia vastatrix*) outbreak and increasing crop vulnerability by stressing the coffee bushes. The International Coffee Organization stated that there is now 53% incidence of the rust, making this outbreak the worst to impact Central America since 1976 (ICO, 2013a). The rust decreased the 2012/13 harvest by about 20% and impacted 32% of coffee production; losses could be greater for the 2013/14 harvest (CAFENICA, 2013) This coincides with a drop in global commodity prices for Arabica coffees from a high monthly average of $3.03/lb in April 2011 to just $1.23/lb in November 2013 (ICO, 2013b).

3.5. *What are smallholders doing to navigate seasonal hunger?*

Many households and individuals have developed adaptation strategies that contribute to building household food security resiliency against future market and climatic events. Narrative responses to the open-ended survey questions suggest that about 15% of households cope with lean months through more careful household administration and 25% through farm diversification. Increased resiliency contrasts with reports of begging and debt, which suggest increased vulnerability (see Fig. 3). The theme of effective administration and planning also emerged in focus group results. The participatory diagnostic gathered a list of 118 potentially effective and locally used practices that could improve food security, and the staff from the partner organizations and farmer promoters deliberated to select 37 of the best locally adapted practices. Such examples in agricultural production include practicing agroforestry management of shade coffee farms for fruit, firewood, construction materials and medicinal plants; practicing contour planting, soil conservation practices, and organic management; and saving drought resistant seed varieties. In addition, participants reported celebrating and eating *comidas tipicas* or the culturally rooted foods through corn and local food fairs and maintaining home gardens. Other strategies included improved grain storage infrastructure (i.e. silos) and practices.

4. A partnership-based response: initiatives and lessons learned

The different partners in this initiative have interacted at multiple moments from 2010 to 2013 as part of an iterative process that informed the evolving research agenda and the collective response to seasonal hunger in the Segovias. After the initial field research in 2009/10, the lead author presented and discussed results in meetings and workshops with CAN and PRODECOOP staff and farmer promoters. The findings about the seasonal peaks of corn prices during the lean months contributed to establishing community-based grain banks; evidence of the lack of vegetable production led to a home garden initiative that now includes 400 households. The wide diversity of culinary knowledge captured in the recipes and during interviews convinced project coordinators that there was little immediate need for cooking classes or new cookbooks. The initial models used in the regression analysis that showed no significant impact from the presence of chickens and livestock were cited to dissuade a proposal to invest $75,000 to donate additional chickens to participating households. The statistically significant correlation associated with fruit trees informed the donation of 13,000 additional fruit trees as part of an emerging agroecology-based farm diversification strategy that includes the expanded use of agroforestry home gardens. Persistent concerns that farmers and key informants stated about climate change and access to water have promoted subsequent research, development projects, and incipient efforts to incorporate climate adaptation into strategies. The following sections summarize the most significant co-op and farmer level responses and several broader government-led food security programs.

4.1. *Cooperative led grain and seed banks to change local agrifood systems*

One of the many bottom-up collective action responses to seasonal hunger started prior to this research with the regular board and coffee commission meetings of a primary cooperative in Las Sabanas, Madriz (see Fig. 1). A group of about 12 farmers recognized that their corn and bean harvests were insufficient to meet basic needs, and they were also aware of the seasonal price spikes in June, July, and August. Deciding to rename their committee the "coffee and self-sufficiency commission," each farmer voluntarily allocated revenues from 25 lbs of their coffee harvest to a special fund used to buy and store corn in December and then distribute it to their members during the lean months.

The CAN-PRODECOOP partnership-based response expanded upon ideas from the cooperatives in Las Sabanas and Pueblo Nuevo, and concepts drawn from the study of agroecology and sustainable food systems (Gliessman, 2007; DuPuis and Goodman, 2005). The lead researcher CAN team encouraged PRODECOOP staff to reconsider its initial proposal to buy corn and beans for export only, suggesting they develop an internal strategy that prioritized food security and form a cooperative food system that links sustainable agriculture to healthy food access.

PRODECOOP worked with primary cooperatives to establish six community-based grain distribution centers that purchase corn and beans from their members and local markets, store it, and sell it back to their members at a "fair price". Barter is common in these centers, and many farmers can borrow corn in July and return it with an additional agreed-upon 50% in November. The seed banks include locally adapted varieties of corn, beans, and cover crops. The seed banks decrease dependence on donations, reduce the need for annual purchases, and increase a sense of food sovereignty (De Schutter, 2009; Samberg et al., 2013). In several cases, farmers included short cycle and drought resistant corn and bean varieties as part of agroecology-based strategy to manage genetic diversity in the context of the anticipated effects of climatic change.

4.2. *An agroecological approach to intensify production and diversify farms*

There are many approaches to diversification. The regression analysis confirms the importance of the corn and bean fields, which Mesoamerican farmers have managed in their *milpa* production systems for thousands of years (Isakson, 2009). It also shows the potential benefits of improving corn yields and incorporating more fruit trees. In this study, we found that simply adding more crops, additional animals, or the partial use of soil conservation practices had no significant impacts on seasonal hunger. An agroecological approach to diversification requires more than just implementing a set of environmentally friendly and certified organic practices (Chappell and LaValle, 2011); it is holistic, and could include the use of cover crops, intercropping, and new composting techniques to yield more corn, beans, and squash from the *milpa* (Gliessman, 2007; Altieri, 2002; Holt-Giménez, 2006). Iterative participatory action research cycles offer a process-based approach to create agroecological landscapes and more sustainable food systems (Méndez et al., 2013). Although farmers use several diversified farming *practices*, such as shade coffee production and erosion barriers in their *milpas*, they have not yet developed agroecology-based diversified farming *systems* that integrate these strategies in way that generates critical ecosystem service, such as soil nutrient circulation and natural pest control that benefits to production (Kremen et al., 2012). Strategies to intensify production and increase yields in this context could draw from the example of integrated approaches, such as the system of rice intensification (Noltze et al., 2013). However, if farmers adopt these practices they will likely increase farm labor demand, and this could have other unanticipated impacts on community reciprocity relations, gender relations and more (Mutersbaugh, 2004; Lyon et al., 2010). A study of the sociocultural impacts of different intensification and diversification strategies and technologies is an important next step.

4.3. National food security and food sovereignty initiatives

Although seasonal hunger persists for many of Nicaragua's rural residents, overall food security indicators have improved significantly in the past two decades (FAO, 2013b). Contributing factors likely include per capita income growth, increased investment in agriculture, and government policies. In 2009, the government passed legislation on food security, food sovereignty and nutrition that further codified the human right to food and established additional programmatic support. *Hambre Zero* is the government's largest food security initiative, claiming the participation of 100,000 households and plans to reach 200,000 within the next five years (MEFCCA, 2013). The program prioritizes livestock donations, but also creates new cooperatives. Results of the program's first phase were mixed (Kay, 2010), but it recently received international recognition (FAO, 2013b). The Ortega administration transferred *Hambre Zero* to the newly created Ministry of Family, Community, Cooperatives and Associative Economy, and this will create new possibilities to partner with fair trade cooperatives.

5. Conclusions

In this paper, we contributed to explanations of 'the hungry farmer paradox' through a theoretically informed case study in northern Nicaragua's coffee growing communities. The households in our sample experienced an average of about 3 months of seasonal hunger. We developed an analysis at the farm, climate, household, and institutional levels that considers food production, exchange and use. As expected, we found that seasonal patterns in precipitation, agricultural calendars, and exchange entitlements to food contributed to explaining the presence of the lean months before the first corn harvest in June, July and August. An analysis of the 2007–2009 drought and domestic agricultural market prices suggests that seasonal hunger is influenced by multiple factors, including: (1) annual cycles of precipitation and rising maize prices during the lean months; (2) inter annual droughts and periodic storms; and (3) the long-term inability of coffee harvests and prices to provide sufficient income.

Our study suggests that strategies to reduce rural hunger in coffee growing regions and beyond should coordinate action at the farm, household, and institutional scales. Coffee smallholders must navigate unfavorable exchange entitlements often related to commodity prices that limit their ability to access corn and beans during the critical lean months. This can be addressed through production-oriented strategies that diversify and intensify farms as well as exchange oriented strategies that include storage, better prices, redistribution, and credit.

Agricultural cooperatives are well positioned to simultaneously address both the production and exchange dimensions of food security. Strategies to improve storage and provide food access during lean months could work more quickly than production-based approaches. Individual agro-environmental practices and even organic certification should be distinguished from a comprehensive agroecology approach (Gliessman, 2007; Kremen et al., 2012). In the cases where the starting point is low intensity smallholders with limited use of best management practices, an agroecology-based intensification strategy can improve yields and potentially generate environmental and human health benefits. More research, experimentation, and innovation are needed to identify which strategies fit best within existing labor routines and community preferences and are most effective for coffee, *milpa*, and home gardens based approaches. There is also a dearth of research that links these strategies to household food security. Community-based participatory action research can unite researchers, farmers, and rural development in developing an improved and integrated response to this challenge. These proposals could further increase farmer autonomy and help fulfill the human right to food.

Latin America coffee co-ops are heterogeneous mix of large and small organizations with different capacities and levels of accountability (Fox, 2008; Bacon et al., 2008). Through previous participation in many rural food security, climate adaptation, and sustainable agricultural initiatives, they have accumulated lessons about what works and what fails. Specialty coffee industry firms realize that food security and climate change represent significant risks to their supply chains, but current investments are still too small. All stakeholders will need to do more to innovate and implement farm and landscape-based strategies coupled with food system and institutional changes that improve access to natural resources, income, and healthy food for all.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2014.02.005.

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