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Vulnerability to Cumulative Hazards: Coping with the Coffee Leaf Rust Outbreak, Drought, and Food Insecurity in Nicaragua

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Summary. — Recurrent food insecurity in the highlands of Central America has been exacerbated by the recent convergence of a coffee leaf rust outbreak that began defoliating crops in 2011 and a drought that started in 2014. In the context of these multiple challenges, this paper explores how seasonal hunger is related to smallholder organizational affiliation, farm and farmer characteristics, and post-hazard household-level coping strategies. The study integrates qualitative research, hydro-climatic data analysis, and a survey of 368 households completed in 2014. A number of household capacities correlate significantly with shorter periods of seasonal hunger: households with larger farms, with off-farm employment, and that produce more than half of their food, maintain more fruit trees, and harvest more coffee reported fewer lean months. We find evidence consistent with path dependence in how households cope with a sequence of environmental hazards, as the reported use of less preferred coping responses to past events (e.g., Hurricane Mitch and the 2009 drought) tended to correlate with their continued use after subsequent hazards. A comparison of coping responses of households affiliated with a farmer-to-farmer institution promoting subsistence-oriented production with those affiliated with cooperatives prioritizing sustainable coffee exports shows that farmer institutions were not strongly correlated with the number of lean months or coping mechanisms.

Key words — Nicaragua, resilience, livelihoods, agriculture, climate variability

1. INTRODUCTION

Seasonal hunger is a well-known livelihood challenge that remains the most common type of food shortage in the agricultural communities of developing countries (Devereux, Vaitla, & Swan, 2008). Notably, the world's more than 470 million smallholders (Lowder, Skoet, & Raney, 2016) constitute a substantial portion of the food insecure population worldwide (FAO, 2014a), in spite of their contributions to food supplies and the conservation of agricultural biodiversity (Tscharntke *et al.*, 2012). [1] For smallholders, a hungry season typically starts in the months prior to the first harvest in a growing season, when the previously harvested and stored food supplies are depleted, household incomes are low, and food access is limited by unfavorable prices and other factors, giving rise to a recurring period of lean months (Chambers, Longhurst, & Pacey, 1981). When households face crop failures from pathogens or hydro-climatic variability and change (Battisti & Naylor, 2009), or suffer decreased purchasing power with which to buy food (Sen, 1987), the hungry season lasts longer and may become more severe. Smallholders and institutions have developed coping mechanisms that seek to sustain access to food and other basic necessities in the context of persistent seasonal hunger and frequent hazards.

There is a need for explanatory theories that link these livelihood insecurities to the vulnerability context (Watts & Bohle, 1993; Klasen & Waibel, 2015; Ribot, 2014) and help to identify resilience-enhancing adaptations for different circumstances (Ensor, Park, Attwood, Kaminski, & Johnson, 2016; Hinkel, 2011). Although integrated studies about livelihood vulnerability to multiple stressors continue to emerge (Gloede, Menkhoff, & Waibel, 2015; McCubbin, Smit, & Pearce, 2015), more research is needed to understand the cumulative effects of several hazards (Cutter *et al.*, 2008), and how exposure to these hazards relates to household coping responses, and local institutions (Ostrom, 2005; Smit & Wandel, 2006; Wise *et al.*, 2014).

In this paper, we employ an interdisciplinary approach and a case study to offer a situated assessment of coffee-producing smallholder vulnerability and coping responses to a sequence of environmental hazards. We identify household capacities and farming approaches that are associated with shorter periods of seasonal hunger and the use of less severe post-hazard coping responses. We are especially interested in assessing the importance of two potential determinants of resilience to hazards in the context of our study area. First, we compare the coping responses of smallholders affiliated with farmer

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institutions pursuing different strategies (diversified farming *vs.* coffee exports), as they navigate two recent droughts, a coffee pathogen outbreak, and changing commodity prices. Second, in light of the succession of droughts, hurricanes, and other hazards that have impacted Central America, we explore how a household's response to past hazards influences the coping response to subsequent ones and the extent to which a path-dependent evolution of coping responses could perpetuate poverty or alternatively help households "bounce back better than before" (Frankenberger, Constas, Nelson, & Starr, 2014, p. 3; Folke, Biggs, Norström, Reyers, & Rockström, 2016).

The remainder of the paper proceeds as follows. Section 2 provides an overview of the conceptual framework we employ, linking our approach to the literature on livelihoods, vulnerability, and adaptive capacity. Section 3 presents our research questions. Section 4 describes hazards, coffee, and food security issues relevant to our research area in northern Nicaragua, and Section 5 explains our methodology, which combines qualitative and quantitative social science with hydroclimatic analysis. Section 6 presents and then discusses our primary findings, and Section 7 concludes.

2. LIVELIHOODS, VULNERABILITY, AND RESILIENCE

The livelihoods perspective (Scoones, 2009) offers a useful framework for analyzing food security and vulnerability (Reed *et al.*, 2013). This perspective situates a study in the context of how and where people are making a living and what they do to make it meaningful (Bebbington, 2000), integrating foundational theories drawn from Sen's entitlement approach (Dre'ze & Sen, 1989) with human capabilities (Nussbaum, 2011) and an analysis of institutions (Poteete, Janssen, & Ostrom, 2010). There are four types of entitlements (Sen, 1987) relevant to the determination of food security and vulnerability to hazards in our study: *Production* entitlements determine how much food a household can command at different points in the year from assets, such as land and equipment; *employment-based* entitlements entail income-based access to resources; *trade-based* entitlements are a function of the terms of exchange among goods bartered or sold; and *transfer entitlements* consist of food aid, gifts, and related sources. Food security is also a function of individual capacities, such as education, health, and the degree of autonomy *versus* structural forces that constrain local choice (Eakin, Lemos, & Nelson, 2014). These factors influence household engagement with institutions, markets, and farm management shaping their ability to command food entitlements.

Smallholder households and institutions in rural Central America have developed a wide range of adaptive responses as they seek to sustain their food entitlements and navigate risk (Adger, 2006). The choice of coping mechanisms and adaptive actions in response to a given hazard in a specific context is influenced by a complex web of factors, including the hazard exposure, commodity price fluctuations, cognition, development project histories, geography, and institutional responses (Kuruppu & Liverman, 2011; McSweeney & Coomes, 2011; Wood, Jina, Jain, Kristjanson, & DeFries, 2014). Some adaptive responses–such as crop diversification or off-farm employment—could reduce vulnerability and alleviate lean periods, while others—such as liquidating assets—could potentially exacerbate future risks. The dynamic and sequential nature of responses to hazards suggests a focus on "pathways of change and response" (Wise *et al.*, 2014, p. 325), an idea that informs our research question on path dependent hazard responses.

The terms *vulnerability, adaptive capacity, and resilience* are often employed in different ways, suggesting the need to start with clear definitions, scales of analysis, and relationships (Ensor *et al.*, 2016; Hinkel, 2011). Conflicting interpretations often focus on a systems-level analysis *vs.* a human-centered approach (Eriksen, Bohle, & Stewart, 2010), and consideration of political economic context *vs.* an analytic focus limited to quantitative comparisons (Turner, 2014; Weichselgartner & Kelman, 2015). We focus on both context and quantitative analysis, and adopt the IPCC's (2014) definition of vulnerability as "the propensity or predisposition to be adversely affected." Given exposure to a hazard (such as a drought), vulnerability is a function of sensitivity (such as dependence on rain-fed irrigation) as well as adaptive capacity (such as flexibility of crop mix or diversity of income sources).

Building adaptive capacity is an iterative process that links strategies and practices that enhance risk management (*specific* adaptive capacity) with those that address structural deficits (*generic* adaptive capacity) through time (Lemos *et al.*, 2013). Generic capacities include income, education levels, health, mobility, and—at the system level—economic productivity, poverty levels, inequality, and governance. Specific adaptive capacities concern traditional risk management strategies (e.g., crop diversification), formal and informal insurance at the household level, as well as early warning systems, disaster compensation, and insurance provisioning at the systems level (Eakin *et al.*, 2014, p. 2; Nelson & Finan, 2009). Finally, we use the term *resilience* to describe the capacity of a household to recover reasonably quickly (bounce back) from a hazard (Frankenberger *et al.*, 2014, p. 3).

Informed by this conceptual framework, our research questions focus on understanding how vulnerability, adaptive capacity, and resilience interact to determine livelihood outcomes, and are in turn shaped by the specific institutional context of our case study region and the sequence of hazards to which its households have been exposed.

3. RESEARCH QUESTIONS

We focus on three research questions: (1) Which livelihood strategies and adaptive capacities are associated with shorter periods of seasonal hunger and greater resilience to environmental hazards among coffee growers in northern Nicaragua? (2) Did affiliation with different types of farmer organizations influence vulnerability to seasonal hunger, the coffee rust outbreak, or drought? (3) To what extent does a household's response to past environmental hazards influence the coping mechanisms in response to subsequent ones?

Our first research question is motivated by the hypothesis that specific adaptive capacities, such as subsistence-oriented diversified farming and organic certification, and generic adaptive capacities, including income and wealth, are proximate determinants of both the duration of seasonal hunger and degree of resilience to hazards (Eakin *et al.*, 2013).

Our second and third research questions move beyond identifying these proximate determinants to explore the influence of institutional affiliation and historical experiences on household capacities and outcomes. In the context of our study area and population, farmer organizations play a potentially important role in influencing household strategies and resources. The two principal farmer organizations working in the area emphasize alternative strategies, and thus provide an interesting comparison: fair trade cooperatives (FTCs) pursue a market-oriented sustainable value chain approach through sales of certified fair-trade and organic coffee, whereas the *Campesino a Campesino* movement (MCaC) places a greater weight on local subsistence production (Holt-Giménez, 2002). Either of these strategies could contribute to greater food security, although through different mechanisms: the market-oriented fair-trade approach may provide higher average incomes and some insurance against adverse commodity price fluctuations (Jaffee, 2014); on the other hand, farmers affiliated with MCaC may pursue a more diversified and robust crop mix, and thus experience less sensitivity to agricultural hazards that target specific crops (Schroth & Ruf, 2014). Our study is among the first in Central America to assess the relative impact of these two strategies on smallholder vulnerabilities in a multiple hazard context.

Our third research question is motivated by the expectation that a household's responses and adaptations to a given hazard may shape its capacity to cope with subsequent hazards, and may also reveal patterns of persistence over a sequence of hazards. By asking farmers about their response to current and past hazards, we study coping as both an outcome related to vulnerability and an input variable that helps explain household responses to subsequent shocks. We expected to find that some households used the same asset depleting coping responses (like selling off land or accepting poor terms of trade) as their response to a series of hazards, and that this behavior could further contribute to marginalization, and exacerbate vulnerability. In contrast, other households and institutions may learn from past hazards and develop more effective responses and precautionary measures. Evidence for these patterns is starting to emerge in studies focused on assessing vulnerability to poverty (Klasen & Waibel, 2015), including one study finding that in some cases poor and vulnerable households respond to exposure to shocks with greater risk minimization strategies that reduce their likelihood of escaping poverty and potentially perpetuate vulnerability (Gloede *et al.*, 2015).

4. HAZARDS, COFFEE, AND FOOD SECURITY IN NICARAGUA

Nicaraguans have responded to frequent social, economic, and political upheavals, often developing innovative strategies (e.g., interfaith reconciliation processes, or forming rural housing cooperatives among ex-combatants from opposing sides) in response to decades of dictatorship (1930s–79), wars (1980s), and the consequences of rapid economic liberalization (1990s to early 2000s) (Horton, 2013). Although it remains one of the most economically poor countries in Latin America, Nicaragua has significantly lower homicide rates than surrounding countries, and its national economy has expanded, contributing to a fall in general poverty from 42.5% to 29.6% since 2009 (World Bank, 2016). Nationwide, food security has also improved, as the prevalence of undernourishment dropped from 55.1% to 20.1% between 1990 and 2010 (FAO, 2013), and several government assistance programs have expanded (Chamorro & Utting, 2016). Despite these gains, food insecurity remains a pressing challenge among many rural Nicaraguan smallholders.

According to the Global Climate Risk Index, Honduras, Myanmar and Nicaragua topped the list of countries affected by extreme weather events from 1992 through 2011 (Harmeling & Eckstein, 2013). Major environmental hazards in Nicaragua have included frequent drought, hurricanes (e.g., Hurricane Mitch in 1998), earthquakes (e.g., the 1972 earthquake that destroyed downtown Managua), landslides, and volcanic eruptions. Future prospects related to climatic change include the likelihood of increasing rainfall intensity for the wettest periods, more dry days, and warmer temperatures in many areas (Kharin, Zwiers, Zhang, & Wehner, 2013).

Coffee production is a key economic activity in northern Nicaragua and throughout Mesoamerica's highlands, with significant environmental benefits associated with shade tree, as opposed to sun grown, production (Bacon *et al.*, 2014; Jha *et al.*, 2011). Since 2011, the area has seen one of the largest recorded outbreaks of coffee leaf rust (CLR) in Latin America—the fungus *Hemileia vastatrix,* also known as *la roya*—which causes leaf damage, decreases yields, and can ultimately kill coffee plants (Avelino *et al.*, 2015). Estimates of coffee plant damage attributed to the rust during 2011–13 fluctuate widely; however, one report found that it impacted 53% of the region's coffee growing area, provoking losses of USD 500 million (ICO, 2013). In addition, smallholders must also grapple with a drought that started in May 2014 and resulted in crop failures for the first planting season of rain-fed corn and beans, with losses estimated at 75% in Nicaragua. In August 2014, a research group declared that extremely poor households in Guatemala, Nicaragua, Honduras, and El Salvador would likely need levels of food security assistance not seen since Hurricane Mitch struck in 1998 (FEWS, 2014).

While many aspects of the genesis and impact of CLR remain to be understood, there are indications that the relationship between the presence of CLR and crop loss is contingent upon plant health, the severity of the outbreak, and agricultural practices. In Nicaragua and Honduras, the total national coffee production quantities and the area planted started to expand before the recent CLR outbreak; thus the return of total harvests and exports in these two countries to pre-rust levels in 2014 and 2015 masks areas of highly concentrated crop loss, often among smallholders in specific geographies (ICO, 2015). In contrast, coffee production areas have not expanded in El Salvador, and the CLR is associated with national harvests declining by 59% from 2012–13 to 2013–14, which is an 80-year low for the country. This drop in coffee production in El Salvador is similar to those experienced by smallholders in specific parts of Nicaragua, Honduras, and Guatemala. The livelihood impacts of coffee crop losses were exacerbated by the reduction in revenues due to falling coffee prices paid to producers, which in Nicaragua fell from USD $0.79 cents/lb. in 2010 to $0.40/lb. in 2013 (FAO, 2015). Past studies have correlated CLR outbreaks in Latin America to preceding depressions in coffee commodity prices, lower investments in agriculture, use of susceptible varieties, older weaker coffee bushes, and meteorological conditions (Avelino *et al.*, 2015).

We conducted our field research during the early phases of the post 2014 drought that impacted crops, livelihoods, and livestock throughout Nicaragua and Central America (WFP, 2014). The severity of the drought impacts was such that by July 2014, more than 15,000 cattle were found to have died, largely due to malnutrition, and about 600,000 of the 4.1 million cattle in Nicaragua were at risk (Jones, 2014). Prior to this most recent drought, more than 8.5 million people living in Central America's dry corridor's were impacted by the 2009 drought, during which the average maize yield fell by 33% in Nicaragua (Cáceres, 2010). During the 2009 drought, development agencies responded with regional food assistance and disaster risk reduction programs, but many livelihoods remained vulnerable (Segnestam, 2014).

Our study area is situated in Nicaragua's north central highlands (Figure 1), where the geography, climate, and political ecology make the region a hotspot for food security risks related to the hazards discussed above, including climate variability and global change (Diffenbaugh & Giorgi, 2012). The physical geography of our study area includes plateaus, low mountains, and hills (Figure 1), with altitudes of 550–1,600 masl, average daily temperatures of 20–32 °C

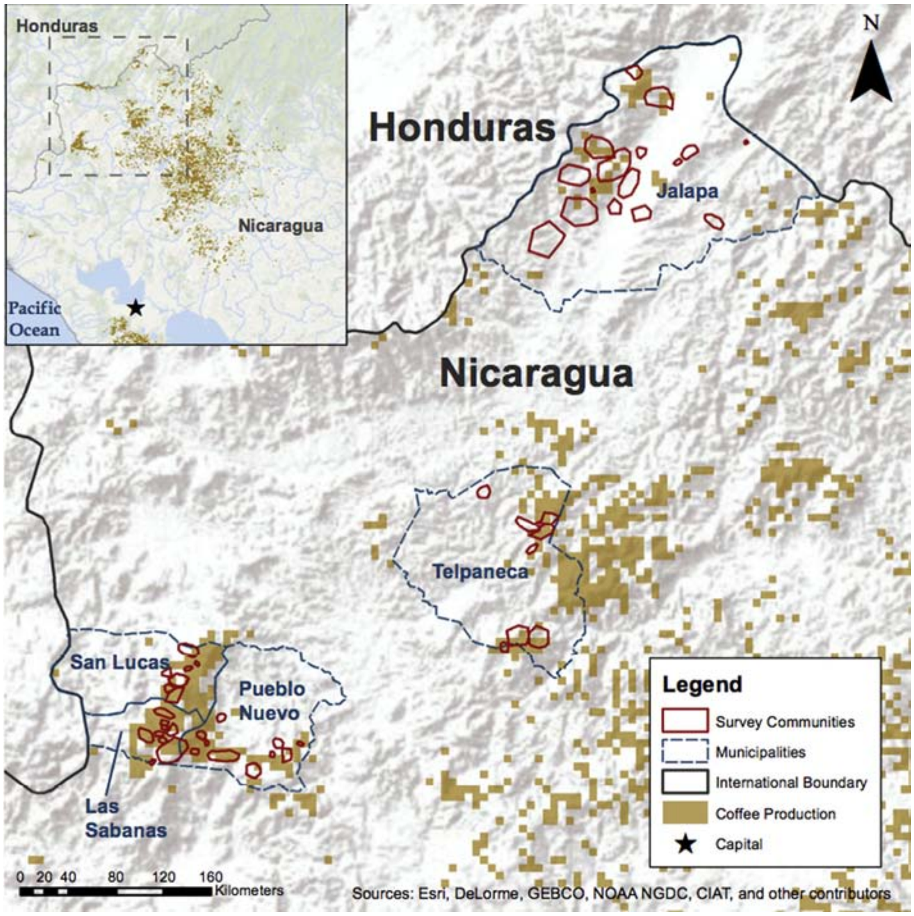

Figure 1. *Location of the surveyed communities and municipalities in study area. Notes: CIAT calculated the coffee production areas based on GPS points collected on farms before 2013, and crop suitability models. Red polygons represent villages in which households were surveyed in 2014. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.) Sources: Household surveys 2014, Carmona-Balanta (CIAT) 2013; ESRI basemap. Nicaraguan Government for municipal boundaries (INETER, 2011).*

(INIFOM, 2015), and an average annual rainfall rate of 991 mm (Funk *et al*., 2014).[2] The highlands in this region are primarily grassland and cropland, with evergreen forests representing around 15% of the land cover in the higher altitudes (Sayre *et al*., 2014). Seasonal precipitation patterns divide the climate into a rainy season, from May through November, with a mid-summer drought from July through August, and a dry season from December through April. The climatic and geographic patterns in the municipalities are broadly similar across the study area.

5. METHODS

Smallholder vulnerability and food security are influenced by complex histories, cultural practices, markets, institutions, meteorology, and multiple livelihood and agricultural activities, suggesting the need for detailed household level and mixed methods research (Aeberhard & Rist, 2009; Fraser, Fisher, & Arce, 2014; Zimmerer, 2013). Thus, we address our research questions using a community-based and participatory approach that draws on mixed methods to generate detailed information at multiple scales. The field research conducted in northern Nicaragua emerged in response to the current convergence of hazards, ongoing engagement with the scholarship around issues of farmer food security, vulnerability, and adaptation, and in the context of a long term participatory action research partnership that includes collaboration with university-based researchers (e.g., professors and undergraduate students), non-profit organizations (e.g., the Community Agroecology Network and ASDENIC), and smallholder cooperatives, farmer associations, and Nicaraguan farmers, youth, and community members (Bacon *et al*., 2014).

These partnerships facilitated the conduct of this study, including a survey of 368 households, the compilation of relevant hydro-climatic and geospatial data, and a combination of statistical and qualitative strategies to analyze the findings. Our team identified the stratified population and conducted household surveys from July to August of 2014 in 51 communities shown in Figure 1. The survey measured food insecurity, post hazard coping mechanisms, and potential covariates, including indicators of both specific and generic adaptive capacity. Consistent with community-based participatory action research approaches, staff from local organizations helped revise the survey and nominated local residents to help conduct research. Participants were interviewed individually in homes or community centers.

Below, we describe the household survey, the interviews and focus groups, and the hydro-climatic data and the regression analysis that are the basis of our study.

(a) *Household survey*

In order to address the role of local institutions, the spatial variation in the intensity of hydro-climatic hazards, and the impact of hazard exposure, we sampled households based on two characteristics: (a) their location in northwestern Nicaraguan municipalities with high concentrations of coffee smallholders that local experts identified as likely to experience food insecurity (see Figure 1), and (b) their participation in one of two networks of farmer organizations with contrasting strategies, participating in either a fair-trade cooperative (FTC) or the *Movimiento Campesino a Campesino* (farmer-to-farmer movement; MCaC). To facilitate comparisons, we also surveyed a control group of farmers unaffiliated with either organization.

The MCaC is a rural social movement consisting of a diverse set of loosely affiliated groups, associations, and supporting non-profit organizations that share an orientation toward diversified and subsistence-oriented production, and shared principles, such as cultural resistance, solidarity, autonomy, farmer experimentation, and an agroecological approach (Holt-Giménez, 2006). Although the population of MCaC-affiliated farmers was relatively small in the study area, across Nicaragua there are at least 20,000 participating smallholders, including 2,085 promoters, active in 986 communities (Bienert, López Herrera, Medina Paz, Aguirre, & Marschke, 2010, p. 12).

The second farmer institution, PRODECOOP (The Promoter of Cooperative Development in the Segovias), is Nicaragua's best known FTC. After initially organizing farmers to secure land tenure gains earned in the 1980s agrarian reform, during the 1990s and early 2000s PRODECOOP prioritized working with affiliated smallholders to earn higher farmgate coffee prices and provide access to credit, training, and political representation in policy debates. Their primary strategies were upgrading the value chain through the purchase of a dry coffee mill and export plant, developing sophisticated quality control and certification systems, and training professional staff to market the smallholders' coffee to premium organic, fair trade, and specialty markets. This second-level organization integrates 40 community-level cooperatives, representing about 2,300 families, and 10,000 individuals.

With the help of the FTC and MCaC organizations, we identified a representative population of households affiliated with one or the other organization within each municipality, and selected a random sample of 25–35% of those households. We then matched this sample with equal numbers, to the extent possible, of randomly selected producers from the other association and from an unaffiliated "control group." To be included in the sample, households needed to have produced coffee in plots that were 10 *manzanas* (5.9 ha) or less in the last three years, and those affiliated with FTC or MCaC needed at least three years of active membership. In some places, it was challenging to find a sufficient number of households that were affiliated with a given association or unaffiliated producers: For example, there were no MCaC-affiliated farmers in Jalapa (see Table 1).

Survey responses were collected from 368 households; after data checking for consistency and duplication, four records were deleted. An additional 11 households reported affiliations with other or both organizations and were dropped from the sample, leaving 353. Table 1 summarizes the sample by municipality and organization.

The household survey included sections with questions on demographics, income, food security, land use, farm management, agricultural and agroforestry practices (e.g., tree crops, soil fertility management, and yields), farmer institutions, and responses to hazards. These questions were adapted from several international survey instruments (e.g., IFRI, 2013 and the UN Human Development Reports) and the lead author's past work in Nicaragua (Bacon, 2005), as well as related work in Mexico and Central America (Jaffee, 2014; Méndez, Bacon, Olson, Petchers, *et al.*, 2010). The survey design was also informed by valuable feedback from staff of local collaborating organizations.

Questions on food insecurity were experience-based and have been validated in multiple contexts worldwide (Maxwell, Caldwell, & Langworthy, 2008; Pérez-Escamilla, 2012; Webb *et al.*, 2006). The key measure of food insecurity used in this paper is the reported number of "lean months" during the preceding year. An advantage of self-reported household food security reports is the inclusion of holistic perceptions and the possibility of identifying "hidden" hunger, which is often overlooked by other measures (e.g., 24 h dietary recalls or anthropometric measurements). A disadvantage is that they are limited by the subjective perceptions of what counts as a lean month, and the possibility of over-reporting (Maxwell *et al.*, 2008).

Finally, the survey included a section that asked retrospective questions about coping mechanisms in response to three past hazards with significant known impacts in northern Nicaragua, including the CLR outbreak from 2011 to the present, the 2009 drought (which coincided with an El Niño—ENSO event, see Figure 2), and Hurricane Mitch in 1998. We drew questions from the field research guides produced by the International Forestry Resources and Institution project (IFRI, 2013), adapting them for use in this context.[3] We also included detailed questions about the timing of the most recent coffee rust outbreak and the extent of damage during the previous years. Answers to retrospective questions about past hazards rely on memories filtered through time and must be interpreted cautiously, especially in the case of Hurricane Mitch, which occurred 16 years prior to the survey.

We used standard methods to code survey variables and then drew from the existing literature (Hahn, Riederer, & Foster, 2009) to combine related variables into thematic index numbers. To generate indices of the severity of coping responses to hazards, we conducted a series of focus groups to record farmer perceptions and score each coping mechanism ranging from 1 (least severe) to 4 (most severe) (Maxwell & Caldwell, 2008). Coping mechanism scores were added up to calculate the coping index numbers used in the statistical analysis. Details are discussed in 5(b) below.

Table 1. *Study population and sample*

Municipality	PRODECOOP Population	PRODECOOP Sample	MCaC Population	MCaC sample	Control
Jalapa	160	33	0	0	20
Telpaneca	216	56	63	35	13
San Lucas	131	29	77	28	27
Pueblo Nuevo	62	14	80	13	15
Las Sabanas	62	24	80	26	20
Total	631	156	300	102	95

We generated a farm diversity index (FDI) to quantify the range of edible fruits, basic grains, and crops within each farm (Jones, Shrinivas, & Bezner-Kerr, 2014). To calculate this index, we scored each crop reported on the farm with either "0.5" or "1" based on the crop's quantity and significance, and aggregated them using the formula below.[4] The index varies between 0 and 1, with higher values representing greater farm diversity.[5]

$$Farm\ Diversity\ Index\ (FDI) = 1 - \left[1/\sum(weighted\ scores)\right]$$

Quantitative analysis of our survey data explores the linkages among coping strategies (hazard responses), seasonal hunger, hazard exposure (past and present), and adaptive capacity, as indicated by household practices and characteristics as well as institutional affiliations. To explore the role of farmer organizations, we first compare the means of variables across organizational affiliation. We then employ a regression approach to explore how the measures of generic and specific adaptive capacity, including organizational influence, were associated with seasonal hunger, as indicated by household self-reported lean months, and with coping responses to two hazards: a severe drought in 2009, and the recent coffee rust outbreak.[6] To explore potential path dependence in post-hazard responses, we calculate coping severity scores and use these scores as regressors for subsequent hazards. After identifying specific adaptations associated with mitigated hunger or hazard responses, we use a second set of regressions to identify correlates of those adaptive practices. These regressions allow us to explore the extent to which producer organizations may have had indirect effects on food security or hazard responses by shaping specific adaptations.

(b) *Qualitative research*

We draw on data from two rounds of focus groups conducted in 2014 and 2015 with study participants and community leaders, as well as ethnographic research including key informant interviews with peasant leaders, government officials, and civil society members, and participant observation during events with farmers and in the offices of local farmer associations. The themes of focus groups that were conducted in June and July of 2014 included the history and severity of hazards within local communities, responses to the coffee leaf rust outbreak, initial responses to a drought that began in 2014, and a comparative assessment of the impacts of major environmental hazards[7].

In July and August of 2015, the lead author returned to the same communities and organized a series of 12 focus groups with a total of 52 participants. In these focus groups, farmers discussed their range of impacts and responses to the post 2014 drought and the CLR, and participated in a ranking activity to score the severity of post-hazard coping responses (Maxwell & Caldwell, 2008). Farmers ranked the coping mechanisms (e.g., selling future crop harvests for low prices, out migration, or borrowing money) reported in the surveys in response to each of the key hazards. Participants first divided all coping responses into two groups (least and most severe), and then subdivided the two groups into two subgroups, resulting in four ranked groups that were scored from 1 to 4 (Maxwell & Caldwell, 2008). The subsequent discussion about why different coping mechanisms were placed in each category made it clear that participants shared a common interpretation that the reported use of the more severe coping mechanisms represented more significant hazard impacts to food security and household wellbeing. By using the same scoring weights across the three different hazards–Hurricane Mitch, the 2009 drought, and the CLR outbreak—we can compare the post-hazard impacts using consistent measures of coping responses.

Our hazard coping measures are subject to some limitations. One challenge is that these scores address household and not individual experiences and thus omit the important and often gendered patterns of intra-household hardship experiences. In addition, coping indices are usually constructed from questions involving shorter recall periods (Maxwell *et al*., 2008) and in ways that include the opportunity for frequency counts (e.g., meals were skipped 3× last week); however, such questions were not well-suited to our study, given the different durations and time elapsed after the hazards studied here, and the fact that we wanted to measure the severity of the hazard impact on household food security and wellbeing. Thus we modified the list of possible responses based on common post-hazard adaptations reported in the area. A related limitation is that farmer recall over longer time periods is subject to error.

(c) *Hydro-climatic analysis*

Smallholders are exposed to hydro-climatic hazards of varying intensity and geographic extent. Smaller-scale local hazards, such as landslides or high wind events, as well as those internal to the households, such as illness and death within the family, make up the majority of the hazards impacting rural residents in multi-stressor environments (McCubbin *et al*., 2015; Wisner, Gaillard, & Kelman, 2012). However, their social and economic impact mostly remains local and is thus difficult to compare across communities. For this study, we focus on high-intensity hydro-climatic events that affect the study area with regional-scale economic impact. This facilitates a comparison of the coping response to the same hazards across households.

We used precipitation data from CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) (Funk *et al*., 2015) for the 1981–2014 time period to analyze trends in precipitation, to determine the strength of hydro-climatic events and their spatial variability, and to calculate the Standardized Precipitation Index (SPI) across the region. CHIRPS uses a combination of satellite data and in-situ station data to create a gridded rainfall time series at 0.05° resolution (Funk *et al*., 2015), which corresponds to approximately 5.5-km grid cells at the latitude of Nicaragua. To facilitate the comparison between household survey and climatic data, the monthly precipitation values for all cells with more than 50% of the area within a given of the 51 village areas (see Figure 1) were extracted, and then averaged over each municipality. Thus, climatic data associated with each municipality are derived from the communities that are part of this study. The resulting time series for each municipality were then examined for linear trends in the monthly (J-D) and seasonal (JJA, SON) precipitation values, especially those of the midsummer dry period (JJA). We calculated the means and standard deviations of monthly and seasonal precipitation for the first (1981–97) and second (1998–2014) half of the study period for each community and municipality. We also compared the mean and standard deviation of the 2008–14 precipitation to the previous years in the study period (1981–2007) to measure recent climatic shifts.

We evaluated the presence and strength of drought events in the region using the well-established Standardized Precipitation Index (SPI) (McKee, Doesken, & Kleist, 1993) and the time series of precipitation derived from the CHIRPS data set. The SPI is computed from precipitation over a 30-year period, can be computed for different time scales using moving averages, and offers an effective comparative measure of the severity in precipitation changes. The output values range from −3 ("extremely dry") to +3 ("extremely wet"). A score between −0.99 and +0.99 is classified as near normal (WMO, 2012). The measures are relative to past precipitation—for example, a 3-month SPI at the end of February compares the December–February precipitation total in that particular year with the December–February precipitation totals of all years for that location. A range of shorter timescales (1–6 months) are useful for assessing agricultural drought in different contexts, as soil-moisture conditions respond to drought within this range.

6. FINDINGS

(a) *Hazards context: hydro-climatic variability and the coffee rust*

The farmers in this study grow coffee and rely on rain-fed agriculture for their corn and beans production areas, rendering them vulnerable to hydro-climatic variability as well as other factors that impact food security, such as commodity prices and plant pathogens. Our analysis of precipitation data indicates that the communities surveyed for this study experience broadly similar patterns in climatic variability and climatic extremes, but that discernable differences in the magnitude of these events exist between municipalities. Notably, annual precipitation rates vary across the region, with yearly rainfall in Las Sabanas (1188 mm/yr) and Jalapa (1230 mm/yr) about 25% larger than that of other municipalities. Telpaneca (921 mm/yr) is the driest municipality in the study area. Hurricane Mitch and the recent drought periods also affected the village exposures to hazards in these municipalities in somewhat different ways. During Hurricane Mitch, Las Sabanas received approximately 300% of normal precipitation, Jalapa 180%, and all other municipalities about 250% of normal October precipitation. While midsummer precipitation for all municipalities has followed the same temporal pattern, precipitation totals over the past decade were lowest in Telpaneca, reaching about 65% of Jalapa, the municipality with the wettest midsummer period.

While the communities in our study area are exposed to recurrent periods of drought and higher rainfall, the droughts of 2009 and 2014 stand out as the most intense drought periods of the recent years as indicated by 3-month SPI values (Figure 2). The SPI values in Figure 2 indicate severe drought periods (with SPI < -2.0 or "extremely dry" in at least part of the study area) for September–November (SON) 1987, June–August (JJA) 1994, and SON 2009, with moderate drought conditions already occurring in March–May (MAM) of that year. We found that the 2009 SON period was the second driest 3-month period since 1981, while the 2014 drought has been of lower intensity but longer duration (Figure 2); precipitation during the 2009 and 2014 drought periods was 60% and 80% of the 1981–2014 average, respectively. Only the 1987 and 2009 droughts are associated with El Niño Southern Oscillation (ENSO) events. In addition, drought periods (with SPI $\leqslant -1.5$) are noted for MAM 1983, February 1998, August 2001, and MAM through JJA 2014.

The timing of regional drought periods identified here are corroborated by the FAO (2014b), which recognizes significant drought events across Nicaragua for 1991–92, 2002–03, 2009, and May to August of 2014. Generally, the intensity and timing of regional drought cycles in the area are variable and exhibit some linkages to the El Niño Southern Oscillation phenomenon as represented by the Oceanic Niño Index (NWS, 2016). More frequent or intense drought periods, such as those observed since the beginning of 2014, are consistent with the warmer temperatures expected with climatic change (Rauscher, Giorgi, Diffenbaugh, & Seth, 2008). In our survey, we focused on the 2009 and 2014 droughts because they represent the most significant recent events, and are thus most likely to be accurately recalled by respondents.

In focus groups and interviews, farmers frequently noted an increase in rainfall variability. Our analysis of the CHIRPS data finds some indication that variability and overall rainfall amount in the study area recently increased. Between the first (1981–97) and second (1998–2014) halves of the study period, as well as between 1981–07 and 2008–14, the standard deviation in annual rainfall was greater for the later time per-

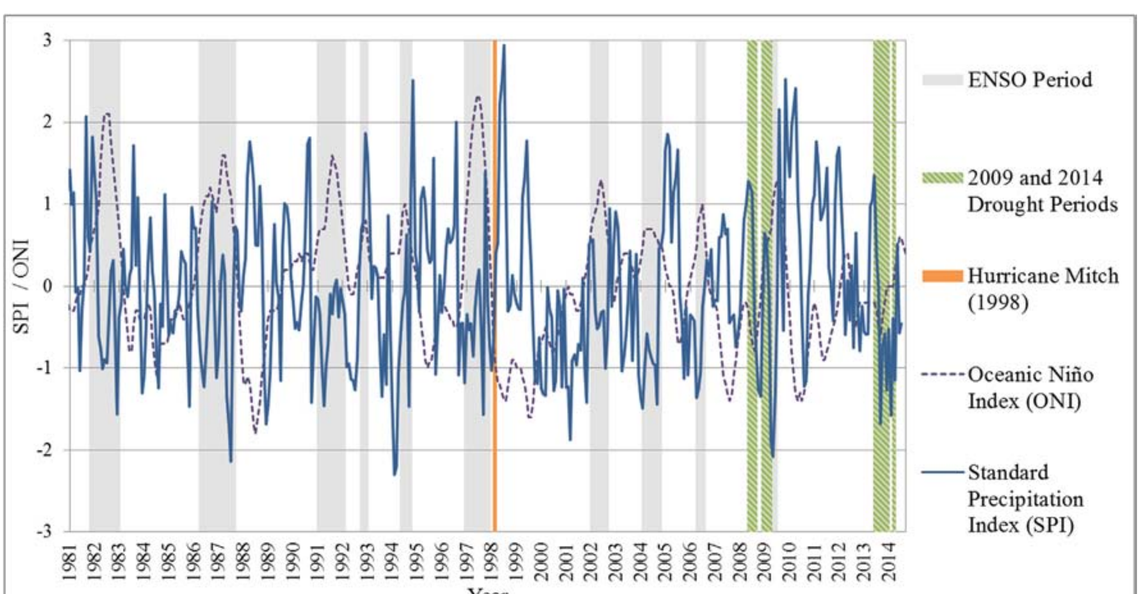

Figure 2. *The 3-months Standard Precipitation Index (SPI) as compared to the Oceanic Niño Index (ONI) across the study area.*

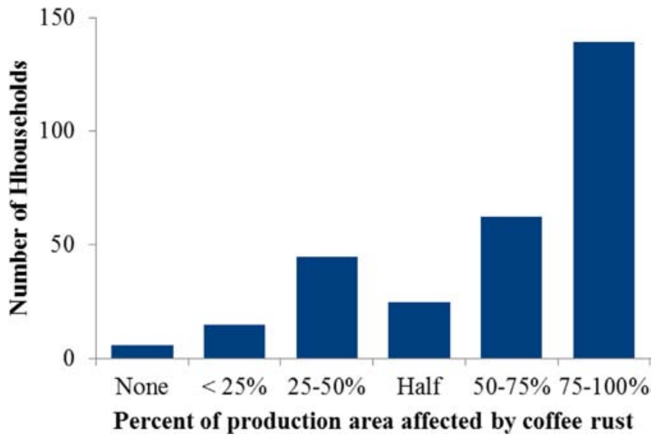

Figure 3. *Percent of production area affected by coffee rust. Notes: Reported coffee plot area affected by coffee leaf rust from 2011 to 2014. N = 292. Source: Household surveys 2014.*

iod, across all six municipalities. Similarly, mean annual rainfall was greater in the later time periods, although none of these increases was statistically significant at conventional levels.

In the household surveys, farmers were also asked about their coping response after Hurricane Mitch, an exceptional precipitation event that affected livelihoods in our study area. Although Mitch impacted household food security and potentially contributed coping responses that shaped livelihood strategy changes after 1998, the 2014 drought and coffee leaf rust (CLR) outbreak were more likely to have influenced the food security experiences reported by the smallholders we surveyed in 2014. There are no published studies that use a standardized approach to map and measure the intensity of the pathogen's outbreak in Central America (Avelino *et al.*, 2015). However, subnational studies have used several direct and indirect indicators to assess harvest loss and pathogen incidence. Figure 3 shows that 69% of the farmers reported that CLR damaged half or more of their production area. This rate of incidence is higher than averages in Mexico and Central America; however, reports from other researchers suggest it is common for CLR outbreaks to occur in clusters (Mutersbaugh, personal communication). Surveyed farmers also reported coffee harvest losses of 60–72% from 2011–12 to 2013–14 (see Table 2 coffee production variables).

(b) *Smallholder demographics and farm characteristics by organizational affiliation*

Our stratified survey design allows us to examine the extent to which the livelihoods, farm management strategies, coping responses, and experiences of food insecurity differ among farmer organizations in our sample. Table 2 reports the means for the entire sample and comparing mean responses across smallholders affiliated with the two organizations (FTC and MCaC) and in the control group (Cont). The last four columns summarize the results of significance tests of the null hypothesis of zero difference between the means, first for the joint hypothesis that all three means are equal, and then for each pairwise comparison between the organizational subsamples. [8]

In our sample, the average household had 4.6 members, and 12% of householders were women without spouse present. The demographic profile was fairly similar across the households with different organizational affiliations, although household heads affiliated with FTCs were somewhat older than others, and MCaC-affiliated households tended to be larger, with younger members. Household heads in the control group were somewhat more educated on average: 25% reported at least some secondary education, compared with 13% and 11% of the MCaC and FTC affiliates, respectively. These differences are statistically significant. However, the education of the most-educated household member (presumably often a young adult) was similar in all groups. [9]

We found that for our sample, farms run by members of FTCs tended to have significantly larger areas (by a third to a half) than farms in the MCaC or control groups. Differences in gross income across groups were not statistically significant. [10] Compared with FTC members, MCaC-affiliated farmers tended to have more diversified sources of income, and were significantly more likely to hold an off-farm job (54% *vs*. 33%). MCaC farmers also had somewhat more diversified crops, as indicated by our farm production diversity index, although the difference was relatively small. Farmers affiliated with FTCs tended to grow more coffee than the other farmers, based on the three-year mean of coffee harvest, and perhaps for this reason they also suffered the largest coffee production loss from 2011 to 2014.

(c) *Seasonal hunger and hazard coping responses*

Table 2 includes several alternative measures of food insecurity or seasonal hunger. On average our households reported about three lean months per year. These typically included the months of July and August. There is little evidence of differences in average aggregate food insecurity between the different organizational affiliations.

The indices for coping responses to Hurricane Mitch in 1998, the 2009 drought, and the CLR outbreak represent weighted sums of reported coping responses. Table 3 reports the frequencies of responses and the severity weights used for the indices. The similarity of the top four most frequently reported responses across the hazards is notable. Reduced expenditure was the most common and one of the least severe responses. Off-farm employment as day laborer was the second most common coping mechanism. The importance of access to common property is evidenced by the responses that show increased harvest of wild foods from forests and other non-forest land uses. Participant observation and interviews indicate that during the last decade many key common property resources have been divided into individual property. Emigration was less frequent here than in non-coffee growing areas in northwestern Nicaragua (Carte, Radel, Schmook, & Green, 2015), and this could be related to the use of seasonal migration as a livelihood strategy. Coping response #11 ("Seek help") is the only one for which the response frequency was considerably greater for Mitch than for either of the other hazards; this is likely a consequence of the rapid onset of Hurricane Mitch and the greater availability of post-hazard international relief.

An advantage of using severity scores is that they offer a multidimensional and context-specific approach to assessing vulnerability and resilience. Context is important in understanding why some responses were deemed more severe (undesirable). For example, the relatively high score for off-farm day labor—which often consisted of work on nearby large farms applying pesticides, weeding, picking coffee, or similar tasks—might be unexpected. Indeed, in some contexts wage labor could be an important and potentially effective part of a livelihood strategy, but the average focus group score of nearly three assigned to seeking off-farm day labor in *response to a hazard* shows its lack of desirability here. The lead author's ethnographic research in this area as well as that of

Table 2. *Household and farm characteristics by organization type.*

Variable	N	Mean	S.d.	Means by organization type				Difference in means		
				Control	MCaC	FTC	Means equal?	MCaC-Cont	FTC-Cont	FTC-MCaC
Household demographics										
Age of head of household	353	51.0	14.0	48.1	49.5	53.7	**		++	+
Female householder—spouse absent (binary)	353	0.12		0.12	0.10	0.13				
Total number in household	353	4.61	1.93	4.29	4.91	4.60				
Number in household under 15 years old	353	1.22	1.18	1.18	1.52	1.04	**			–
Dependency ratio (<15 or ⩾65)	353	0.30	0.23	0.28	0.32	0.29				
Education										
HH head approx years education	353	3.61	3.83	4.46	3.92	2.88	**		–	
HH head education: at least some secondary (binary)	353	0.15		0.25	0.13	0.11	**		–	
Years of education of most educated person in HH	353	9.42	4.30	9.77	9.84	8.93				
Wealth and income										
Farm size (ha)	353	5.93	7.85	5.32	4.75	7.08	*			+
Total gross income from all sources (US$)	353	1,286	2,010	1,581	1,043	1,265				
Log total gross income from all sources (US$)	351	6.49	1.19	6.60	6.50	6.43				
Income sources										
Number of sources of income	353	2.87	1.26	2.77	3.17	2.73	*			-
Sells coffee (binary)	353	0.69		0.61	0.61	0.78	**		++	++
Sells corn (binary)	353	0.24		0.25	0.25	0.23				
Sells beans (binary)	353	0.47		0.45	0.54	0.43				
Has labor or salaried job (binary)	353	0.42		0.45	0.54	0.33	**			–
Proportion of income not from primary source	351	0.45	0.33	0.46	0.45	0.44				
Farm production										
Farm production diversity index	353	0.84	0.09	0.81	0.88	0.84	**	++		–
Total number of fruit and nut trees	353	157	353	171	128	167				
Produced more than half of food on farm (binary)	351	0.27		0.27	0.24	0.29				
Total corn harvest (kg)	351	965	1,718	900	764	1,135				
Total bean harvest (kg)	349	411	599	407	463	379				
Corn shortfall = HH need—harvest if positive (kg)	349	231	334	200	246	239				
Bean shortfall = HH need—harvest if positive (kg)	348	95	141	84	70	118	*			+
Coffee production										
Proportion of farm area in coffee	296	0.31	0.21	0.38	0.29	0.28	**	–	–	
Produces certified organic coffee (binary)	353	0.52		0.23	0.43	0.75	**	++	++	++
Change in coffee harvest 2011–12 to 2013–14 (kg)	285	−329	516	−248	−291	−394			-	
Prop. change in coffee harvest 2011–12 to 2013–14	270	−0.68	0.45	−0.68	−0.60	−0.72				
Total coffee harvest 2013–14 season (kg)	287	154	454	87	139	198				
3-year mean coffee harvest 2011–12 to 2013–14 (kg)	282	344	480	248	299	419	*		+	
Greater than half of coffee affected by CLR (binary)	280	0.68		0.66	0.57	0.77	**			++
Severity of coping response										
Coping index Mitch	353	5.67	3.72	5.04	5.50	6.15			+	
Coping index drought	353	4.46	3.71	3.96	5.34	4.18	*	++		-
Coping index coffee leaf rust	353	5.95	3.44	5.39	5.25	6.75	**		++	++
Food insecurity										
Number of lean months (food scarce)	353	3.10	1.21	2.92	3.26	3.10				
Food insecurity index	353	16.70	21.12	16.28	19.08	15.41				
Number of days per week eat vegetables	353	2.29	2.08	2.36	2.49	2.12				
Number of days per week eat fruits	353	3.41	2.13	3.63	3.26	3.37				
Number of days per week eat beans	353	2.01	2.63	2.35	1.51	2.14		-		
Typical number lean months of neighbors	346	3.99	2.23	4.09	3.81	4.05				
Misc.										
Altitude in kilometers	339	1.06	0.23	1.05	1.04	1.07				
Years in producer organization	259	14.0	10.3	0.0	7.5	18.5	**	++	++	++

Notes: Direction of difference indicated by signs; ++, –, $^{**}p < 0.01$; +, -, $^{*}p < 0.05$
Test of equality of means across categories is one-way ANOVA for continuous variables, Fisher exact test of association for binary variables. Pairwise tests of difference between groups are Bonferroni-adjusted for multiple comparison.
Source: Household survey (2014).

Table 3. *Frequency and severity weights of household coping mechanisms response to three hazards*

Hazard/coping mechanisms	Coffee rust (2010 to present)	Drought (2009)	Hurricane Mitch (1998)	Weight (1 = less severe)
1. Reduce household expenditures	204	157	197	1.44
2. Off-farm day labor	176	141	164	2.78
3. Spend savings	176	127	161	2.56
4. Future crop sales for a lower price	108	76	100	3.67
5. Increase wild food harvest from forest	49	32	37	1.22
6. Selling assets (cattle or land)	45	28	34	4.00
7. Credit, loans, and/or NGO Assistance	44	20	43	2.22
8. Increase harvest from farm	29	20	24	1.44
9. Increase wild food harvest (non-forest)	27	27	36	1.44
10. Do nothing ("suffer through it")	25	27	21	4.00
11. Seek help from family, friends or organizations	19	14	66	1.38
12. Emigrate	3	6	5	3.67

Sources: Household Surveys (2014); Focus Groups (2014 and 2015), Maxwell *et al.* (2008).

others (Horton, 2013) reveal smallholder preferences for autonomy and work on their own farms rather than work for larger landowners, a preference made especially salient in the context of land reform and persistent smallholder struggles against large landowners, even after the agrarian reforms of the 1980s (Edelman, 2008; Wilson, 2013). In several of these communities, farmers have felt compelled to go and work for the same landholders they once fought against during the wars of the 1970s and 1980s. This work is sometimes done in a spirit of reconciliation, but at other times resentment and mistrust remain.

(d) *Examining the determinants of seasonal hunger and hazard coping*

In this section we report OLS regressions of seasonal hunger and post-hazard coping responses on various measures of adaptive capacity, as indicated by household practices and characteristics. The generic capacities include household characteristics that are likely to mitigate any hazard's impact, such as income and wealth, or likely to facilitate more resilient responses, such as education. Specific capacities include farming practices that may reduce risk in certain circumstances (e.g., diversified farming) (Kremen, Iles, & Bacon, 2012), livelihood strategies, such as market orientation, and affiliation with producer organizations that could offer assistance or promote specific practices. The regression results directly address our second and third research questions by including indicator variables for institutional affiliations and measures of the intensity coping responses.

Although the generic-specific scheme is useful conceptually (Eakin *et al.*, 2014), there are practical issues in implementing it empirically. For example, consider a variable like cash income. Income-earning capacity increases the generic capacity of any household to respond to various hazards. But in practice we measure income as the response to a question about recent gross inflows, which reflect recent events, including hazard impacts. A crop failure that results in a significant but temporary reduction in cash income is the *consequence* of a hazard, not necessarily a reflection of long-run income earning or adaptive potential.

These observations complement our conceptual approach and motivate our specifications for the regressions for the seasonal hunger outcome, classifying the regressors into three broad categories: (1) demographic and locational characteristics that are likely to be exogenous to short run household decisions; (2) anticipatory adaptive capacities, including generic capacities such as wealth and investments in physical, human, and social capital, and specific capacities such as crop diversification; and (3) income and production variables that are partly the consequence of current hazard impacts. The third group of variables encompasses the production and employment-based entitlements that help shape a household's short run food access (Sen, 1987).

Table 4 presents the regression results for both seasonal hunger and hazard response. Coefficients for the demographic and municipality controls are omitted from the table to save space; the full regression results are available from the authors on request. [11] The first two columns report alternative specifications of regressions in which the dependent variable measures food insecurity (lean months). The third and fourth columns examine the covariates of coping responses to the 2009 drought and recent CLR events, respectively.

The regressors refer to household characteristics and conditions reported in July 2014. Therefore the drought coping score regression regresses an index of 2009 behaviors on household characteristics five years later. We judge it plausible that a household's characteristics might be sufficiently stable over five years to allow 2014 regressors to capture relevant conditions in 2009. We are less sanguine about a time lag of 16 years, which is why we do not report a similar regression for coping responses to Hurricane Mitch.

In the food insecurity regressions, a positive coefficient implies that increases in the variable are associated with more lean months (greater hunger). In the first specification (1), current income and production variables are excluded. This regression represents a "reduced form" estimate of determinants of seasonal hunger, not controlling for current entitlement flows. The second specification (2) adds income and production variables, allowing us to examine the potential effect of adaptive capacities on hunger, controlling for current entitlements flowing from food production, cash crop (coffee) production, and income sources generally. We use log-transformed values of the income and wealth variables.

The lean month regression results reinforce research in the same general study area conducted in 2010 about which factors correlate with reduced incidence of seasonal hunger (Bacon *et al.*, 2014). In the first specification (1), farm size has a significantly negative effect on lean months, although the effect is not huge. A one-standard-deviation increase in log farm size is associated with a reduction in seasonal hunger of about 3–5 days. Off-farm labor for a wage or salary is another strategy associated with less seasonal hunger. This is also consistent with exchange-based strategies to increase food security (Devereux *et al.*, 2008).

Table 4. *Food insecurity and hazard response regressions.*

	Dependent variable			
	Number of lean months		Drought coping score	CLR coping score
	(1)	(2)	(3)	(4)
Adaptive strategies				
Produced more than half of food on farm	−0.324**	−0.363*	−0.311	−0.162
	(0.118)	(0.159)	(0.404)	(0.367)
Sells corn	0.103	0.0995	0.283	−0.247
	(0.142)	(0.172)	(0.514)	(0.495)
Sells beans	−0.398**	−0.494**	−0.923*	−0.378
	(0.127)	(0.152)	(0.391)	(0.372)
Farm production diversity index	1.110	0.745	5.431*	4.233*
	(0.771)	(1.061)	(2.331)	(1.879)
Produces certified organic coffee	0.0911	−0.0643	0.696	0.572
	(0.148)	(0.186)	(0.401)	(0.428)
Has labor or salaried job	−0.301*	−0.455**	0.855*	−0.313
	(0.136)	(0.165)	(0.375)	(0.372)
Organizational affiliation				
Fair trade cooperative (FTC) affiliation	0.0839	0.123	−0.736	0.312
	(0.171)	(0.223)	(0.462)	(0.486)
Campesino-a-Campesino (MCaC) affiliation	0.0970	0.299	0.878	−0.691
	(0.163)	(0.181)	(0.520)	(0.530)
Land assets and agroforestry				
Log of calculated farm size (ha)	−0.178*	−0.181	−0.118	0.671**
	(0.0762)	(0.0996)	(0.233)	(0.230)
Log of number of trees	−0.146**	−0.163**	0.0426	−0.251*
	(0.0469)	(0.0567)	(0.130)	(0.115)
Income and crop production				
Log total gross income from all sources (US$)		−0.0200	0.129	0.331*
		(0.0625)	(0.171)	(0.149)
Coffee harvest 2013–14 season (1000 kg)		−0.367**		
		(0.0946)		
Prop. change in coffee harvest 2011–12 to 2013–14		−0.326		
		(0.168)		
Corn shortfall (1000 kg)		0.315		
		(0.236)		
Bean shortfall (1000 kg)		−0.725		
		(0.708)		
Past hazards				
Coping index Hurricane Mitch			0.384**	0.230**
			(0.0594)	(0.0573)
Coping index 2009 drought				0.172**
				(0.0563)
Observations	351	261	349	349
Adjusted R-squared	0.152	0.241	0.253	0.226

Notes: $^{*}p < 0.05$, $^{**}p < 0.01$. Heteroskedasticity-robust standard errors reported in parentheses. All regressions include controls for age and education of household head, number of household members, and municipality.

Food security appears to be enhanced for households growing more of their own food, harvesting and selling beans, and growing more fruit trees. The magnitude of the effect of selling beans is fairly large: *ceteris paribus*, a household that reported selling beans reported the equivalent of 12 fewer days of seasonal hunger than a household that did not. The advantage of selling beans is presumably related to the unusually high red bean prices during the survey (see Figure 4). This result is consistent with an entitlement approach to food security, in which the value of market entitlements is contingent on both endowment (production) and relative prices (exchange). As a strategy for food security, the success of market-oriented production would be contingent on the ability to take advantage of favorable price movements.

The favorable effect of maintaining fruit trees also echoes a finding from our previous work in the same region (Bacon *et al.*, 2014), as well as studies linking agroforestry and fruit trees to rural food security (Leakey, 2012; Méndez, Bacon, Olson, Morris, & Shattuck, 2010). A one-standard-deviation increase in the log number of fruit trees (about 75 trees) implies a reduction of about 6 lean days.

The coefficients on the dummy variables for producer organization are positive but not significantly different from zero (the excluded third category is the unaffiliated "control" group). That is, adjusting for other generic and specific adaptations, we cannot reject the hypothesis that organizational affiliation had no influence on household food security. However, organizational affiliation was associated with some prac-

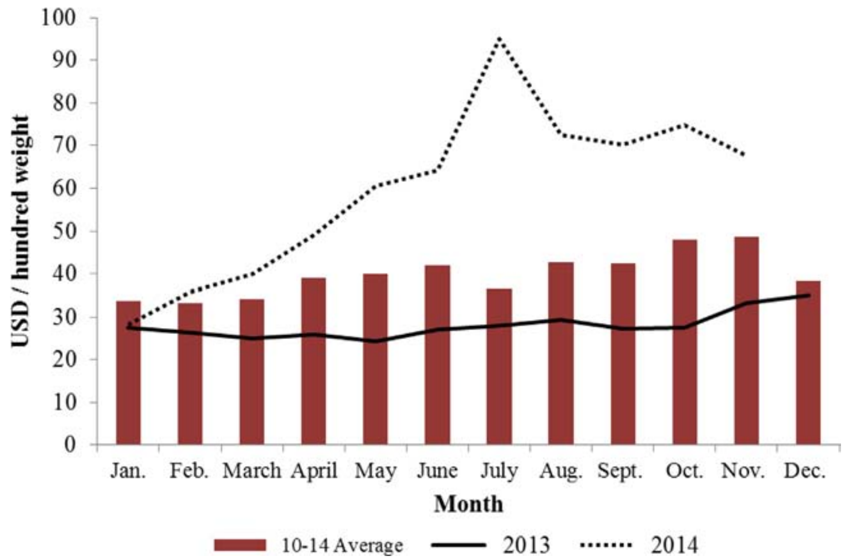

Fig. 4. *Monthly red bean wholesale prices 2010–14 in Managua, Nicaragua. Sources: FEWS (2015).*

tices that were in turn associated with reduced seasonal hunger, as we discuss below. The municipality effects (not reported in the table) are imprecisely estimated, and we cannot reject that all of them are equal to zero.[12]

The second column in Table 4 repeats the lean-months specification of the first column, but adds log income from all sources for the past year as well as regressors that capture the level and change in the coffee crop and production of corn and beans. Together, these variables provide controls for household economic entitlements in the form of cash and output of the main cash and staple food crops. Consequently, the coefficients on the adaptive strategy variables in this regression indicate whether these strategies are associated with reduced seasonal hunger, holding constant basic economic entitlements.

Of the income and production variables, only the coffee harvest coefficient is significantly different from zero, and as expected it is negative in sign. The change in coffee harvest over the preceding two seasons also has a negative coefficient, although it is not quite significant at the 5% level. The coefficients on the corn and bean harvests—represented here as harvest shortfalls relative to self-reported household consumption needs—are imprecisely estimated and not statistically significant.

Once we include controls for current income and production in column (2), the farm size effect remains similar in magnitude but is no longer quite statistically significant, possibly due to collinearity between the farm size and coffee production variables. Otherwise, the pattern of results from column (1) is reproduced in column (2)—specifically, the coefficients on producing food on the farm, selling beans, off-farm labor, and fruit trees generally retain their magnitude and statistical significance. These strategies thus proved to be robust even controlling for measures of basic economic entitlements.

Columns (3) and (4) of Table 4 exhibit results for regressions to account for variation in the hazard coping scores for the 2009 drought and the recent coffee rust outbreak respectively. In regression (4), farm size is associated with more severe coping mechanisms in response to the coffee rust outbreak. This result contrasts with the negative relationship between farm size and seasonal hunger. In the case of the coffee rust, larger farms may have experienced a more severe impact simply because larger coffee plots represent greater exposure (farm size and total coffee production are positively correlated).

These regressions also suggest the favorable effects of selling beans (drought regression) and tree crops (coffee rust regression), consistent with the protective effect of diversified production. However, not all diversification is equally beneficial, as is evidenced by the positive (adverse) coefficients on the farm diversity index, which counts the total number of crops planted on a farm. In some cases, farmers planted a relatively small quantity of many different crops, especially vegetable gardens, which increased the farm diversity score but did not correlate with improved coping index scores or number of lean months. The magnitudes of these effects are, at any rate, modest, with standardized coefficients all in the range of 0.10–0.14 in magnitude.

Perhaps the most striking results in these last two regressions are the large and statistically significant positive coefficients of past hazard coping scores on the subsequent hazard responses. Various interpretations of these estimated effects are possible. First, earlier hazard responses may have had path-dependent (persistent) effects on subsequent hazard impacts and responses. A farm that was hard-hit by the 2009 drought, for example, may have been left more vulnerable to the subsequent damage caused by the coffee rust outbreak that started in 2011. Second, coping scores for past hazards may serve as proxy variables for unobserved household characteristics that affect coping responses across multiple hazards. For example, households whose members more regularly engage in off-farm labor as a livelihood strategy may naturally be more likely to turn to off-farm labor in response to a hazard. Finally, questions about coping responses for one hazard may have influenced survey responses for other hazards.

The correlation between the coping responses to different hazards holds not only for the aggregate coping index numbers but also for every one of the 12 component responses listed in Table 3. For example, across households in the sample, the correlation between spending savings to cope with Mitch and spending savings to cope with the CLR is 0.51.[13] These correlations suggest that households may have repeatedly used the same coping mechanisms when confronted with a hazard. These results highlight the need for further research

Table 5. *Adaptive capacity regressions*

	OLS		Probit (mean dP/dX)			
	Farm diversity	Log fruit rees	Grow > half of food	Wage-salary worker	Sells beans	Organic coffee
Fair trade cooperative (FTC) affiliation	0.0169	0.0786	0.0149	−0.0256	−0.0618	0.448**
	(0.0139)	(0.207)	(0.0596)	(0.0616)	(0.0660)	(0.0453)
Campesino-a-Campesino (MCaC) affiliation	0.0608**	0.412*	−0.0266	0.0818	0.106	0.185**
	(0.0132)	(0.200)	(0.0640)	(0.0646)	(0.0693)	(0.0595)
Log of calculated farm size (ha)	0.0102*	0.249*	0.0114	−0.155**	0.101**	0.0480
	(0.00488)	(0.105)	(0.0286)	(0.0288)	(0.0311)	(0.0283)
Log total gross income from all sources (US$)	−0.00688	0.0660	0.0386	0.00586	−0.00107	−0.100**
	(0.00520)	(0.0763)	(0.0218)	(0.0228)	(0.0240)	(0.0213)
Observations	351	351	349	351	351	351
Adjusted R-squared	0.087	0.032				

Notes: $^{*}p < 0.05$, $^{**}p < 0.01$. OLS coefficients with robust SEs for continuous dependent variables; probits report sample mean predicted dP/dX for binary. All regressions include controls for age and education of household head and number of household members.

assessing the cumulative impacts and smallholder responses to a sequence of shocks.

The regressions in Table 4 included dummy variables for five municipalities as crude controls for unmeasured sources of spatial variation, but they do not directly control for spatial variability of hazard intensities. For the 2009 drought, we calculated SPI indices for community-level spatial units to measure the intensity of the drought at a finer-grained scale. When SPI indices for the months of May–June–July and for August–September–October 2009 were added to the drought coping index regression (3) in Table 4, either separately or together, the coefficients were not significantly different from zero (results available from the authors). The drought event was most severe from August to October, but because its impact was relatively uniform across the region, there may not have been enough cross-sectional variation to quantify the differences in effect across locations.

(e) *Exploring the determinants of specific adaptive capacities*

The regressions in Table 4 do not find a statistically significant effect of affiliation with the different types of producer organizations on lean months or hazard coping responses, other variables held constant. [14] However, organizational affiliation or other household characteristics may indirectly affect food insecurity and/or hazard responses by way of specific adaptations associated with membership in that organization. In Table 5, we investigate this possible channel in a preliminary manner through a set of regressions using specific adaptations as the dependent variables. The dependent variables selected were specific adaptations shown to have significant effects (positive or negative) in at least some specifications of Table 4, such as fruit trees or selling beans, along with production of organic coffee. The regressors include basic household demographics (not shown in the table), and income and farm size, along with organizational affiliation.

The regressions in Table 5 explain rather little of the variation in farmer adaptive strategies across these households—for example, less than 3% of the variation in log of fruit trees grown. Nonetheless certain suggestive patterns stand out. First, income and wealth (as indicated by farm size) are often significant, and usually in the expected direction. For instance, larger farms exhibit greater farm diversity, grow more fruit trees, and are more likely to sell beans and organic coffee. In addition, these results hint at the influence of producer organizations on adaptive practices. In particular, *ceteris paribus*, households affiliated with the food-security-oriented M*CaC* movement have more diversified farm production and grow more fruit trees. The latter practice is in turn related to lower incidence of seasonal hunger, while the former is related to greater severity of coping scores in the drought and CLR hazard regressions in Table 4.

The spike in red bean prices was one of the most immediate regional food system responses to the 2014 drought. Figure 4 compares average dry bean prices for the previous five years with the 2014 price spike, and helps explain the regression finding linking bean sales to fewer lean months (see Table 4). If farmers had a bean harvest during this drought, they could sell them for extra income. From August 2013 to 2014 Nicaragua's dry red bean prices shot up 210%, and in El Salvador they were up 239% (FEWS, 2015). Although relatively few surveyed households reported the reception of food aid entitlements in 2014, in other areas of Central America and parts of Nicaragua institutional and food system responses from 2013 through early 2016 have included food aid from the World Food Program and governments, as well as some food aid distributed through the local organizations (e.g., MCaC and FTC), and the development of community-based grain reserve programs. Analysis of these additional responses is beyond the scope of this paper.

7. CONCLUSIONS

Our research questions posit the potential importance of generic and specific capacities, organizational affiliation, and the response to past hazards in accounting for the severity of seasonal hunger and post hazard coping among Nicaraguan coffee producing smallholders. Our study was conducted in the context of the ongoing coffee leaf rust outbreak and beginning of a drought in 2014 that would later last into 2016. It is one of the first to collect original data at the household level during the depth of these hazards.

(a) *Local determinants of adaptive capacity and seasonal hunger*

With respect to our first research question about adaptive capacity, our empirical results identified several household characteristics and practices that were correlated significantly with fewer lean months, including the production of more than half of the food consumed in a year and the number of fruit trees, as well as farm size, off farm employment, and coffee harvests (see Table 4). The protective benefits of agroforestry were also evident in the correlation linking more fruit trees to less severe coping responses to losses from the CLR outbreak.

With respect to the potential influence of institutional affiliation, we found little evidence of a direct correlation between affiliation and seasonal hunger in 2014. In the unadjusted comparison of means (Table 2), MCaC farms reported somewhat greater impact of the 2009 drought, while FTC-affiliated farmers generally managed larger quantities of coffee and suffered greater harvest loss due to the rust. These patterns did not hold up, however, in the regressions that control for other relevant household characteristics (Table 4). We did find that some specific practices, such as certain types of farm diversification and the number of fruit trees, were modestly correlated with affiliation to MCaC.

There are contextual considerations associated with the comparison of these two institutions and generalization beyond the study population. The MCaC-affiliated groups in this area represent several of Nicaragua's less active MCaC groups. In contrast, the FTC-affiliated farmers are members of a regional cooperative union with a significantly larger budget. Coffee production in this part of Nicaragua is more difficult than in the wetter and cooler conditions of the north central mountains, where most of the country's coffee is produced and average yields are significantly higher. Although the MCaC promotes several agricultural practices associated with shorter periods of seasonal hunger and less severe coping strategies, movement leaders have often ignored the importance of other livelihood practices, such as off farm employment. In contrast, the FTC oriented strategy focuses on improved coffee prices and higher farmer incomes. Another consideration is that the quantitative variables examined in our analysis do not address other collective goals related to farmer empowerment, cultural resistance, and autonomy.

With respect to our third research question, about possibility of a path-dependent impact of earlier hazards on later hazard responses, we find some supportive evidence: namely, the severity of coping mechanisms used in response to the 2009 drought and Hurricane Mitch was associated with the selection of more severe coping mechanisms (e.g., selling land or future crop sales for low prices) in response to subsequent hazards, such as the CLR outbreak and the 2014 drought.

Our finding showing a strong correlation between the number of fruit trees on the farm and the length of seasonal hunger is especially important, and reinforces previous findings from surveys conducted in the region (Bacon *et al.*, 2014) and the broader importance of agroforestry and agroecology for food security (Gliessman, 2014; Leakey, 2012). Significant correlations also exist between seasonal hunger and hazard coping–farmers who sold dry beans reported shorter periods of seasonal hunger and less severe coping mechanisms in response to the 2009 drought.

(b) *The role of institutions in building adaptive capacity*

There are gaps in the knowledge of the mechanisms that poor households use to cope with agricultural risks and how rural institutions build adaptive capacity and shape coping responses. [15] The sequence of coping responses employed over time often become part of an adaptation pathway and potentially new livelihood strategies (Wise *et al.*, 2014). In some cases, institutions could find synergies that promote beneficial short-term coping responses and that also contribute to longer term disaster risk reduction (Lemos, Lo, Nelson, Eakin, & Bedran-Martins, 2016; Wisner *et al.*, 2012). For example, in several communities, the FTC allocated grant funding to support farmers during the lean months as they planted new fruit trees and improved soil fertility. They also used the support to buy food after crop failures due to the drought. The two farmer institutions analyzed in this study both supported diversification, but this study found that some types of diversification (e.g., fruit tree production, subsistence crops, and off farm employment) were more effective than others (e.g., the total number of crops or some types of soil conservation). Although the presence of more diverse crops did not correlate with shorter periods of seasonal hunger, such practices, including the presence of home gardens, could be correlated with more household dietary diversity (which was not systematically measured in this study). There is opportunity for knowledge sharing between these institutions. Indeed, PRODECOOP's staff and affiliated farmers are interested in several MCaC-related agroecological practices. Farmers' reliance on common property-related coping strategies suggests that coffee smallholders and their institutions could learn from community-based forestry initiatives (Chhatre & Agrawal, 2009).

An initial review of several multilateral CLR recovery projects suggests that the conventional response to these hazards by mainstream aid agencies and parts of the coffee industry is not supporting several of the more promising practices, and, in some cases, it might be producing more vulnerability instead of building resilience. Many strategies focus on planting new coffee varieties and increasing the use of chemical inputs. Industry and multilateral agencies have funded the expansion of coffee production in areas that some studies predict will become increasingly unsuitable for production given the anticipated effects of climatic change (Läderach *et al.*, 2016). This suggests the possibility of a counterproductive influence on coping responses and future livelihoods, and the lack of an integrated strategy.

The persistence of seasonal hunger and the use of adverse post hazard coping mechanisms in the context of fluctuating food prices, drought, and plant pathogens, as well as the expected impacts of climatic changes, suggest that it will become increasingly important to understand the causal pathways that link these phenomena to farmer livelihoods and food security (Phalkey, Aranda-Jan, Marx, Höfle, & Sauerborn, 2015). There is corresponding need to identify which adaptive capacities, livelihood strategies, and coping responses are culturally preferred and most likely to improve food security and nutrition, while also reducing disaster risk (Wisner *et al.*, 2012). *Campesino a Campesino* is a smallholder institution and a rural social movement that promotes many of the diversified and subsistence production oriented farming practices that could be useful for these circumstances; however, a greater emphasis also needs to be placed on raising smallholder incomes, a major challenge in a political economic context that generally prioritizes larger agricultural enterprises and activities that generate revenue for governments.

NOTES

1. Researchers have used the terms "food security", "hunger", "malnutrition" and "food insecurity" in different ways (Pinstrup-Andersen, 2009; Vaitla, Devereux, & Swan, 2009). In this paper, we consider that food security is met 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). We use

"hunger" to mean a general sense of food shortage (Vaitla *et al*., 2009). Hunger may contribute to malnutrition, which is "a condition resulting when a person's diet does not provide adequate nutrients for growth and maintenance or when a person is not able to adequately utilize the food consumed due to illness." (WFP, 2016). Food insecurity refers the inability of individuals, households, or communities to maintain their food security and its severity can be measured in different ways ranging from calorie counts and anthropometric measures, to experience-based measures of human perceptions and coping responses (Pinstrup-Andersen, 2009). We focus on experience-based food insecurity measures, as explained in the methods section.

2. We mapped the location of all communities using standard GIS software (ESRI) (see Figure 1 red polygons). To identify these locations we combined the geographic coordinates of all farmers interviewed within their household together with the local village names reported in the surveys conducted at central locations. Since many of these local communities were not listed in Google Earth Maps, we consulted with local experts, and maps produced by Nicaraguan government agencies (e.g., the national hazard maps) to geolocate specific villages. A small percentage of these survey village areas (red polygons) could occur outside of the coffee production areas identified by CIAT for several reasons: The CIAT layer covers the regional to global scale and is based on GPS points collected on farms before 2013 and crop suitability models. CIAT's coffee extent layer in Nicaragua is the best data that we are aware of, but there could be new coffee production areas identified by the surveys we conducted in July 2014, or areas overlooked by the CIAT data. It is also possible that some surveyed HH noted their village as their primary residence that did not produce coffee, although they had coffee farms in a nearby village.

3. The International Forestry Resources and Institution (IFRI) has produced a methods guide including eleven survey instruments that can be used to characterizing a forestry site (IFRI, 2013). The surveys include both open-ended and closed responses. We reviewed the materials and drew questions primarily from the household form, including those related to hazards response and adaptations. More information is available here: http://www.ifriresearch.net/resources/methods/.

4. Crop scores for the diversity index were as follows: Coffee in development or production = 1. Crops commonly grown on the patio, including camotes, malangas, yucca, chiltoma, ayote, pipian, chaya, repollo, papas, zanahorias, cebollas, lechuga, apio, pepino, and remolachas = 0.5 each. Banana trees = 0.5 if there are less than 50 trees, and = 1 if greater than 50. Non-banana fruit trees = 0.5 for less than 5 trees, and = 1 for greater than 5, including orange, avocado, mango, granadilla, passion fruit, lemon, nancite, and all other fruit trees. Corn and beans = 1 for each variety present.

5. All farms had a summed score of at least 1, so a negative-value FDI was never produced.

6. All data analysis was performed using Stata version 14.0. Data and Stata do-files for all analysis are available from the authors upon request.

7. Crop loss estimates attributed to CLR are imprecise and range widely for several reasons. First, Central America is well known for the annual variability in harvest sizes, as a smaller harvest generally follows a relatively large one. Second, the health, age, variety, climate, management (especially fertilization, pruning, and pest control) of the coffee bushes all influence the harvest. Third, crop loss could be due to other diseases, such as coffee borer (*Hypothenemus hampei*) or *ojo de gallo* (*Cercospora coffejcola*). Fourth, the management response including the use of organic methods, fungicides and/or pruning can decrease coffee rust damage. Fifth, farmer estimates may be imprecise compared to measured values. Finally, high loss estimates can be related to other issues related to farmers' decisions to remove old coffee bushes and plant new ones, and claims made to attract international development assistance.

8. The pairwise tests are two-sided independent groups *t*-tests, with Bonferroni correction of the critical values for multiple comparisons.

9. Answers to the education questions were categorical (such as "secundaria incompleta") and were aggregated to approximate years of education by assigning a typical number of years completed to each category.

10. Currency conversion of the previous year's income to dollars used the average of the official exchange rate reported by the Central Bank of Nicaragua for the months of July 2013–July 2014.

11. The most consistent pattern among the demographic variables is a negative (favorable) coefficient on the education of the householder in the hunger and hazard response regressions.

12. In additional specifications (not reported here), we included as regressors coping scores for past hazards: specifically, the 2009 drought and the CLR outbreak. The coefficients on the past hazard variables are not statistically significant.

13. A full table of these correlations for all coping responses is available from the authors.

14. The organizational coefficients are imprecisely estimated, and some sizable positive or negative effects cannot be ruled out. For example, in column (2) of the table, the 95% confidence interval implied by the coefficient on the MCaC variable ranges from −0.06 up to 0.66, the upper bound implying an increase of about 20 days of food insecurity per year relative to the unaffiliated households.

15. For more on a project developing an analysis of poverty, agricultural risks, and coping see: http://www.ifriresearch.net/studying-poverty-agricultural-risks-and-coping-strategies/.

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