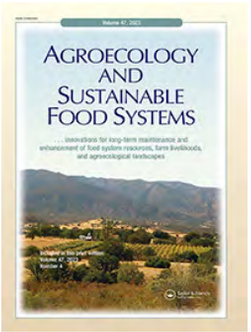

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Beyond the bean: Analyzing diversified farming, food security, dietary diversity, and gender in Nicaragua's smallholders coffee cooperatives

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ABSTRACT

Diversification is key for agroecological transformations, but little is known about how it relates to farmers' dietary diversity and food sovereignty. Our team and coffee cooperative staff conducted a participatory action research mixed methods study, including 171 surveys and 50 interviews. Over 70% of the farmers reported self-initiated diversification activities. Statistical analysis showed a significant positive correlation between crop diversity and dietary diversity, while controlling for farm size and income. To assess gender relations females responded to 41% of the surveys, and we separated focus groups by sex. Average male-owned farms were 1.8 ha larger than women-owned farms, yet we found no significant differences in household food security or dietary diversity. Additional disparities included male vs. female perceptions about who does additional diversification work and who decides about strategies. Although the co-op has a strong gender equity and technical assistance program, our analysis of extension training documents identified useful content and a smaller percent of female participants in diversification vs. gender sessions. Suggested strategic actions for co-op planning include supporting: (1) female land ownership, (2) diversification focused farmer-led experimentation, and (3) more training for men on gender, women on diversification, and all participants in feminist agroecology.

KEYWORDS

Agroecology; gender; Central America; diversification; food sovereignty; participatory action research; Climate adptation

Introduction

Agroecology-based transitions toward more sustainable production, livelihoods, and food systems generally include diversification as a key strategy to decrease dependence upon a single product, increase food security, help manage pests and cycle nutrients, and build resilience (Altieri et al. 2015; Bezner Kerr et al. 2021; FAO 2018; Lin 2011; Stratton, Wittman, and Blesh

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2021). In a seminal report entitled, *From Uniformity to Diversity*, the International Panel of Experts on Food Systems (IPES) analyzed obstacles and opportunities for moving from either traditional subsistence agriculture or industrialized monoculture toward diversified agroecological farming, which is associated with multiple potential social and ecological benefits (IPES-Food and Frison 2016). The IPES Report contributed to a rapidly expanding body of literature on agroecological transitions and agri-food system transformations (Anderson et al. 2019; DeLonge, Miles, and Carlisle 2016; Gliessman and Ferguson 2020; Chappel 2018). However, the IPES generalized the conditions necessary for transitioning to an agroecological system and therefore oversimplified the strategies smallholder farmers used to begin their transitions. In practice, many – if not most – of the over 570 million smallholder farmers (defined here as those managing 5 ha or less) (from Lowder, Sánchez, and Bertini 2021) are neither purely subsistence producers nor entirely specialized commodity farmers; instead, they often combine subsistence production and cash crops to provide for themselves, their families (Author et al. 2014; Burnett and Murphy 2014), and most of the food consumed in tropical climates (Samberg et al. 2016 cited from Shyamsundar et al. 2022). Studies of diversification with smallholder farmers and associated community-based organizations in the Global South are important given smallholders' contributions to conserving agrobiodiversity and sustaining Indigenous cultures. These farmers produce over half of the food consumed by humans, yet paradoxically face some of the highest rates of food insecurity, poverty, and exposure to climate change and other hazards (Altieri et al. 2015).

Questions about diversification are urgent among smallholder farmers involved in tropical commodity exports as they navigate multiple and deepening risks and hazards ranging from climate emergencies, to wars, and rising food and input costs (Clapp and Moseley 2020). The stakes are high as global food insecurity recently increased by 150 million, and hundreds of millions of farmers and workers continue to grow, process and trade coffee, cacao, bananas, and other tropical crops (Jezeer et al. 2017). These production systems influence biodiversity conservation, climate emissions, poverty, and farmer food insecurity. These challenges remain despite the many voluntary sustainability initiatives, such as fair trade and rainforest alliance, launched to address these issues (Bair and Palpacuer 2015; Bennett 2017). The accelerating impacts of climate change on plant health, crop loss, rising input and food costs, and COVID-19's disruption of supply chains further threaten the state of smallholder commodity producers (Rhiney et al. 2021). Key farmer responses to these challenges often focus on reducing or spreading risks, adding additional value to the primary commodities through price premiums and sustainability certifications, on-farm processing, increasing yields, planting drought- or disease-resistant cultivars, migrating, and diversifying farms

and/or livelihoods (Bacon et al. 2008; Rhiney et al. 2021; Kalfagianni 2021). Among these responses, an agroecological transition toward diversified farming arguably offers the most benefits to farmers, communities, climate, and ecosystems through its promise to contribute to increased farmer autonomy, dietary diversity, food security, biodiversity conservation, climate mitigation, and more resilient farms and livelihoods (Altieri et al. 2015; Clapp and Moseley 2020; Gliessman et al. 2022).

Our study contributes to filling the evidence gaps about the relationships between farm diversification, agroecology, and dietary diversity, through an analysis of smallholder coffee and subsistence farmers in Nicaragua. In this article, we examine several ways that the existing diversified farming practices and broader diversification processes among coffee producers organized into cooperatives relate to different dimensions of agroecology with a focus on farmers' food security and dietary diversity. Additionally, we studied farmers' motivations for starting diversification activities, and we assessed the obstacles and opportunities for diversification among farmers that also produce coffee. Drawing on long-term ethnographic research, we were particularly interested in the role of smallholder cooperatives – in this case, multiple service coffee exporting cooperatives – and allied partners in fostering agroecology and farm, food system, and livelihood diversification among affiliated smallholders.

Smallholder diversification, food security, and diverse diets

On-farm diversification strategies typically involve increasing planted biodiversity, by incorporating additional crops or varieties into a one plot or farm. Diversification can occur over time and across space, and include farm management practices, such as crop rotations, intercropping, and agroforestry, as well as on or off farm livelihood and other economic activities (Prefecto et al. 2019a). While sometimes used interchangeably, diversity and diversification are distinct. Diversity usually refers to biological variation within agricultural systems, whereas diversification refers to the process of adopting additional income-generating activities or crops in either livelihood or agricultural systems (Hufnagel, Reckling, and Ewert 2020).

The existing literature on smallholder diversification and coffee growers in Latin America helps summarize the extent of current practices, potential benefits, and trends over time and space. Although many of these farmers report coffee as their most economically important crop, most of the small-scale coffee producers studied in Mexico and Central America were already relatively diversified as they also often cultivated subsistence foods (especially corn and beans), medicinal plants, and managed agroforestry systems that sustain a high number of native and planted tree species and other associated biodiversity (Prefecto et al. 2019a; Bacon et al. 2008; Méndez et al. 2010). Studies have documented multiple benefits associated with diversified

practices on smallholder coffee farmers, finding correlations between diversified production and food security in some cases (Bacon et al. 2021), reduced expenditures on firewood since they can harvest it from the coffee shade trees (Méndez et al. 2010), income stabilization during the agricultural calendar (Anderzén et al. 2020), and the potential for more resilience in the face of environmental hazards, such as hurricanes (Perfecto et al. 2019b; Philpott et al. 2008; Fernandez and Méndez 2019) and droughts (Bacon et al. 2021) as well as falling commodity prices or rising input expenses (Rhiney et al. 2021). Farmer reported motives for implementing diversification strategies across a range of different farms are usually related to increasing income, achieving basic needs, managing risk, responding to a changing market and political context, the desire to experiment with something new, and/or adapting to climate change and hazards (Anderzén et al. 2020; Eakin et al. 2012).

The persistent evidence showing that hundreds of millions of smallholders and rural residents worldwide continue to suffer food insecurity while billions fail to consume sufficiently diverse diets to fulfill basic nutritional requirements highlights the importance of examining diversified smallholder production as a potential response to this problem (FAO et al. 2022). Seasonal hunger, a consistent and predictable annual pattern of diminished food access during one or more months of the year, remains the most common form of food insecurity especially among rural residents and smallholders worldwide (Devereux, Vaitla, and Swan 2008), throughout Mesoamerican coffee growing communities (Bacon et al. 2008; Méndez et al. 2010), and in our northern Nicaragua study area (Bacon et al. 2017). Although the relationships linking smallholder production to farmers' food and nutrition security seem to be intuitive (e.g., higher yields of subsistence crops contribute to food availability, access, and household use or consumption), the reality is more complex (Hawkes and Ruel 2008; Herforth and Ballard 2016). Farmers can access additional food by growing it or through what Amartya Sen calls production entitlements, producing new crops, selling them, and using the additional income (provided there is no loss) to buy more food (exchange entitlements), or securing donations from the government or development agencies (government entitlements) (Devereux 2001). Studies conducted in different contexts have found that the expanded use of on-farm diversification practices was associated with benefits to farm households ranging from higher crop yields and higher incomes to improved food security, and, importantly, dietary diversity (Bezner Kerr et al. 2019a; Frison, Cherfas, and Hodgkin 2011; Gliessman 2015; Kremen and Miles 2012; Mustafa, Mayes, and Massawe 2019; Pretty and Ward 2001). A study of coffee growing smallholders in Mexico found positive relationships correlating on-farm diversification with food security and income (Anderzén et al. 2020). Some farm and livelihood diversification processes focus primarily on income generation and smoothing to address seasonal cash flow shortages during the lean months (Gerlicz et al.

2019). While lean months and coping responses (e.g., skipping meals, eating less preferred foods) are important indicators studying how diversified farming relates to food insecurity, dietary diversity helps to measure nutritional security and dietary quality.

Researchers who study relationships between farm diversity and household dietary diversity have often identified correlations and causal pathways between these variables (Islam et al. 2018; Jones, Shrinivas, and Bezner Kerr 2014; Ng'endo, Bhagwat, and Keding 2016; Pellegrini and Tasciotti 2014). However, this association is often not statistically significant (Sibhatu and Qaim 2018), and it is made more complex by intersecting influences of gender dynamics, the market vs. subsistence orientation of agricultural production, household income, and other factors (Islam et al. 2018; Jones, Shrinivas, and Bezner Kerr 2014, 201). For example, in a context, like rural Nicaragua, in which gendered roles frequently assign household food preparation to women (Bacon et al. 2022), changes in gender relations that increase women's decision-making power over farm production and/or control over income could potentially lead to more diverse and healthier diets, as they have in Honduras (Larson et al. 2019) .

In addition to the multiple potential benefits of diversification, there are limitations, including: new costs, more labor and capital requirements, risks of new crop or activity failure, the need to learn new skills and build new marketing relations, and the risk of environmental damage. Instead of further diversifying their coffee plots, recent evidence suggests that many farmers in Latin America and the Caribbean (e.g., Mexico, Colombia, and Nicaragua) have intensified and further specialized coffee production activities, reducing the diversity of shade trees and/or changing to other land uses that further reduce crop diversity (Jha et al. 2014; Babin 2015; Rhiney et al. 2021). At the same time, they remain interested in diversifying other parts of their farm. For those reducing coffee area, the new crops could be more environmentally damaging than diverse shade grown coffee. For example, some farmers aim to generate short-term income by adding high input chemical-dependent crops (e.g., tobacco) or other extractive on-farm activities (e.g., mining or intensive cattle ranching) that violate agroecological principles, such as biodiversity conservation and enhanced nutrient cycling (IPES food and Frison 2016). Smallholder farmer diversification into non-traditional export crops can increase incomes in some cases, but it can also displace subsistence cropping systems, enhance dependence on external markets, and undermine local food security and sovereignty (Méthot and Bennett 2018). To avoid these harms, help realize the potential benefits, and contribute to a broader food system change process, several leading global food policy experts have argued for the need to invest in agroecological diversification as part of a strategic response (Clapp and Moseley 2020).

Our study conceptualizes diversification through an agroecological lens. There are multiple ways to define agroecological diversification (Stratton, Wittman, and Blesh 2021), but for the purposes of this article we will focus on the presence of diversified farming activities, and specifically crop species richness as well as farm management guided by a set of agroecological principles or elements, such as decreasing reliance on external nonrenewable inputs, activating synergistic ecological relationships, building soil fertility, engaging diverse marketing and distribution channels, supporting farmer autonomy and empowerment, and fostering resilience (Gliessman et al. 2022; Altieri et al. 2015; Wezel et al. 2020). Drawing on recent scholarship and narrowing our focus to farm-level activities, we define diversification as "the intentional addition of functional biodiversity to cropping systems at multiple spatial and/or temporal scales . . . " (Tamburini et al. 2020). The added biodiversity we focus on here are new crops and tree species, and the key functional benefits (and costs) analyzed are related to food security, income, and dietary diversity. We also consider how diversification relates to gendered labor patterns, land access, and the potential for building food sovereignty.

In summary, our review of literature on diversification and agroecology offers an operational distinction between diversified farming vs. diversification processes and suggests several findings. First, there is a growing body of evidence establishing the association between household food security and dietary diversity and adoption of diversified agroecological strategies for farm and food system design and management (Kremen, Iles, and Bacon 2012; Nyantakyi-Frimpong et al. 2016; Bezner Kerr et al., 2019a). Second, although there are multiple pathways to increasing farmers' food and nutrition security through farm and livelihood diversification (e.g., more subsistence crops, more export crops, or adding additional on or off farm activities), specific approaches identifying which strategies are correlated with different sets of desired outcomes for farmers in different sets of circumstances remain underexplored (Méthot and Bennett 2018; Ng'endo, Bhagwat, and Keding 2016). With a few notable exceptions (Bezner Kerr et al. 2019a; Guzmán Luna et al. 2022; Kremen, Iles, and Bacon 2012; Stratton, Wittman, and Blesh 2021; Gerlicz et al. 2019;), we found relatively few empirical studies that investigate the benefits and costs of diversified farming practices *together with the* processes, outcomes, obstacles, and opportunities to effectively integrate agroecology-driven diversification into hybrid, commercial, and subsistence smallholder systems, like those managed by coffee producers, as part of broader strategies to achieve food and nutrition security and, food sovereignty, and gender equity.

Diversification, gender, and feminist agroecology

Diversification processes occur within the context of gender relations and power dynamics, which influence how women, children, men, and LGBTQ+ individuals spend their time and access land, training, and other assets with implications for food security, autonomy, and dietary diversity (Amugsi et al. 2016). Scholars and social movement leaders explaining how agroecology with its principles of diversity and dialogue can transform food systems, cite the evidence that "women perform most of the 'care work' involved in producing crops for self-consumption as well as storing and preparing food, but in most of the world women farmers do not own the land and rarely have access to credit or government support . . . [and] because, in most cases, 'we' are the ones who organize agroecological markets and community gardens, who study agroecology and promote programs for food sovereignty, but our names and work are often unacknowledged" (Morales 2021, 955) as part of a compelling argument for developing a feminist agroecology (MacInnis et al. 2022). Along the same lines, scholars have argued that "Agroecology needs to increasingly integrate feminist contributions to understand and transform power relations in the food system" (Espinal et al. 2021, 1029). While feminist agroecolgical studies that integrate theoretical and institutional approaches will help guide strategic change processes, it's also important to engage empirical research and change at the individual, household, and community level that examine which agroecological strategies and feminist approaches are most likely to contribute to gender equity and improved food security and nutrition among women and all household member (MacInnis et al. 2022; Bezner Kerr et al. 2019b). In addition to powerful examples from Malawi (Benzer Kerr et al. 2019), with Zapatista compañeras in Chiapas (Espinal et al. 2021; Morales 2021; Trevilla) and multiple Via Campesina spaces (Via Campesina 2021) many researchers and local institutions engaged in agroecology-inspired diversification and change processes will benefit from a more profound engagement with feminist approaches and greater attention to third gender positionalities which are beyond the scope of this article.

In addition to assessing and advancing the transformative potential of diversification processes that foreground gender equity, feminist agroecology shines a critical light onto the ways that diversification projects could contribute to gender inequality (Assan et al. 2018). Women are more likely than men to be restricted or pushed out of specific occupations (e.g. agricultural work) due to gendered cultural norms (Ellis 2000; Herrera, Dijkstra, and Ruben 2019). Additionally, a disparity in access to credit makes it difficult for women to take part in diversification strategies that require financial investment (Adzawla et al. 2019). Secure land tenure is key for farm-based diversification, food security, and building food sovereignty (Chigbu et al.

2019). In 2005, a survey conducted in Nicaragua revealed that only 19.9% of the farm landowners were women (Deere, Alvarado, and Twyman 2012).

Furthermore, women are less likely to participate in other supplemental diversification activities due to time-consuming gendered household responsibilities in many contexts – especially in low-resource settings. For example, many women are more likely responsible for collecting water and wood for fuel, and female-headed households often face higher vulnerability to livelihood insecurity (Niehof 2004). These gender disparities in the division of agricultural labor, under compensation for women, and higher likelihood of food and nutritional insecurity among women and children persist despite ongoing efforts to address inequalities (Agarwal 2018; Broussard 2019). Women's land rights in Latin America and globally are affected by marital property rights, divorce, inheritance, division of labor, and other societal factors (Ravnborg et al. 2016). In this context, men have greater authority over land use. This unequal distribution of power hinders women's ability to participate in sustainable agricultural activities (Bose 2017). That said, a study from northwestern Nicaragua demonstrated that both men and women are confronted with land tenure issues, as landownership in this region is concentrated among small number of very wealthy individuals (Radel et al. 2018).

In addition to documenting disparities and critically analyzing the gendered impacts of agricultural development projects, feminist agroecologists engage in participatory action research processes that integrate field research, critical theory, and change processes partnering with local associations to support women's empowerment through processes that leverage agroecology research, training, and practice. For a powerful example of this work consider the findings of study in Malawi that used a baseline and then a follow-up survey – coupled with focus groups and interviews to examine how an intervention fostering participatory agroecology experimentation led to farmers increased use of legume diversification, intercropping, and organic soil amendments as well as more dialogue among spouses about farming practice (Bezner Kerr et al. 2019a). After crunching the data, this study found associations linking intercropping with food security, the use of organic soil amendments and gains in dietary diversity, and that "households who discussed farming with their spouse were 2.4 times more likely to be food secure and have diverse diets" (Bezner Kerr et al. 2019a, 109). Evidence accumulated from studies worldwide shows positive relationship linking women's empowerment, which can include asset ownership, changes in the attitudes of all genders to respect women's rights and autonomy, as well as expanding women's access to credit, assets, education and training, and power over income usage, to improved household food security, decreased vulnerability, and increased dietary diversity (Aziz et al. 2022). There is also an association between increased social support of women and improvement of children's nutritional status (Ziaei et al. 2015).

However, alongside the potential benefits of integrated agricultural diversification women's empowerment efforts come the risks that diversification investments exacerbate existing inequalities. Many women farmers including coffee producers face the "double burden" of being expected to work at home *and* participate in on-farm production activities, often while having little or no voice in agricultural or income-related decisions (Lyon, Bezaury, and Mutersbaugh 2010). Recent studies with women affiliated to coffee cooperatives have documented a "triple burden" associated with the time burden related to their increasing leadership in cooperative governance and ongoing roles in community making and cultural reproduction (Lyon, Mutersbaugh, and Worthen 2017). While livelihood or farm diversification projects that prioritize women could add additional income or food production that contributes to women's autonomy, income, and food access it's also possible that the "additional" work and meetings could be another part of this "triple burden." Furthermore, poverty alleviation strategies that prioritize women's off-farm diversification still must contend with existing norms. For example, a study in Uganda shows that "female household heads face distinct constraints stemming from differential access to productive resources and cultural norms, which mediate their access to livelihood strategies that are more lucrative (Dolan 2004, 665).

Local institutions, including cooperatives and farmer to farmer networks can be key in generating and spreading agroecological knowledge and generating changes that accelerate the use of agroecology-based principles for diversified farming among smallholders (Holt-Giménez et al. 2010; Stratton, Wittman, and Blesh 2021). Gender norms within these local institutions significantly affect the type of work women engage in and their ability to access training and resources (Nara, Lengoiboni, and Zevenbergen 2020). Agricultural extensions' historical failure to acknowledge gender disparities in labor and resource access have also contributed to gender inequalities in women's participation in agricultural activities and training (Diaz and Najjar 2019). Most agricultural cooperatives have women members, but their ability to hold authority within these organizations is often suppressed (Sylvester and Little 2020). Women's limited access to some types of formalized agricultural knowledge and resources (including some types of vegetative material and training for farm and livelihood diversification) has, in some cases, diminished their dietary diversity, food security status, and adaptive capacity in changing conditions (Bezner Kerr et al. 2019a).

In this section of the literature review, we focused on synthesizing existing evidence that shows how an analysis of smallholder diversification, farmer food and nutrition security, and food sovereignty is also shaped by gender relations. Feminist agroecology (FA) offers a critical and engaged approach that unpacks power dynamics within households, local institutions, such as land tenure regimens and cooperatives, and the broader political context. FA

approaches offer a framework for analyzing and working toward more transformative change in food and farming systems drawing attention to the uneven power relations and gendered inequalities that represent obstacles for diversification efforts that also aim to improve gender equity and food sovereignty (Espina et al. 2021; Morales 2021; Espinal et al. 2021). This framework also draws analytic attention to studies analyzing the risks of farm diversification contributing to a double or triple burden on women's labor (Lyon, Mutersbaugh, and Worthen 2017). Although there is a well-established scientific literature focused on the role of gender relations and women's empowerment in food security, and an exciting and rapidly emerging literature in feminist agroecology, with a few notable exceptions (Bezner Kerr et al. 2019b) there are very few studies that simultaneously contribute to advancing feminist agroecological theory and conduct careful empirical field research that seeks to both understand and support locally led strategies to foster gender equity and improve food security and sovereignty. Our study aims to contribute to filling this gap in the literature.

Methods

Research questions

In order to examine the relationships between smallholder coffee farm diversification activities and livelihood outcomes (food security, dietary diversity, gender relations, etc.) in context of efforts to build food sovereignty, this study used mixed methods embedded into a broader, community-based participatory action research (CB-PAR) process. CB-PAR can be defined as an approach that includes the process of constructing trust and establishing mutually accountable partnerships that work toward shared goals by linking researchers with community-based partners through an iterative process as partners engage in research, reflection, and action (Bacon et al. 2013; Chevalier and Buckles 2019; Shapiro-Garza et al. 2020). We organized this study around the following research questions: (1) What are the most common diversified farming activities that smallholder coffee farmers use in northern Nicaragua?, (2) Which household, farm characteristics, and diversified farm and livelihood activities are correlated with improved household food security and dietary diversity?, (3) What is the role of a coffee-exporting cooperative rural extension training programs in agroecological diversification and women's empowerment?, and (4) What are the obstacles and opportunities for using CB-PAR and agroecology to help strategically plan co-op led diversification efforts that aim to improve food and nutrition security and sovereignty?

Study site

Nicaragua is an ideal location to conduct this research, as the country is global leader in the production and export of fair trade, certified organic, and shade-grown coffee, and the development of alternative value chains that support farmer livelihoods and agroecology (Bacon et al. 2014; Jha et al. 2014). Many of the 44,000 coffee smallholder farmers in Nicaragua continue to face challenges with food security, especially as they respond to crop hazards, climate variability, and unfavorable market forces (Bacon et al. 2017). While past studies with Nicaraguan smallholder farmers have identified farm characteristics and practices (Bacon et al. 2017; Bacon et al. 2014) that correlate with food security, less attention has focused on how diversification is related to improved diets and livelihoods in this agricultural context. Nicaragua's agricultural sector produces over 60% of the country's annual exports and over 70% of its food supply (IFAD 2012). Smallholder farmers play a substantial role in this sector – farmers who manage less than 3.5 hectares of land (approximately 75% of Nicaraguan farmers) collectively produce over half of agricultural exports (IFAD 2012). More than 94% of the coffee producers

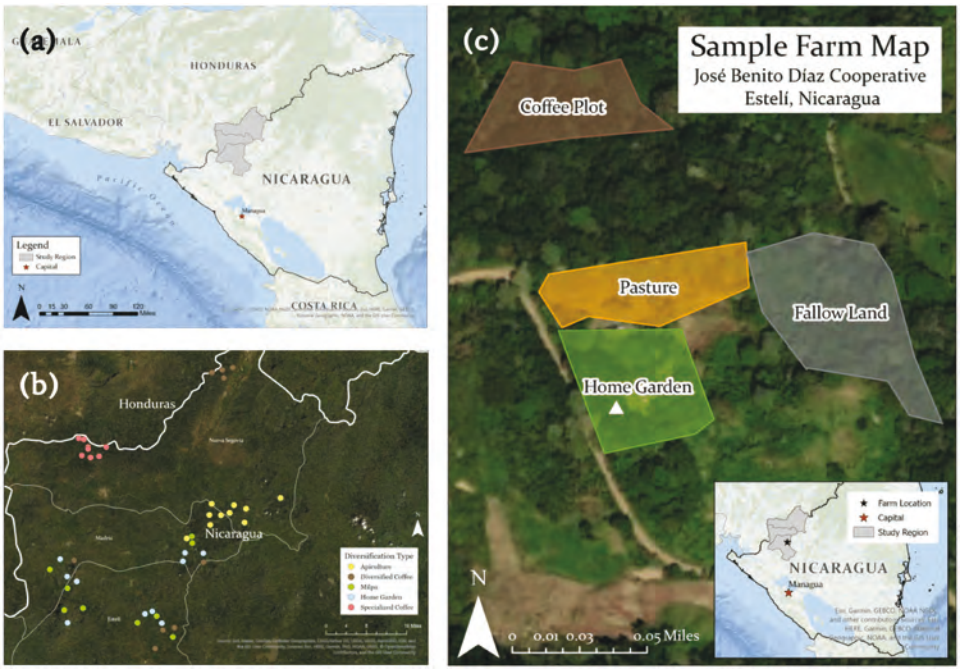

Figure 1. (a) study region in Nicaragua, (b) location and primary diversification type of farms that participated in the on-farm monitoring program, (c) sample map of the smallholder coffee farms investigated in the on-farm monitoring program. Data sources: Participatory action research farm mapping conducted in 2018, ESRI ArcGIS Basemaps, Nicaragua subnational administrative data from Humanitarian Data Exchange (https://data.humdata.org/dataset/nicaragua-administrative-level-0)

manage small-scale operations, but according to official records larger farms (>100 ha) still produce more than 30% of all coffee exports, valued at $400 million annually (USDA 2015). We conducted this study in Nicaragua's north central highlands, an area with a high concentration of smallholder farmers, and part of Central America's dry corridor, which is a global hotspot for food and water security risks (Bouroncle et al. 2017). The study site landscape is made up of low mountains, rolling hills, and plateaus. It has altitudes of 550–1,600 masl (Figure 1), average daily temperatures of 20–32°C, and an average annual rainfall of 991 mm (Funk et al. 2014). The uplands are primarily forests, including 15% of evergreen forest land cover, pastures, and mixed crop production (Kelley, Pitcher, and Bacon 2018). The annual agricultural calendar is structured around an expected May-November rainy season, July-August mid-summer drought, and December-April dry season. Although there is a degree of spatial variation in precipitation and drought severity, the physical geography of lowland mountains is broadly similar across the study area.

Long-term partnerships, participatory action research, and mixed methods approach

Our goals were to a) describe diversified farming and income generation activities and b) analyze how they relate to smallholder livelihood, gender relations, and climate resilience. To do so, we drew from transdisciplinary participatory and mixed-methods research approaches (Aeberhard and Rist 2009; Gomez and Jones 2010; Scoones 2009). A community-based participatory action research (CB-PAR) approach informed the design and conduct of this study (Bacon et al. 2013; Chevalier and Buckles 2019). This participatory study design fits well with an interpretation of agroecology as a transdisciplinary action-oriented approach that is useful for fostering farm and food systems change (Méndez, Bacon, and Cohen 2013).

We partnered with the PRODECOOP farmers' cooperative union that is over 25 years-old and represents more than 2,000 farmers in northern Nicaragua. PRODECOOP focuses on coffee exporting and marketing to fair trade, organic, and specialty coffee. Co-op membership data shows that about 35% of the farmers affiliated with PRODECOOP are female. This cooperative union integrates smaller farmer co-ops and offers professional services to affiliated members, including links to preferred markets channels as well as agricultural training, credit, and other social development training and investments. We also partnered with a Nicaraguan led regional nonprofit agency, the Association for Social Development in Nicaragua (ASDENIC), The Community Agroecology Network (CAN), and Universidad Nacional Agraria (UNA, Nicaragua). ASDENIC helped with the farmer survey campaign and organized together with PRODECOOP, CAN, and our university

a six-day International Learning Exchange. The Community Agroecology Network (CAN) is the third long-term partner in this region. CAN is a U.S.-based 501(c)(3) nonprofit organization whose mission is to sustain rural livelihoods and environments in the global south through the integration of agroecology-based research, education, and development strategies.

The two lead authors of this article have worked with the partner organizations and smallholders in the study area of northern Nicaragua for more than two decades. During this time, we have engaged in long-term ethnographic research consisting primarily of participant observation in many meetings, farmer training days, and the participatory implementation and evaluation of several agroecological development projects that aim to foster sustainable production and reduce seasonal hunger (Bacon et al. 2014, 2021). Our work has included multiple iterations of PAR cycles with these same partners, as we combined mixed methods into a broader approach that relies on a focused ethnography to both study and engage with co-op staff, farmers, and residents (Pelto et al. 2013). Thus, the past 20 years of our work with these partners in the study area informed the design, findings, and interpretation of the study conveyed in this article, which focused on fieldwork from 2017 to 2020. We draw on this research to help explain the context and change over time in gender relations as part of PRODECOOP's strategic planning element focused on food security and food sovereignty.

Household survey

To design the household survey, we worked in partnership with co-op staff members. We drew from questions included in past surveys conducted with smallholder coffee producers in northern Nicaragua (Bacon et al. 2021, 2017). Additionally, we formed a cross-national collaboration with a team of researchers – led by the University of Vermont, Ecosur University, and the CESMACH cooperative – conducting a similar study in Chiapas, Mexico (Anderzén et al. 2020). Survey questions addressed basic demographics, livelihoods, farming practices, diversification activities, food security, dietary diversity, vulnerability, coping mechanisms, and other responses to hazards. In addition to developing a sample that included close to 50% of the interviews with female farmers, to further assess gender relations we included sex-disaggregated questions about land ownership, farm decision making, and access to money from crop sales, and a range of characterizations for the head of household (e.g., Female head w/male spouse, two household heads, single male, single female, other, etc.).

Co-op staff helped identify the research population. Our farmer sample was stratified by participation in different projects among co-opmembers. Farmers that had participated in a co-op or nonprofit-sponsored diversification project for at least three years made up one stratum, and those that had not made up

the other. We also relied on the expert knowledge of our collaborators within the cooperative to further stratify the former group of farmers (those who had 3+ years of experience in a diversification project) by their key diversified farming production strategies that were known to the expert group. These strategies included: specialized coffee, diversified coffee, milpa, home gardens, and beekeeping. Households were then randomly selected from this population and a sample of 171 farmers was completed. Most households have several adult male and female members; however, many surveys create a bias by only interviewing the men as the "presumed" head of household. To avoid this bias, interviewers sought to interview an equal percent of men and women from each farm.

Assessing farm diversity and analyzing quantitative data

A common strategy to assess farm production diversity is to develop a simple count of the total number of crops produced (Sibhato et al. 2015). We have included this information to help compare to other studies. However, we also wanted to account for the fact that some crops were grown in very small quantities and to produce an index-based output on a scale of 1 to 0 to compare to dietary diversity index scores (see below). To quantify and compare agrobiodiversity on each farm, we referred to a context-specific farm crop diversity index developed for smallholder coffee farmers in Nicaragua (Bacon et al. 2017). Each crop, including coffee varieties, edible fruits, and basic grains were scored based on its quantity and

Table 1. Summary of demographic, agricultural, and food insecurity indicators ($n = 171$).

Variable	N	Mean	SD
Household Age of HH (Years)	169	52.1	13.3
% Females interviewed	169	43%	–
Number in household	169	4.1	1.8
Dependency ratio	169	0.29	0.24
Education			
HH head approximate years of education	169	4.1	2.9
Years of education of most educated person in HH	169	8.66	3.42
Wealth and income			
Farm size (Ha)	171	5.5	10.0
Number of income sources	171	2.6	1.2
Income source - Sells coffee (binary)	171	0.82	
Income source - Sells corn (binary)	171	0.11	
Income source - Sells beans (binary)	171	0.30	
Gross income (US$)	164	$2643	$3325
Farm production			
% of farm area in coffee	164	54%	36%
Farm Diversity Index	165	0.84	0.07
Number of fruit trees	171	293.3	322.8
Food Security			
Number of lean months	171	1.6	2.1
Reporting food insecurity only	85	3.3	1.9

Notes: HH = Head of Household Source: 2017 Farm and household Surveys.

significance (see supplemental Table 1 for additional details). We decided to add a weight for coffee varieties since most farmers still listed coffee as their most important crop and given most farmers had over 1 ha of coffee, which could consist of 2000 to 2500 coffee plants, furthermore, coffee varietal differences can be useful for disease resistance. In all other cases this was a species richness count. Crops grown in very small quantities, such as a single fruit tree values ranged from 0 to 1, with higher scores representing greater crop diversity. So, if a farmer grew a single crop, such as a one coffee variety, they would be completely specialized and have a farm diversity index score of zero. However, if they grew coffee and one other crop (say corn) their score would be 1 - ½ = 0.5.

$$\text{Farm Diversity Index(FDI)} = 1 - [1/\Sigma(\textit{weighted scores})]$$

Dietary diversity scores, which are often used to evaluate nutrition and diet quality, estimate the range of food groups (grains, fruit, dairy, etc.) included in a diet (Frison et al. 2006) (see appendix for details). The Berry Index was applied to estimates of the number of days within the last week that each food group was consumed. In this metric, a "meal" refers to each instance of consuming a single food group.

$$\text{Berry Index} = 1 - \sum_{i=1}^{n} p_i^2$$

where p_i = share of all "meals" consisting of food group

Past research has illuminated the relationship between income diversification and household livelihood strategies, whereby many individuals adopt a portfolio of assets and income-generating activities that contribute to risk reduction and stabilized income flows (Barrett, Reardon, and Webb 2001; Niehof 2004). The diversity of income sources was quantified through the diversity of income index (Zhou et al. 2010).

$$\text{Diversity of Income Index} = \sum_{i=1}^{n} p_i \, ln\,(P_i)$$

Where p_i=probability of 1 unit (extracted from the total income) belonging to source i.

Data cleaning, statistics, and visualization were performed primarily in RStudio,, as well as Excell spreadsheets. A linear model was fit between household dietary diversity scores with each of the variables hypothesized to be correlated with dietary diversity based on previous research (Bacon et al. 2017). This model was also used to assess several factors that correlated with food insecurity. These findings were then presented and discussed with collaborating farmers, and triangulated with past research, farmers interviews, and direct observations.

Administrative data and document analysis

To relate diversified farming to gender relations and women's participation in agricultural extension and farmer training activities, we collected and analyzed PRODECOOP's annual reports from 2011 to 2019. Within these reports, we reviewed the summary tables of all training and technical assistance visits, and then conducted a document analysis (Frey 2018) to systematically assess topics covered in the trainings and the sex of participants in attendance. The participants were reported as binary, and therefore the term sex is used for the data, but gender (which is non-binary) is used elsewhere to recognize the effect on gender relations on the roles, work, and impact assigned to individuals based on perceptions of their sex. We coded the descriptions and titles of all workshops and used Excel Chi-square tests for independence comparing female vs. male attendance at PRODECOOP training workshops focused on 1) gender-related topics vs. all others, 2) diversification-related topics vs. all others and 3) gender *and* diversification vs. all others. We also performed a goodness of fit test between the sex distribution of participation in each training type and the known percent of male and female members affiliated with PRODECOOP.

Farmer interviews

Twenty-three "exit interviews" were collected in June 2020 from farmers as the research team neared completion of a five-year collaborative project. The interviews were recorded, transcribed, and coded by researchers at the National Agrarian University in Nicaragua and Santa Clara University in California. The interviews were conducted, transcribed, and analyzed in Spanish; the illustrative quotes shared in the results section were translated into English and reviewed by one of the coauthors who is a native speaker. Because multiple interviewers collected data, the interview questions differed slightly based on a farmer's location. To account for these discrepancies, the exit interviews were coded by theme. These themes included the farmer's thoughts on the advantages of farm diversification, reasons for participating in our diversification study, and challenges the farmers have faced. Some interviews did not discuss all the themes coded by researchers. The coding process for these interviews consisted of two rounds. In the first, interview responses were condensed to one or two phrases summarizing the farmer's reaction to the theme in question. In the second, a code sheet was developed to identify key patterns in the responses. For each theme, researchers conducted frequency counts for the number of times each code word was mentioned in an interview. Additionally, the responses to each theme were stratified by the farmer's sex (male vs. female) and farm type (conventional vs.

organic) to identify associations between these variables and farmer responses.

Preliminary results sharing and strategic action planning

Throughout the research process we shared preliminary results with the cooperative's leadership and affiliated members during meetings, results dissemination workshops, and focus groups. As part of our dialogue with their board of directors and senior staff, the research team helped develop the elements of the co-ops overall strategic plan focused on food and nutrition security, climate resilience, and diversification. In a series of online and in person dialogs, interrupted by COVID-19, hurricanes, and other hazards, we co-developed a draft element of their strategic plan. The methods for developing the plan included a bibliographic review, the administrative review (mentioned above); compilation of past research project findings; design and use of self-assessment tool for work completed from 2014 to 2019; a situational and contextual analysis of existing institutional and political opportunities and challenges.

Findings

Characterizing farmer livelihoods and production systems

Household

A total of 171 smallholder farmers participated in the survey, representing households comprising around four members each, 43% of whom were female (Table 1). The youth dependency ratio (number of children aged 0–14/number in population 15+) was 0.29. The mean farm size was 5.5 hectares (ha) with

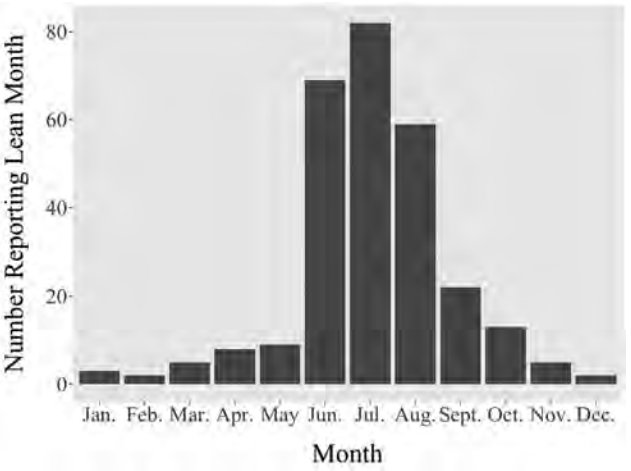

Figure 2. Reported food scarcity by month shows peak from June to August (n = 171).

an average of 54% farm area devoted to coffee production, though these values varied greatly across the study. While still considered smallholders, which are characterized by family-focused motives including some subsistence production and reliance on family labor and thus (Kalfagianni 2021), the average farm size in this study was about 1.8 ha larger those in a sample of similar smallholder coffee growers surveyed for previous studies in northern Nicaragua (Bacon et al. 2021, 105468). We attribute this difference to a different population and sample taken for this study. Farmers reported coffee sales as the most frequent source of income (82%). The average number of lean months for respondents was 1.6.

We used household dietary diversity as a proxy indicator for nutritional security, and a common seasonal hunger indicator – lean months – to assess food security (Bacon et al. 2021). Lean months occurred during the expected period between June and August (see Figure 2). As documented in previous studies, this period of seasonal food insecurity coincided with Nicaragua's agricultural calendar. The planting season for key annual staple crops (corn and beans) usually starts in May or June, but the first bean harvests are not available until late August or September. Cash is also low during these lean months as the income earned through day labor or selling of the coffee harvest – which generally runs from December through February – is often spent by May and June (Author et al. 2014). The average number of lean months of 1.6 (2.1 standard deviation) across all respondents was lower than that of previous studies conducted in 2010 and 2014 in the study area, both of which were drought years, while the year when we conducted this survey (Bacon et al. 2017) was not (Bacon et al. 2021). Across this sample 85 farmers or 49.7% of all survey respondents reported no lean months during the previous year, and the remaining 86 farmers reported an average of 3.3 lean months, which is more comparable to the quantity of lean months in previous surveys.

Although coffee remains the most frequently reported (see Table 1) and monetarily significant income source, the 171 surveyed farmers reported a wide range of diversified farm and income activities. The top eight most frequently reported diversified production activities were fruit trees (99% of farmers), coffee sales (82%), poultry (79%), vegetables (75%), milpa production (57%), livestock (51%), other animals, such as pig and goats (38%), and beekeeping (19%). The number of distinct diversified farm activities reported ranged from 1 to 6, and averaged 3.8 per farmer (SD = 1.2). Moving beyond these activity categories, our count of the total number of crops based on the survey responses, without including varieties or the weights we used for the diversity index below, shows relatively high levels of diversity. We found that average combined crop, livestock, and fruit tree counts across the sample was 11.66 with a standard deviation of 5.48, dropping the fruit trees number of crops and livestock types was 5.41 (3.71). In response to a survey question that

Table 2. Assessment of correlates associated with dietary diversity and lean food months.

	Dietary Diversity		Lean Food Months	
Variable	Coefficient	P-Value	Coefficient	P-Value
Farm Diversity	0.09	0.0002 ***	3.95	0.062 *
# Of Lean Months	−0.002	0.090 *	-	-
Total Income	4.5×10^{-8}	0.044 **	-1.5×10^{-6}	0.40
Income Diversity	0.008	0.20	−0.65	0.19
Female Head	0.004	0.35	0.18	0.59
Total Area	0.0001	0.55	−0.030	0.090 *
Sells Corn	−0.001	0.83	−0.19	0.73
Sells Beans	−0.0006	0.91	−0.20	0.62
R^2	0.1802		0.1053	

Note: *** < 0.01, ** < 0.05, * < 0.1: Source: Household Surveys, 2017.

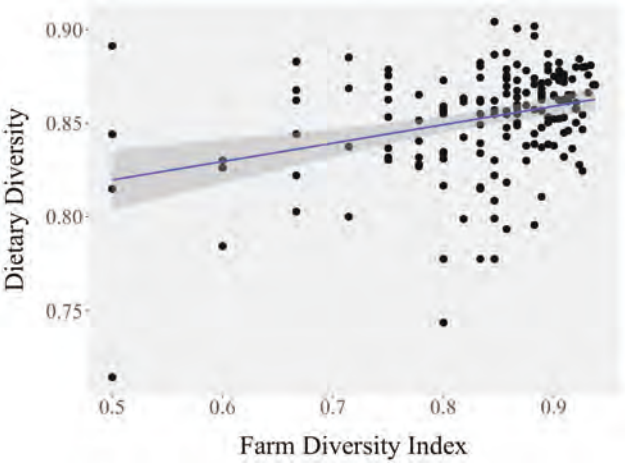

Figure 3. Positive correlation between dietary and farm diversity indices. Source: 171 Household Surveys

asked about the percent of annual income by source, farmers reported on average that coffee sales constituted a majority of their income (56.4%), followed by animals & animal products (11.6%), beans, corn, & basic grains (11.0%), off-farm labor (11.0%), salaried off-farm work (8.4%), fruit & vegetables (4.0%), other business activities (3.5%), support from government programs (2%), and honey production (1.9%). The mean number of income sources was 2.6 (SD = 1.2).

Correlations between diversified farming, dietary diversity, and food security

Across all respondents, on farm crop diversity emerged as a significant predictor of dietary diversity (coefficient = 0.09, p-value < 0.001) (Table 2); dietary diversity and farm diversity were found to be positively correlated (Figure 3). Other suggestive variables that correlated with dietary diversity include number of lean months (coefficient = −0.002, p-value = 0.090) and

total income (coefficient = 4.1×10^{-8}, p-value = 0.044) (Table 2). Although the relationship is relatively weak for lean months the correlation is in the expected direction, as farmers reporting more lean months could potentially be expected to consume less diverse diets, as measured by consumption of the 12 major food groups. The correlation with income is in the expected direction and given the p value of less than 0.05 we can consider this to be moderate evidence of a significant relationship. Higher incomes can be used to purchase and then consume more diverse foods.

In the food security multiple regression model with lean months as the dependent variable (see right two columns in Table 2) total farm area (coefficient = −0.03, p-value = 0.090) was also a suggestive predictor, however, this is considered weak evidence of a relationship between the variables. This figure also suggests the possibility of a weak positive relationship correlating the farm diversity index with the lean food months, which is contrary to the negative relationships one would expect. However, the strength of the correlation coefficient 0.063 is not enough to draw statistically significant conclusions. To further explore this potentially contrary finding we produced a figure correlating the farm diversity index (FDI) and lean months (See Supplemental) in which once again we see a very slight positive correlation. To further examine these potential relationships we analyzed how income, farm size, and dietary diversity scores relate among respondents with 0 or 1 lean months. We found that the average income of farmers reporting 0 lean months was $3,140.58, while the average income for those that reported at least one lean month was $2,165.75, nearly $1000 less than those with no lean months, and below the average income of all surveyed farmers. The average farm area for those reporting 0 lean months was 6.19 ha, a full 1 ha more than the average of 5.24 ha for farmers reporting at least one lean month. The difference was even greater if we considered the average farm size of those reporting 0 to 1 lean month vs. those reporting two or more (6.34 ha vs. 5.05 ha). These numbers are consistent with previous studies correlating farm size and lean months in the study region (Bacon et al. 2021), and the fact that farmers generally need to purchase food during the most frequently reported lean months of June, July, and August as they wait for the first planting of beans from May to come in from the fields. However, there was no clear relationship between the average FDI score for those with 0 months, which was 0.839, compared to the index score for all those with one more lean month 0.836. We explore several reasons why this could be the case in the discussion, but one reason is that the exception of fruit trees is that the diversity index (and our crop count data) does to account for the number of individual plants or the area covered. As a robustness check, we replicated this analysis using the crop counts instead of the FDI, but the results were very similar and thus not included here.

To explore the magnitude of the relationships between selected variables and the household dietary diversity index score, we can work backwards from a scenario focused on increasing dietary diversity by 0.03 or one standard deviation (Table 1). An increase of 0.03 in the dietary diversity, as measured with the Berry Index, could represent a household whose diet consists of an average of four food groups consumed per day averaged over a weekly period introducing a new food group that is eaten once per day. This type of increase in dietary diversity by a score of 0.03 could correspond with: 1) an increase in farm diversity by 0.33, which may result from introducing two new vegetable crops for relatively low-diversity farms or 2) increasing annual income by US $24,300, which is highly improbable given an average yearly income of ~ $2,500.

Gendered land access, crop management, and participation in diversification trainings

A gendered analysis of resource access starts with land tenure. The average farm size across all 171 survey respondents was 5.6 ha (Table 1), disaggregating the data we find that 96 male farmers owned an average 6.5 ha, which is 1.8 ha more than the average farm size of 4.7 ha reported by female respondents. When asked about land tenure, nearly all of both male and female farmers said that farm plots were owned by the family implying shared ownership, yet 55% of the male respondents reported receiving land through inheritance vs. 39% of the women. Average household sizes were also similar and our regression analysis (Table 2) found no significant correlations relating the sex of the survey respondent to dietary diversity or food security. The average number of lean months for both male and female farmers was about 1.6 months during the previous year.

We also asked about who manages different crops, who possess knowledge about them, and how key decisions are made about future diversification efforts. Of the 95% of respondents who reported that coffee was their most important parcel, 49% said that men managed it, 24% reported female managers, 21% said it was managed by both or all family members, and the remainder said it was managed by adult children or others. Approximately 43% of the sample responded to questions about who managed the *milpa*, of these responses 66% said men were the primary managers, followed by 26% stating it was managed by both sexes, and ~ 8% who claimed that women managed it. Despite cooperative-led diversification projects supporting beekeeping projects with female participants, only about 19% of the sample reported beekeeping and of these 64% said they were managed by men. These gendered crop management patterns reversed in our assessment of the 61% who reported a home garden and/or chickens, as we found that females managed 55.2% of them, while 30.5% were managed by both, and 14.3% by men.

Table 3. Sex disaggregated perceptions of diversification impacts on gendered labor.

Variable	N	More work for Women	More work for Men	More work for both
Male survey respondents	96	4.2%	44.8%	51%
Female survey respondents	74	47.3%	14.9%	37.8%
Total	170			

Source: Household surveys 2017.

Table 4. Sex disaggregated perceptions of who plans farm diversification.

Variable	N	Women decide	Men decide	Children/Others	Both decide
Male survey respondents	96	2.1%	55.2%	1%	41.7%
Female survey respondents	72	34.7%	13.8%	5.6%	45.8%
Total	168				

Source: Household surveys 2017.

In addition to the gendered patterns of crop management, we found several important differences between male and female survey responses to questions about who is better informed about the sales of agricultural products, how diversification activities impact family and women's labor patterns, and who decides about future diversification efforts. While close to 50% of both male and female respondents reported that both men and women in the household were well informed about agricultural crop sales, 45% of the male respondents claimed they knew more about these sales vs. 4% that identified females as more informed, while 47% of the female respondents claimed that women knew more about these sales vs. 15% that claimed that males in their household were better informed. Importantly, we found disparities in responses to a question about how diversification activities have affected the distribution of work for women and family members within the household see (Table 3). Although many identified additional labor for both sexes, 43% more female vs. male respondents identified additional impacts to women's labor, and 30% more male vs. female respondents identified more work for men.

We also found sex-based disparities arising from gender inequalities in perceptions of who plans future diversification efforts see (Table 4). While close to 46% of females and 42% of male respondents claim that both men and women decide on future diversification efforts, only 2% of the male respondents listed females as the key decision makers vs. ~ 35% of female survey respondents who described women as the key planners of future diversification efforts. Our experience is that in focus groups with both men and women present respondents often start by emphasizing shared decision making, but additional probing questions reveal these different perspectives. Moving our analysis from the household level to institutional influences on gender relations and access to knowledge for diversification through PRODECOOP-led agricultural training activities also revealed several important trends and disparities.

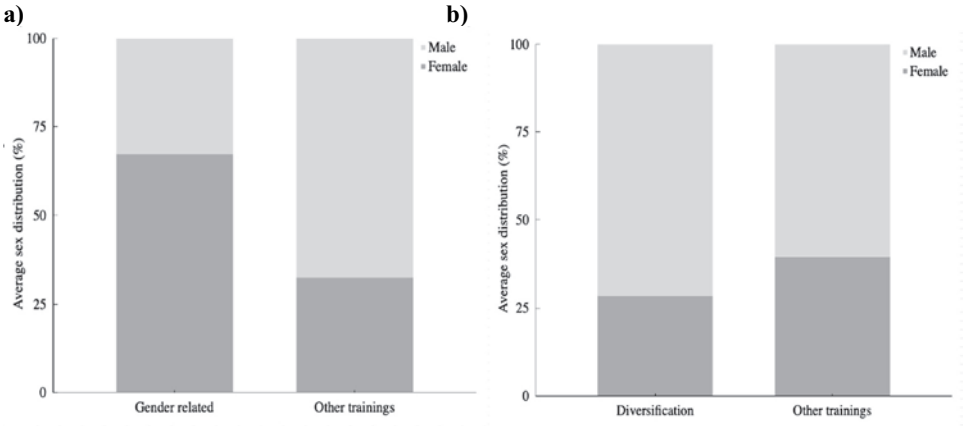

Figure 4. (a). Average percent of women attending gender-related training vs. all other extension training events, from 2011 to 2019. dark gray bars = female attendance. (b). average sex distribution of participants in diversification related training vs. all other extension training events, from 2011 to 2019.

We found that the sex (data was binary) of the agricultural training participant and training topic were not independent of one another. The sex of the agricultural training participant was statistically significant when training topics were grouped as: 1) gender-related trainings vs. all other trainings (χ^2 (1, $N = 24743$) = 20.983, $N < 0.05$), 2) diversification-related trainings vs. all other training (χ^2 (1, $N = 24730$) = 56.393, $N < 0.05$), and 3) gender-related *and* diversification-related trainings vs. all other trainings (χ^2 (2, $N = 24765$) = 1483.84, $N < 0.05$). We observed disproportionate female participation in gender-related training events (see Figure 4A), and disproportionate male participation in diversification-related training events (see Figure 4B).

Source: Our Analysis of PRODECOOP's annual reports.

Farmer perspectives on diversification

Data from the survey shows that 72% of the reported diversification activities began through the individual farmer's own initiative, whereas 15% were attributed to a project and 5% to membership in a cooperative. When asked about the advantages of farm diversification in interviews, most respondents (16 out of 23) of the farmer exit interviews said diversification allowed for increased crop production on existing land parcels. Notably, all farmers who responded that diversification comes with environmental benefits operated certified organic farms. The most common reason respondents gave to justify their choice to diversify their farm was a desire to increase farm or family income (12 out 23 respondents). Around a third of respondents expressed a desire to provide necessary resources for their family, to fight food insecurity, or to care for the environment (many respondents gave multiple reasons for

diversifying their farm). Some additional questions illustrate this point, for example, female farmer said, "*It is advantageous because we are not only growing a single crop, at least for food, so we not only eat beans and corn, but with the vegetables we can make the stew and we can cover the needs in our home and we also sell to bring things that we do not we have.*"

In discussing challenges that they have faced in farm diversification, 9 out of 16 farmers mentioned climate-related issues, including problems with drought, infertile soils, and irregularities in precipitation during the rainy season, May to November, which coincides with their key growing season. To illustrate this point, a diversified Farmer, affiliated with PRODECOOP shared his perspective in an exit interview, stating *"Basic grains [primarily corn and beans] are vulnerable to [surplus] rainfall as well as drought, but through diversification I have crops that are resistant to both conditions. For example, I am going to harvest oranges either way, unless there is a big drought. One has assurance that he has a Plan B. In addition, I consider improvement of the soil to be an important aspect of diversification. We have also started recovering eroded soils that were previously abandoned for lack of harvests."*

One quarter of respondents said they struggled with implementing diversification strategies. Farmers used various strategies beyond diversification to mitigate the impact of lean months. These strategies included doubling down on farm management to increase harvests, storing food for lean months, saving money to purchase food during lean months, obtaining loans, barter, and gathering wild foods. The importance of the lean months and offering modest support to farmers enrolled in the monitoring research was also evident in their statements about use of the monetary stipend. We found that 13 out of 23 farmers used the stipend to purchase food, 12 invested in their farm, seven in their house, and seven used the money to compensate farm laborers (Note that some respondents used their stipend in more than one way).

Our analysis of interviews also contributes to explaining how gender relates to diversification. For example, in focus group consisting adult females when the conversation turned toward coffee production one woman said, "We have been in training about coffee. We all meet together to reach a shared agreement, and after we have united and developed a work plan, we attend to all members, including the smaller producers and those who have more there." When asked about who gives the training, this same respondent continues, saying, "[I as a promoter of the cooperative have also been involved in replicating [the workshops]. We participate in the [farmer] field school and there are more women involved in beekeeping. They have been given boxes [hives], they have participated in beekeeping and then sharing the initial gift with others. Sharing the gift works like this: if I receive three hives, I have to return the same three in a period of three years, so that more women can participate in that beekeeping project." This testimony is in reference to

a beekeeping and honey production diversification project that specifically aims to support women's economic empowerment among smallholder coffee producers. In addition to this project in Nicaragua, a similar project and ongoing practice were developed with smallholder coffee producers in Chiapas Mexico. Although research with producers in Mexico found correlations linking beekeeping with fewer lean months and slightly higher incomes, there was no analysis of gendered impacts in this study location (Guzmán Luna et al. 2022). In Nicaragua, we also found a high degree of interest in beekeeping, however, our analysis did now show significant correlations linking beekeeping to food security or income improvements. However, our analysis of survey data above suggests that in >60% of the cases men managed beekeeping activities. It's possible that these gendered patterns influenced these findings, and more research is needed to further unpack these relations and assess costs and benefits these activities,

Our research team also asked PRODECOOP staff to help identify exemplary farmers with significant experience diversifying beyond coffee and a potential willingness to share their diversification stories, and then conducted interviews and farm visits to document these experiences. To complement the aforementioned analysis and highlight farmer voices, we have selected the following testimony and a photo (see Photo 1) that they gave permission to share in research publications:

"Well, look! Talking about the place where we are [see Photo 1], the home garden, the benefits are that I am no longer going to go to the market to buy these leafy greens, the beets, the onions, because if I have it here in the yard . . . For example, today I came to fill a basket of what is here, to make a meal for the funeral that we were [celebrating], so that is the great importance, the great

Photo 1. Farmers stand in their homegarden with coffee agroforest in the background.

advantage . . . because here you only come to your garden, you harvest, and ... quickly, you are going to prepare a dish.

If I tell you that this is organic, it is organic! How can you prove it to me? Of course, here I have the inputs: I have worm compost, I have the organic fertilizer production; it's where I check it out. And, if you get to a place where they talk to you about this, and they don't have evidence, not even the traces of what's organic management, it's hard. So, it's nice, when the woman gets involved with the kids in all the jobs [in the home garden], and that not only the woman, but the whole family."

- Female Diversified Farmer, affiliated with PRODECOOP, in Miraflor, Estelí Nicaragua.

Synthesis of co-op led strategic planning element on agroecology and food sovereignty

Much of the PRODECOOP's overall strategic planning focuses on how to strengthen coffee production, purchasing, sorting, and commercialization together with participation in fair trade, organic, Rainforest, and other certified markets. However, their mission, which has remained the same for the last 28 years , is "To contribute to improving the quality of life of the families of small producers associated with their base cooperatives, and of our communities in Las Segovias, Nicaragua; investing in development through quality services throughout the value chain of coffee, honey, and other organic and non-organic products, with an emphasis on production, transformation, and marketing." The planning documents add that they pursue their mission while manifesting the values of fair trade, environmental sustainability, gender equality, food safety, among others; all of which transfer knowledge, economic, financial, and social empowerment to all affiliated members and their families. While PRODECOOOP invests in integral agricultural development and more diversification efforts than most coffee exporting cooperatives, our analysis of the 2017–2018 annual report data shows that coffee exports accounted for USD $ 15.87 millions of their gross revenue representing 90% of their total gross revenue (PRODECOOP 2018). Interviews and participant observation over more than ten years suggest that the internal logic model of commercial growth in coffee sales to sustainable markets leading to improved quality life, has gradually shifted to a recognition that issues like seasonal hunger and gendered oppression will not disappear with higher coffee prices alone. In response, starting the last cycle, the co-op's strategic planning process includes elements focused on food security and food sovereignty as well as gender equity and empowerment.

The revised draft strategic plan is entitled, Plan Estratégico en Seguridad y Soberanía Alimentaria y Nutricional con Enfoque de Género y Resiliencia para el Período 2022/23–2027/28 (Strategic plan on food and nutrition

security and sovereignty with a gender and resilience approach for 2022/23–2027/28). It includes an assessment of the impacts of the coffee rust, droughts, hurricanes, price fluctuation, climatic variability and change, and cooperation trends in Nicaragua and the COVID-19 pandemic. The framework for this approach blended PRODECOOP's mission, vision, and goals with the principles of agroecology, gender equity, and cooperativism that informed this specific part of the plan designed for the next 5 years. A topline summary of key goals within this element includes: (1) developing a co-op-wide institutional policy for agroecology and food sovereignty (this would be modeled after their gender policy and accompanied by creating and implementing committee); (2) further diversifying production and livelihoods practices focused on the production of healthy, diverse, and nutritious food; (3) developing new value chains and markets, (4) increasing the access and sustainable use of healthy food, (5) integrating projects to improve drinking water quality and sanitation as well as small-scale irrigation, (6) developing various actions for the personal development and political and economic empowerment of women, daughters, and wives associated with cooperatives, (7) creating a train the trainers program for, and with, farmer promoters (at one point there were more than 40 involved with PRODECOOP) focused on the productive diversification and support for family-led initiatives, and (8) further expanding strategic alliances. Although the research team has yet to finish their feedback and the co-op has not yet revised and finalized it, these components illustrate anticipated future directions.

Discussion

Diversified farms and incomes

For the average household, coffee production comprises around half of total farm area and revenue (Table 1). However, farmers indicated a rounded average of four diversification activities and three sources of income. Furthermore, off-farm salaried work and labor collectively accounted for about 25% of total income averaged across all households; this suggests that farmers are supplementing their income from agriculture with revenue generated off-farm. While there have been changes to average incomes in Nicaragua in the last two decades, the contribution of off-farm income reported in our study is very similar to the findings of another study using a sample of 4000+ rural residents surveyed in 1998, which found that "The landless earn 65%, the small and medium farmers earn about 30%, and the large farmers earn only 10% of their incomes from nonfarm sources" (Corral and Reardon 2001). Virtually all respondents reported the presence of fruit trees, while three-fourths of participants grew vegetables and raised poultry. Over half of farmers also utilized livestock and milpa, and the second and

third-highest income sources were animal products and beans, corn, and basic grains. The average score from the farm diversity index—0.84 out of a maximum of 1—is relatively high yet comparable to that of similar survey samples from previous studies in this agricultural context (2017).

Predictors of farm household food security and nutrition

Higher crop diversity has been found to be associated with higher dietary diversity in several other studies (Bezner Kerr et al., 2019b; Bellon, Ntandou-Bouzitou, and Caracciolo 2016; O'meara et al. 2019). Dietary diversity can be an important measure of food and nutritional security (Rajendran et al. 2017). Our research question looked to give insight into which diversified farming strategies are correlated with dietary diversity and food security. Our study indicates, farm diversity, the number of lean months, and total income were the most suggestive predictors of dietary diversity (Table 2). The farm diversity index was highly significant and correlated positively with the dietary diversity index (Figure 2). This relationship is supported by similar findings between farm and dietary diversity conducted among smallholder farmers in different regions (Islam et al. 2018; Jones, Shrinivas, and Bezner Kerr 2014; Ng'endo, Bhagwat, and Keding 2016 ; Pellegrini and Tasciotti 2014). While improvements in dietary diversity may be attributed to the greater quantity of food types grown and consumed from the farm or the additional revenue generated by the sale of these crops (Hawkes and Ruel 2008; Herforth and Ballard 2016), more research is needed to deconstruct the pathways underlying this relationship. Our study contributes to the growing body of knowledge that works to unpack these associations. Additionally, while less statistically significant, the number of lean months and total income may also influence dietary diversity. The negative coefficient of the former variable suggests that dietary diversity can be improved by decreasing the number of lean months experienced by the household. As proxies for food and nutrition security in this analysis, lean months and dietary diversity are likely closely related – both dimensions of diet likely stem from similar challenges to food access. Several studies highlight the positive correlations between dietary diversity and wealth (Pellegrini and Tasciotti 2014; Ng'endo et al. 2016), and one argues that the positive association between income and dietary diversity is more pronounced in wealthier households (Jones, Shrinivas, and Bezner Kerr 2014).

Food insecurity and seasonal hunger were challenges for at least 49.4% of the surveyed households (Table 1). The average number of lean food months was 1.6 across all respondents, which is lower than that of previous studies conducted in 2009 and 2014 with coffee smallholders in northern Nicaragua (Bacon et al. 2017). Several contextual points are important when interpreting these results: (1) when considering only farmers who reported experiencing food insecurity, the average of 3.3 lean months is more comparable to the

quantity of lean months reflected in previous surveys (Bacon et al. 2017); (2) the previous studies were conducted during drought or after drought years, so one would expect higher averages; and (3) the average farm size in our sample was 5.5 hectares (Table 1), which is significantly larger than mean farm sizes in previous surveys conducted in 2014 and 2017 that averaged 3.70 hectares (Bacon et al). Consistent with past research in the study area, June, July, and August – the first months of the rainy season when new crops have been planted but not yet harvested – reflected the most frequently reported lean months (2017), suggesting that seasonal hunger is one challenge smallholders may seek to address through diversification.

The positive correlation between farm size and the number of lean months suggested by this model is supported by other studies with smallholder coffee farmers, including one conducted with a larger sample in this same study area (Bacon et al.), another one by collaborators in Chiapas, Mexico, that found that farmers with smallholder plots were more likely to experience increased food shortages (Alpízar et al. 2020), and a third study with 500 plus maize and legume producers in Zimbabwe that also found similar correlations (Makate et al. 2016). The small yet negative coefficient of farm size in our regression model suggests that larger farms experience fewer lean months, even after holding other demographic or livelihood factors constant. Although annual income did not appear to be a significant predictor of lean months in this model, there is evidence to suspect some collinearity between farm size, coffee production, and total income (2017).

Gender equity within households and co-ops

A gendered approach to agroecology allows us to examine food security, dietary diversity, and climate resilience through a lens that can help identify and explain disparities in the distribution of diversification-related benefits and burdens (Agarwal 2018). Women's contributions to the knowledge and work that creates and sustains agriculture and food security are fundamental, extensive, and well known, but too often either overlooked or mythologized with little attention to the empirical data (Doss et al. 2018).

Our analysis of data disaggregated by the sex of the survey respondents and of survey questions about gender roles found several expected patterns regarding gender-related disparities in land access, farm size, and crop-related decision-making power over specific crops (See Table 2), identified gendered differences in perceptions of resource access and decision making about new diversification initiatives (See Table 3), and documented several unanticipated conditions. An unanticipated finding was that on average female survey respondents did not report higher levels of household food insecurity than male respondents, despite smaller average farm sizes. Although this was not a sex disaggregated survey conducted within this same household, the

structure of households (e.g., number of individuals and reported designs of household heads) do not appear to be significantly different between female and male respondents, leading us to suggest that men and women lack a mutual understanding on how diversification activities impact gendered labor patterns and who should make future decisions about diversification.

While we did not conduct detailed time allocation analyses or ethnographic work in this area these findings do suggest that women's labor is being undervalued by men when the study sample, suggesting the presence of a double or potentially triple burden of women labor. Empirical evidence drawn from previous ethnographic research with PRODECOOP shows that female cooperative membership has increased over time, increasing from under 20% to over 30%, and women are increasingly serving as elected leaders within the cooperatives as well as positions in the church and local government agencies. These findings are consistent with other studies showing that women farmers, including coffee producers, face the "double burden" of being expected to work at home *and* participate in on-farm production activities, often while having little or no voice in agricultural or income-related decisions (Lyon, Bezaury, and Mutersbaugh 2010). A "triple burden" is associated with the time burden related to their increasing leadership in cooperative governance and ongoing roles in community making and cultural reproduction (Lyon, Mutersbaugh, and Worthen 2017). While livelihood or farm diversification projects that prioritize women could add additional income or food security crops that contribute to women's autonomy, income, and/or food access it's also possible that the "additional" work and meetings could be another part of this "triple burden." Furthermore, poverty alleviation strategies that prioritize women's off-farm diversification still must contend with existing norms. For example, a study in Uganda shows that "female household heads face distinct constraints stemming from differential access to productive resources and cultural norms, which mediate their access to livelihood strategies that are more lucrative (Dolan 2004, 665)."

Our assessment at institutional scales beyond the household focused primarily on the agricultural extension and training events, and included a review of the PRODECOOP's gender equity programs. Additionally, we found evidence suggesting that PRODECOOP has built a robust and expanding gender promotion program that has strengthened female farmers' leadership among the affiliated members and in the elected governance boards of the first-level cooperatives, and further expanded their leadership within the professional staff, while also offering valuable health care access and economic development opportunities. However, our analysis of the participation and themes in agricultural training found that women were much more likely than men to participate in training about gender while they were under-represented in trainings about agroecology and diversification.

There are several potential explanations for the disparities in women's participation in training programs: the topics of the gender-related training, self-selection of the participants, and persistent patriarchal attitudes. We found that PRODECOOP's gender-related training encompasses a variety of topics like advocacy, inclusion and equity, domestic violence, and women's health among other things. Gender-related training often focuses on the female experience, which likely helps explain higher female participation. Other possible contributing factors may include *machismo* and patriarchal attitudes, which persist in rural (and urban) communities across Nicaragua (and elsewhere), despite important examples of women's empowerment processes with smallholders (Hanson et al. 2012). Additionally, these findings are influenced by the historic patterns of women's unequal access to the necessary training, resources, and control over land and income which are important in their ability to adapt to climate change and improve food security (Mudege et al. 2017; Radel et al. 2018; Schmeer et al. 2015). Agricultural extension programs should consider the double burden that women face: working in the fields while simultaneously being responsible for their children's well-being. It is especially critical to implement social support systems for women considering that they are often undercompensated for their labor in the market (Broussard 2019; Neumann 2013), a challenge that PRODECOOP's gender program aims to addressing through their goals and programmatic work explained below.

These gender-influenced participation inequalities should be interpreted within the broader context of PRODECOOPs gender equity work. Conversations with the director of PRODECOOP's gender program and a review of internal documents helped us outline this effort's development process, scale, and accomplishments. From 2005 to 2008, PRODECOOP invested in a three consultative process with all of the 38 affiliated cooperatives and thousands of members to develop its gender policies. The goals identified included: 1) increasing the number of women in leadership positions, 2) increasing services focused on women, and (3) transitioning from gender commissions as reference points to standing committees within the co-op's farmer led political leadership structure. Some of these changes were possible after reform to Nicaragua's Law of the Cooperatives (Ley 499) in 2004, which allowed cooperatives and co-op union's (like PRODECOOP) to create the standing committees they desired.

PRODECOOP's gender policy served as a framework for mainstreaming gender across the organization over the past 14 years. The gender-related advances claimed by PRODECOOP included: (1) recognizing that women produce 26% of coffee sold, (2) doubling the number of female members from 400 in 2007 to 800 in 2018, (3) graduating 18 young women after participation in a training program focused on cooperativism and gender, (4) empowering women to occupy more leadership positions, (5) providing 1,700 women

medical screenings for cervical cancer prevention, and (6) more recently, working to increase women's access to secure land titles.

In addition to the gap in trainings identified, the co-op's internal reflection identified several additional challenges, including: (1) the workload for women serving in multiple leadership positions, (2) fear of change, (3) the entrenched patriarchal culture, and (4) the statutes and rules reform still underway among several affiliated cooperatives. Additional self-reflection on gender policy implementation, included acknowledgment that (1) cooperatives are people, (2) coffee is only the means to bring their families forward, and (3) as people, both men and women have to be involved in making and changing the laws, including Law 717 (a gender equity law approved in 2010 which creates a fund for rural women who seek to purchase land). As the program director reminded us at the end of her presentation in 2017, "*The welfare and living conditions of families are not generated by selling coffee only at $200 [per 100 lbs.], but rather that the real change is at the level of decisions, opportunities, and understandings, involving the family. It is good to generate income, because coffee is a means to get families ahead, but this must be accompanied by attitude changes.*"

Future research and strategic planning

The finding that the majority of farmers (over 70%) attributed their int;egration of diversification activities to their own initiative, whereas only 5% of on-farm diversification practices stemmed from membership in a cooperative or participation in a development project highlights the importance of endogenous motivations and potentially indigenous knowledge in agroecology and diversified production (Wezel et al. 2020 Altieri et al. 2015), and warrants further explorations (Bro et al. 2019). The fact that 70% had initiative to diversify and the knowledge expressed in farmer interviews also suggests re-thinking several aspects of PRODECOOP's rural extension efforts. Our long-term engagement with PRODECOOP staff shows that changes to the farmer extension program have already started. For example, PRODECOOP leaders have learned farmer-led experimentation and participatory learning methods through several farmer-to-farmer exchanges with Nicaragua's *Campesino-a-Campesino* program (Bacon et al. 2014). Additional planned investments in diversification focused farmer experimentation builds from farmer initiatives and is likely to increase dietary diversity could be an important strategy to help identify locally preferred crops, or other diversification activities that increase incomes. Given farmer interviews showing their skill and a sense of sovereignty related to their approach to organic and agroecological production, the co-op and allies could support farmer experimentation that builds from this knowledge, interest, and practice. Many of these lessons have been incorporated in their draft strategic plan for food and nutrition security and sovereignty, but successfully

implementing the current draft of the plan risks over reliance on external cooperation. Studies in other contexts have also found that cooperative commodity exporters may also promote crop specialization by offering loans and other incentives to affiliated smallholders (Chen et al. 2018). More work remains as this multiservice economically successful coffee export co-op learns from, and potentially share with, the well-established grassroots networks fostering farmer learning of agroecological knowledge, values, and practices and expanding social movements through horizontal *Campesino-a-Campesino* exchanges, experimentation, and decentralized facilitation (Holt-Giménez 2006; McCune and Sánchez 2019). Future research could further explore fostering a *dialogo de saberes*—or deeper dialogue across knowledge systems – about the obstacles and opportunities to further integrate co-op and agroecological education models across Latin America (Rosset et al. 2021), and use diversification as a *punto de encuentro*—a place of encounter – that could foster strategic alliances between more commercially oriented co-ops and social movement-oriented peasant associations that may share commitments to gender equity, food sovereignty, agroecological territories, and transforming food systems.

Conclusions

This article contributes a mixed methods analysis of livelihood and agricultural surveys on crop diversification, diet, and livelihoods conducted in 2017, and shares insights from interviews and a community-based participatory farm monitoring program conducted with Nicaraguan smallholder households and a coffee cooperative. We found that many smallholder coffee farmers in Nicaragua continue to confront food security challenges, and that common responses, including crop and income diversification, show potential for improved diets, and in some cases, shorter periods of seasonal hunger. In particular, the positive relationship between farm diversity and farm household dietary diversity can serve as a baseline for developing future strategies and decision-making tools with smallholder farmers. These findings resonate with a recently published meta-analysis, which concluded that, "A majority of studies (78%) found evidence of positive outcomes in the use of agroecological practices on food security and nutrition of households in low and middle-income countries" (Bezner Kerr et al. 2021). Our analysis of the surveys found sex-based disparities in women vs. men's land ownership patterns (males had about 1.8 ha more on average) and perceptions of who plans future diversification efforts with only 2% of the male respondents listing females [in their household] as the key decision makers vs. ~ 35% of female respondents who described women [in their household] as the key planners of future diversification efforts. Additionally, we found that cooperative-led training events generally had more male participants, except for those focused on gender. Our ongoing CB-PAR dialogs with PRODECOOP staff, encouraged closer ties

between their agricultural extension team and the gender program, examples of this include inviting more women to the agroecology and diversification training sessions and expanding their gender programming with male members. Suggestions also included strengthening their "family" oriented approach by offering workshops that improve communications and spouses planning productive activities together, offering more child care (already offered occasionally) for training events, and developing a credit program that prioritizes female land access, especially among the smallest farmers. Many of these are included in the current draft of PRODECOOOP's strategic plan. A shared reading circle with action researchers and co-op staff focused on feminist agroecology (Trevilla Espinal et al. 2021) and cooperativism could further inform revisions to this plan and generate wider understandings of gender – including third positionalities – and its critical role in diversification processes that aim to advance agroecolgical transitions and food sovereignty.

While these findings are most relevant to the 1 million+ smallholders that also grow coffee across Latin America they are broadly relevant to the many of the world's 600+ million smallholders that help sustain food security and biodiversity, while also facing seasonal hunger and vulnerabilities to climate change and other hazards. More research is needed to explain who, why, and to what extent different farmers combine diversification practices into specific, deliberate, and targeted strategies toward improving diet and health. Understanding the motivation and intention underlying the adoption of diversification activities, use of agroecology, and integration into comprehensive strategies is key. Further steps toward developing a hypothesis-driven diversification typology includes incorporating qualitative insights from focus groups, interviews, and monthly quantitative data from the on-farm monitoring aspect of this project. Additional analysis on the role of women in initiating and maintaining diversification activities can help uncover the gendered aspects of agroecology and nutrition. Given the persistent challenge of food security and dietary diversity exacerbated by risks of climate change, commodity price swings, shifting markets and supply chains, and other hazards, smallholders in Mexico, Central America, and those globally will benefit from greater investment, policy support, and community-based research to understand and support the role of diversification in agroecological transformations toward more inclusive, just, and sustainable livelihoods and food systems (Gliessman and Ferguson 2020).

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Misael Rivas works for PRODECOOP

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