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Effects of on-farm diversification strategies on smallholder coffee farmer food security and income sufficiency in Chiapas, Mexico

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1. Introduction

Diversification has been identified as an important agroecological strategy for rural development (Scoones, 1998; Ellis, 2000; Amekawa, 2011; Gliessman, 2015; FAO, 2018; HLPE, 2019). A growing body of evidence suggests that diversification is important for enhancing food and livelihood security, adapting to climate change, and conserving and protecting natural resources (Altieri, 2009; Amekawa, 2011; FAO, 2018; HLPE, 2019). In this paper, we describe strategies used by smallholder coffee farmers in Chiapas, Mexico, to diversify their agricultural production and earnings. We also explore some of the potential outcomes of these strategies in terms of food security and income sufficiency.

Small-scale shade-grown coffee agroecosystems represent an illustrative example of diversified farming systems that provide an array of ecological, economic, and social benefits (Perfecto and Vandermeer, 2015). In Mesoamerica, coffee systems constitute a central livelihood activity for a large number of smallholder farmers (Jha et al., 2011). Smallholder farmers typically grow their coffee in shade agroforestry systems (Toledo and Moguel, 2012), which are home to a diversity of species that farmer households can sell or use for food, medicine, and timber/firewood (Soto-Pinto et al., 2000; Jha et al., 2011). Although coffee remains the main source of income for many households, farmers often complement their livelihood portfolios with other on-farm production, off-farm labor, and non-farm sources of income (Jaffee, 2014; Fernandez and Méndez, 2018; Gerlicz et al., 2018). Some farmers engage in vertical diversification within coffee (Rodríguez Padrón and Burger, 2015). Despite the diversity of food- and income-generating activities, many smallholder households experience seasonal food insecurity (Morris et al., 2013; Bacon et al., 2014; Fernandez and Méndez, 2018), and face challenges in earning a 'livable' income, even when participating in sustainable certification schemes (Robles Berlanga, 2011; Jaffee, 2014; Caswell et al., 2016; Sherfey, 2017). In addition, a changing climate poses further challenges to coffee producers (Imbach et al., 2017).

Many studies have explored aspects of livelihood diversification in smallholder coffee systems (e.g., Jha et al., 2011; Jaffee, 2014; Vellema et al., 2015; Gerlicz et al., 2018). However, few studies have examined connections between farmer households' resource-base, livelihood activities, and food and/or livelihood security (Eakin et al., 2012; Baca et al., 2014; Donovan and Poole, 2014; Caswell et al., 2016; Fernandez and Méndez, 2018). This study analyzed characteristics and outcomes of livelihood diversification among coffee farmers of the Campesinos Ecológicos de la Sierra Madre de Chiapas (CESMACH), and constitutes the first phase of a 3-year research project on livelihood diversification in the coffee lands of Mexico and Nicaragua. The results of this survey established a baseline for subsequent research that included monthly data collection with a selected cohort of CESMACH members for over a year. We believe that this type of place-based research is important for (1) gaining a deeper understanding of the complex, and dynamic,

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livelihood diversification strategies used by rural smallholder coffee farming communities; (2) understanding what kind of diversification (if any) may be the most optimal for the smallholder producers, in terms of food security and the household economy; and (3) creating actionable knowledge for decision-making at different levels (household, co-operative, and coffee industry).

We applied an adapted version of the Sustainable Livelihoods Framework (Scoones, 2009) to study on-farm diversification strategies, households' livelihood resources (assets), and how these are associated with seasonal food insecurity and income insufficiency. Previous studies and our field experience pointed toward four diversification strategies (combinations of the activities of coffee production, beekeeping and *milpa*) that appeared to be particularly relevant for the provision of food and income. Maize and beans are staple crops that form an essential part of Mexican diets, identity and culture (Eakin et al., 2015; Appendini and Quijada, 2016; Guzmán Luna et al., 2019), while beekeeping provides an additional, relatively stable source of on-farm income for coffee farmers (Magaña Magaña and Leyva Morales, 2011; Bathfield et al., 2013). In recent years, CESMACH has been actively promoting beekeeping among its member farmers with support from NGOs.

To understand the connections between smallholder coffee farmer household livelihood assets, strategies, and outcomes, we posed the following research questions: (1) What livelihood diversification strategies are currently in use by smallholder farmers of the CESMACH coffee cooperative?; (2) What characteristics vary among the smallholder coffee farmer households having different livelihood strategies?; and (3) How are such characteristics and livelihood strategies associated with interacting outcomes of seasonal food insecurity and perceived income sufficiency?

This paper is divided into six sections including the introduction. In section 2, we explore theoretical and empirical perspectives on livelihood diversification in smallholder coffee systems, and describe the socio-economic context of our case study. In section 3, we describe the methods for data collection and analysis, our research approach, and the conceptual framework. In section 4, we present the study results starting with the characteristics of the participants and their livelihood strategies, followed by the outcomes related to income and food security. Finally, we conclude the paper with a discussion of the findings as well as policy implications in sections 5 and 6.

2. Livelihood diversification in coffee agroecosystems: theoretical and empirical perspectives

2.1. Dimensions of livelihood diversification

Livelihood diversification is a dynamic process that is influenced by a range of contextual and interconnected factors (Ellis, 2000). Ellis (2000, p. 15) defines diversification as "… the process by which rural families construct an increasingly diverse portfolio of activities and assets in order to survive and improve their standards of living." Activities refer to a range of on-farm, off-farm, and non-farm pursuits that individuals or households engage in to generate cash income, produce food for household consumption, or gain other benefits, such as personal contentment (Ellis, 2000; Scoones, 2009). Assets, on the other hand, are different resource categories, including natural, financial, human, physical, or social, that are owned or controlled by households (Ellis, 2000; Scoones, 2009).

Households' access to assets and choice of activities is mediated by a variety of factors, and entangled in power dynamics often outside the reach of individual households (Ellis, 2000; Ribot and Peluso, 2003; Scoones, 2009). In the Theory of Access, Ribot and Peluso (2003, p. 153) define access as "the *ability* to derive benefits from things", bringing attention to relational and structural mechanisms that create differing opportunities to gain, control, and maintain access to resources. For example, land ownership does not necessarily imply the access to resources that enable the owner to make use of the land. The access to these resources could be limited by absence of credits or other factors. Moreover, access is not static but a process, and access patterns can change over time (Ribot and Peluso, 2003).

2.2. Coffee farmers as exponents of livelihood diversification

Smallholder coffee production provides ample opportunities for livelihood diversification. Similar to other coffee producing regions in Mesoamerica, many smallholder coffee farmers in Mexico grow Arabica[1] coffee in diversified shade agroecosystems along with multipurpose trees (Soto-Pinto et al., 2000; CEDRSSA, 2018). These agroecosystems generate many vital ecosystem services that provide "agroecological resistance" to climate change (Perfecto and Vandermeer, 2015, p. 230; Altieri, 2009), and contribute to farmer households' food and livelihood security (Toledo and Moguel, 2012). For instance, fruit trees not only provide shade to coffee but also contribute to household nutrition through the production of fruits that are rich in vitamins and minerals (Albertin and Nair, 2004; Morris et al., 2013). Likewise, several species of plants, insects and mushrooms that inhabit the understory of shade coffee plantations are important to traditional cuisine and are used to complement diets (Luna-González and Sørensen, 2018; Fernandez and Méndez, 2018). In addition to nutritional benefits, coffee agroecosystems produce economic value beyond coffee (Albertin and Nair, 2004; Westphal, 2008). In Guatemala, 'shade products' from coffee plots, such as fuelwood, food and lumber, accounted for approximately one fifth of the value of the coffee agroforestry system (Rice, 2008).

In conjunction with coffee agroecosystems, coffee farmers often manage other agricultural activities for food and income, such as raising animals or growing fruit and vegetables in home gardens (Jha et al., 2011; Jaffee, 2014). Corn and beans, often grown in *milpas* (corn-bean-squash polyculture), are traditionally an important part of people's diet and food security in Mexico (Appendini and Quijada, 2016). Although some producers have converted *milpas* into coffee parcels, many households continue to plant corn and beans for self-consumption (Jaffee, 2014; Appendini and Quijada, 2016). *Milpa* production can also serve as a coping strategy that some coffee farmers revert to in times of crisis (Eakin et al., 2012; Jaffee, 2014). In terms of agricultural income diversification, beekeeping for honey has shown to be a promising alternative for some smallholder coffee farmers (Bathfield et al., 2013). Beekeeping does not require much land, and can be economically viable even in relatively small operations (Magaña Magaña and Leyva Morales, 2011). It can also contribute to the health and nutrition of the households, as beehive products have high nutritional and medicinal values (Pasupuleti et al., 2017). Moreover, beekeeping offers pollination services for coffee agroecosystems (Imbach et al., 2017).

2.3. Multiple motives driving diversification among coffee farmers

Multiple motives can drive coffee farmer households to diversify their livelihood portfolios. For example, farmers may pursue diversification in order to manage risk, meet the basic needs of their household, or to respond to shocks or stressors that threaten livelihood assets or activities (Niehof, 2004; Westphal, 2008; Jaffee, 2014; Gerlicz et al., 2018). Examples of these livelihood shocks include natural disasters (Eakin et al., 2012) and declines in global coffee prices (Jaffee, 2014; Hausermann, 2014; Rodríguez Padrón and Burger, 2015). Diversification can also serve as a means of dealing with persistent livelihood stressors, such as seasonal food insecurity (Baca et al., 2014; Morris et al., 2013) or changing climate patterns (Ruiz Meza, 2015).

[1] Arabica coffee (*Coffea Arabica*), the species of coffee dominating specialty markets, is an understory shrub that grows best at moderate temperatures and middle to high elevations (600–2000 m) (Jha et al., 2011).

Regardless of what pushes or pulls farmers to diversify, the decision of what activity to pursue also hinges on whether the household seeks a temporary coping mechanism or a long-term strategy (Westphal, 2008; Jaffee, 2014; Gerlicz et al., 2018).

2.4. Enabling and limiting factors for livelihood diversification among coffee farmers

Access to assets can either enable or limit coffee farmers' adoption of alternative livelihood activities. First, land availability (natural asset) is essential to rural livelihood diversification. Small landholdings and lack of access to additional land can constrain coffee farmers' opportunities to diversify their production (Eakin et al., 2012), or entail trade-offs between cash crops and subsistence production (Ponette-González, 2007). Second, household size and composition (human assets) are important determinants of diversification, as the availability and type of household labor have implications on the allocation of human resources (Vellema et al., 2015). For example, labor demands for coffee production may overlap with other activities, driving farmers to consider trade-offs in labor allocation (Westphal, 2008; Jaffee, 2014).

Third, changes in land-use or crop mix often implies investments (financial assets) that can deter resource-poor farmers, especially if access to financial capital is limited (Westphal, 2008; Ribot and Peluso, 2003). Moreover, farmers may be hesitant to take financial risks and pursue diversification, if market access is uncertain or technical assistance to support new activities is lacking (Tucker et al., 2010). Finally, diversification decisions and access to assets is mediated by various structural factors or processes at different levels, such as shifts in agricultural or trade policies (Ribot and Peluso, 2003). In our analysis, we considered land ownership, agrobiodiversity, household size and composition, sources of income and volume of coffee production as the limiting and/or enabling assets/conditions of livelihood diversification .

2.5. Case study background

Chiapas is the principal coffee producing state in Mexico and among the first states to produce coffee over 200 years ago (CEDRSSA, 2018). Initially, coffee production was largely controlled by foreign estate owners who constituted a class of coffee elites (Jaffee, 2014). Following the post-revolutionary agrarian reforms in the early 20th century, smallholder farmers and cooperatives were able to replace some of these large landowners as important actors in Mexican coffee production (Jaffee, 2014). Today, the vast majority (95.4%) of approximately 500,000 producers in Mexico are smallholders (< 5 ha), and around 90% of them grow coffee in shade agroforestry systems (CEDRSSA, 2018). The creation of the National Mexican Coffee Institute (INMECAFE) in 1958, encouraged smallholder farmers to specialize in coffee by offering credit, agricultural inputs, centralized coffee purchasing and technical assistance. Around that period, INMECAFE was the largest buyer of coffee in the country (Hausermann, 2014). Because of these supports and incentives, coffee production expanded rapidly, in many cases replacing other crops, such as maize (Tucker et al., 2010). The dismantling of INMECAFE in 1989 forced farmers to seek ways to cope with the new situation, leading to the creation of smallholder cooperatives, among other alternatives (Jaffee, 2014).

Campesinos Ecológicos de la Sierra Madre de Chiapas (CESMACH) were among the cooperatives that emerged from the post-INMECAFE context. In 1994, a group of farmers founded the organization to bypass intermediaries for the commercialization of their coffee and thus obtain better prices for their product. In addition to financial viability, conservation of the environment has been an important principle for CESMACH since the beginning (CESMACH, 2019). The 663 members (211 women and 452 men) of CESMACH live in 46 communities (*ejidos*) in the Sierra Madre de Chiapas mountain range, and grow mainly *Arabica* coffee between 900 and 1700 msl (Fig. 1). The communities are located in the buffer zone of the *El Triunfo* Biosphere Reserve, a biodiversity hotspot, which offers ideal conditions for coffee production (Cortina-Villar et al., 2012). The region was largely uninhabited before the 1950s, when, attracted by the possibilities to grow their own coffee and to acquire land through the agrarian reform, former coffee plantation workers, people from other regions of Chiapas, and indigenous people from Guatemala started migrating there (Cortina-Villar et al., 2012; CESMACH, 2019). Today, coffee is the main livelihood activity for many people living in the region, with maize-bean cultivation and some livestock being other important land use systems (Fernandez and Méndez, 2018). The municipalities where CESMACH members live have been categorized as having 'high' levels of marginalization (CONAPO, 2015), due in part to the geographically remote location of the communities.

CESMACH is committed to the wellbeing of its members, and offers them access to markets, financial resources and technical assistance (CESMACH, 2019). It holds Fair Trade and Organic certifications, among others, and participates actively with the Small Producers Symbol (SPP), a global network of small farmers' organizations. In recent years, CESMACH has diversified their own market for coffee sales – continuing to export green coffee, and by creating a commercial subsidiary; *Sierra Verde de Chiapas SC de RL de CV,* which manages two coffee shops in the state capital, and processes and distributes a line of coffee for national consumption. *Café Femenino México* is a registered trademark for coffee grown by female members of CESMACH. It was initiated by a group of female heads of households who, inspired by experiences of a group of Peruvian women, sought to get recognition and direct compensation for their work. Currently, 146 women benefit directly from *Café Femenino.*

In addition to their focus on coffee, CESMACH has partnered with several NGOs and governmental agencies to support its members to diversify their production beyond coffee. Past projects have included the introduction of fruit trees, small family gardens, and beekeeping. These initiatives have proven important partly due to the devastating coffee leaf rust epidemic that affected the region, and illustrated the vulnerability of CESMACH members as coffee producers. CESMACH has enjoyed special success with beekeeping, and in 2019, *Miel Real del Triunfo*, a parallel cooperative with 80 members, was created by CESMACH members to sell their honey. Management of honey bees (*Apis mellifera*) was first introduced in 2009 by the Heifer Foundation through a project that promoted the adoption of different on-farm activities. According to the project manager of the *Miel Real del Triunfo,* beekeeping was the most successful activity, as it generated income for the families and targeted any member of the cooperative who was truly motivated to become a beekeeper. Over the recent years, beekeepers have started to invest more in apiculture, partly through a partnership with Food 4 Farmers, a US-based organization that has provided financial and technical support.

Beekeeping aligns well with the expected benefits of productive diversification. In the words of the CESMACH general manager: "[CESMACH] should be focused on satisfying the dietary needs of families, the conservation of resources *in situ* and (supporting) the role played by the flora and fauna in the *milpa* agroecosystem and surrounding local environments". Although there is support for diversification activities from CESMACH members, the cooperative is aware of the difficulties for diversifying and recognizes previous failures, such as not recognizing the conditions and needs of the member families, at a given time. These contextual factors, and a desire to find solutions, motivated CESMACH to participate in the PAR process, which forms the basis for this paper.

3. Methods and analysis

3.1. Research project and the PAR approach

This paper presents results of a household survey that constitutes

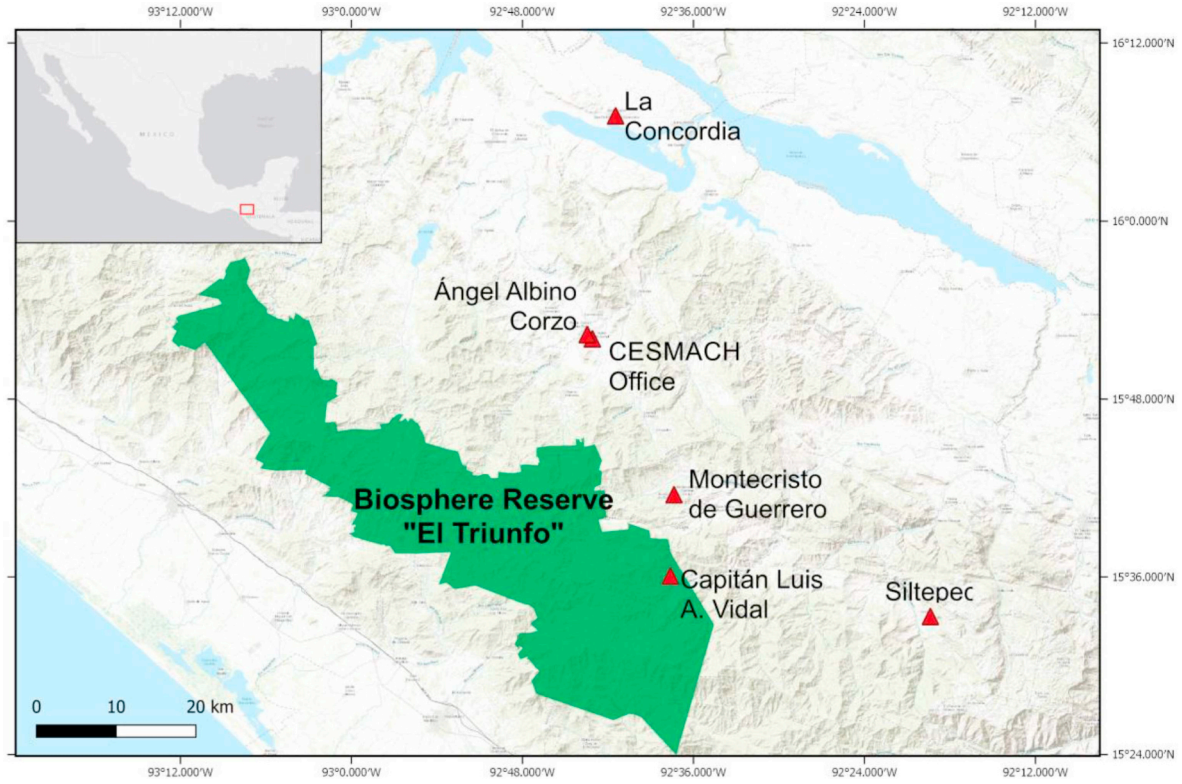

Fig. 1. Map showing the 5 municipalities where the study was conducted, the Biosphere Reserve and the co-operative office . Coffee-growing communities are located in higher elevations.

the first phase of the 3-year, transdisciplinary research project "Assessment of Diversification Strategies in Smallholder Coffee Systems of Mesoamerica". The project was launched in 2017, and aimed to generate scientific and actionable knowledge on livelihood diversification in coffee-growing communities of Mexico and Nicaragua. We used a participatory action research (PAR) approach to frame and guide our research. PAR is better described as a process (rather than project), and usually combines mixed methods research with knowledge co-creation through the engagement of scholar and non-scholar partners. It seeks to generate scientific evidence on a topic of interest to all parties and build capacity for strategic decisions (Méndez et al., 2017). This is commonly done through an iterative process that includes a 'preflection' phase, and cycles of research, reflection and action (Méndez et al., 2017). In this process, members of the Agroecology and Livelihoods Collaborative (ALC) of the University of Vermont (UVM) led the preflection with all partners to define research objectives and roles. The participants of the PAR process in the Mexico site[2] include the leadership of CESMACH, a group of community facilitators,[3] professors/researchers from El Colegio de la Frontera Sur (ECOSUR) in Chiapas, the Community Agroecology Network (CAN, a U.S.-based non-profit), and the ALC. Due to pre-existing relationships between project partners, there was already a certain level of trust among the team members, which facilitated open dialogue from the very start of the process.

The preflection phase was followed by survey data collection that sought to generate a baseline and, subsequently, steer phases of deep reflection and action (see Lewin, 1946; Bacon et al., 2005). Once research was initiated, the team sought to maintain the PAR principles of transparency, communication, and collective action in the generation of methodologies, data collection, its analysis and interpretation (Méndez et al., 2017). In advance of, and parallel to the preparation of this paper, the team has engaged in ongoing dialogue with stakeholders, produced materials, and facilitated activities that fulfil the reflection and action components of the PAR cycle. These include sharing preliminary data among farmers and other audiences, and designing popular educational tools for farmers.

3.2. Participants and data collection

Data was collected through surveys of 167 households, which represent approximately 25% of CESMACH's total membership. Within this sample, 28.7% of the interviewees were women (see Table 1). Households were randomly selected from five groups (30 participants from each group): 1) beekeepers, 2) farmers with *milpa* (selected from a list that was generated in a previous, related study; Fernandez and Méndez, 2018), 3) farmers who had participated in diversification projects, 4) farmers participating in specialty coffee initiatives, and 5) farmers who had not participated in any projects. These groups were chosen with the assistance of the cooperative leadership as potentially representing the range of engagement with diversification present in the cooperative, based on previous data that CESMACH had gathered from all of its members. We added several beekeeper households to the survey in order to obtain a sample size large enough for statistical inference, resulting in an overrepresentation of the beekeeper group in the sample (50.7% of all beekeepers in the cooperative). The selection sought to maintain a gender representation proportional to the cooperative's membership, and include participants from all the municipalities in which CESMACH has members. Due to a policy of CESMACH, participants did not receive a monetary compensation.

The Phase 1 survey included an initial design by the core research team, followed by a round of revisions and edits from the participating field team. The survey was then vetted by the cooperative partners, and underwent several rounds of piloting and testing. The instrument consisted mostly of closed ended questions, and was administered on

[2] In Nicaragua, the project partners include the coffee cooperative PRODECOOP, Santa Clara University, Universidad Nacional Agraria (UNA), and CAN.

[3] Community facilitators are young farmers who are CESMACH members or children of members. They participate actively in all phases of the PAR process.

Table 1
Household and key activity characteristics.

	Livelihood strategy groups									
	Group 1		Group 2		Group 3		Group 4		All	
Number of households	42		89		19		17		167	
	mean	*sd*	mean	sd	*mean*	*sd*	*mean*	*sd*	*mean*	*sd*
Age of interviewee	43.9	10.8	48.7	15.5	41.6	7.8	43.7	16.3	46.2	14.0
Years of formal education completed by the interviewee	5.3	3.3	3.9	3.4	6.6	3.6	5.9	3.9	4.8	3.6
Household size	4.8	2.1	6.3	2.5	6.6	2.0	6.0	2.4	5.9	2.5
Number of children and elderly (age: < 15y and > 64y)	1.7	1.6	2.4	1.6	2.3	1.4	2.1	1.4	2.2	1.6
Number of adults (age: 15y-64y)	3.1	1.7	3.9	1.9	4.3	2.3	3.9	2.0	3.7	1.9
Landholding size (including forest) (ha)	9.2	6.7	8.3	4.7	8.9	8.5	9.7	4.8	8.7	5.7
Coffee										
Land under coffee (ha)	7.1	4.7	5.4	2.6	5.5	1.5	6.7	4.4	6.0	3.4
Land under coffee (% of total land) (n = 155[a])	82	22.9	69.6	19.4	81.0	25.4	64.3	25.1	73.5	22.4
Coffee harvested (quintales of parchment coffee, total)	56.3	63.0	30.1	23.5	45.7	29.6	47.2	48.8	40.2	41.5
Renovation after coffee rust (% of households)	90.5		74.2		84.2		76.5		79.6	
Staple foods										
Land under maize and/or beans (ha)	n/a	n/a	1.4	1.4	n/a	n/a	1.5	1.2	1.4	1.4
Beekeeping										
Number of beehives	n/a	n/a	n/a	n/a	18.6	15.6	21.4	14.2	19.9	14.8

[a] Reliable information was not obtained from 12 respondents.

tablets using Kobo Toolbox (https://www.kobotoolbox.org/), a free open-source tool. The application of the survey took between 40 and 60 min. The survey team consisted of six enumerators, the local field coordinator, two doctoral students and an undergraduate student, who visited 30 communities during June and July 2017. Survey team members held reflection sessions after each workday, both to enhance data quality and also to include the survey team in initial data analysis.

The survey included 79 questions organized in eight sections, as follows: household demographic information, land use, diversification activities, financial capital, shocks and stressors experienced by farmers, food security, social capital and community, as well as a specific section only for beekeepers. The list of on-farm activities was compiled in collaboration with CESMACH and represents the most common activities in the communities. The option "other" was given to ensure identification of other possible activities. The survey sought to obtain information about farmer households' livelihood activities, their resource base as well as indications of the possible economic and food security outcomes of their livelihood decisions.

We used various sources of qualitative data to triangulate survey data, and to engage CESMACH members and staff in the data analysis and reflection. These included key informant interviews with the CESMACH leadership, agricultural calendars developed in three focus groups, and two data-interpretation workshops with the local research team. In addition, we drew information from participant observation and several informal conversations with farmers during the visits to communities. Interviews, workshops and focus groups were recorded, and the recordings from the latter were transcribed; field observations were documented in notebooks. Research instruments were approved by UVM's Committee on Human Research in the Behavioral and Social Sciences (CHRBSS) Institutional Review Board (IRB).

3.3. Analysis

3.3.1. Analytical framework

To guide our analysis, we used a modified version of the Sustainable Livelihood Framework (SLF; Scoones, 1998, 2009). The SLF, and similar livelihood frameworks (e.g., Ellis, 2000), view livelihoods as dynamic processes in which households' assets and livelihood activities as well as contextual and structural factors influence livelihood outcomes. Amekawa (2011) notes that a Sustainable Livelihoods (SL) approach is useful for analyzing agroecological farming systems, as it allows placing "agroecologically based" and "pluriactive" smallholder livelihoods – such as those of smallholder coffee farmers – as the subject of research. The approach is also compatible with other theoretical frameworks, such as the Theory of Access, that draw attention to various structural factors and processes mediating access to resources (Myers and Pilegaard Hansen, 2019). In our study, we adapted the SLF (see Fig. 2) to describe the characteristics of the farmer households and their livelihood portfolios, and to explore which assets and activities (and combinations of these) potentially yield the most beneficial outcomes in terms of food and livelihood security. We further sought to link our findings to some of the socio-economic processes that may influence diversification decisions and access to assets.

As illustrated in Fig. 2, we analyzed three types of livelihood assets: natural (land and agrobiodiversity), human (household size and composition), and financial assets (sources of income and volume of coffee production). We selected these assets after a careful reading of prior, similar studies (e.g., Bacon et al., 2014; Donovan and Poole, 2014; Caswell et al., 2016; Fernandez and Méndez, 2018), and reflection sessions with the research team. We recognize that other types of resources, such as social, physical and political assets/capitals, can also be important determinants of diversification (see Ellis, 2000), and hope to include these factors in our analysis of the Phase 2 data from this study.

Each of the 167 farmer households in our study represents a unique combination of livelihood activities and assets. In order to reduce some of the variability among farmers and explore potential differences and similarities between the farmer households, we re-categorized farmers into four livelihood strategy groups. These groups reflect our increased understanding of livelihood diversification among CESMACH farmers, and thus depart from the original stratification criteria. Reclassification was based on an examination of existing literature (see section 2.2), our field research, and conversations with CESMACH staff and members. This examination pointed to the importance of staple food production and beekeeping for food and livelihood security. In addition, our PAR partner CESMACH had a particular interest in gaining a better understanding of the role of beekeeping and staple crop production in their members' livelihood portfolios. Therefore, our four livelihood strategy[4]

[4] We recognize that the term 'strategy' may have the connotation of a

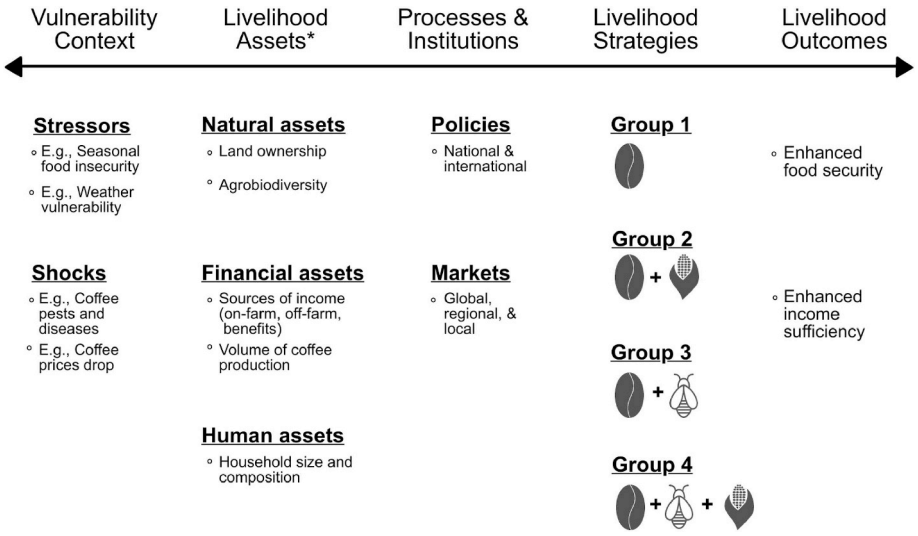

Fig. 2. Adapted Sustainable livelihoods framework (Scoones, 1998, 2009; Ellis, 2000).

groups represent all possible combinations of these two 'key' activities, beekeeping and staple crop production, plus coffee. The farmers in each group may have other on-farm activities in addition to the key activities.

In this study, we narrowed our focus to potential impacts of livelihood diversification on income sufficiency and food security, which are important determinants of households' wellbeing. These two variables are strongly interrelated (Dasgupta and Ray, 1986) and are affected by agricultural production, and therefore diversification (HLPE, 2019). We used an ordinal, self-reported variable, 'perceived sufficiency of income for basic needs' (levels: 'not sufficient', 'more or less sufficient', 'sufficient') as a proxy for the economic success of the farmer households' livelihood portfolio. We chose not to add questions about actual cash income for two main reasons: (1) our local partners informed us that farmers would not necessarily be comfortable talking about their income with strangers, (2) the answers would have provided information about the gross income which, without counting all the investments in coffee and other agricultural production, would have been an inaccurate indicator of the net income available for the households.

For learning about farmer households' level of food (in)security, we used the FANTA indicator 'Months of Adequate Household Food Provisioning' (MAHFP; Bilinsky and Swindale, 2010). Participants were asked if in the previous 12 months they had experienced food shortages. If the answer was positive, we asked in which months they did not have enough food to meet their family's needs, and, in consequence, had to reduce their consumption or change their habitual/preferred diet. We then counted the number of food insecure months, or 'thin months', reported by farmers. This variable was treated as ordinal. Other studies with coffee farmers have also used the variable 'thin months', which allowed us to compare our findings (Bacon et al., 2014; Baca et al., 2014; Fernandez and Méndez, 2018).

3.3.2. Data analysis

The survey data were summarized and analyzed in R version 3.5.1 (Wickham et al., 2018). Mean, standard deviation, maximum and minimum, and/or percent were calculated for all variables (Tables 2–4). Comparisons among groups (e.g., among the four livelihood strategies, and among the three levels of income-sufficiency) were analyzed using one-way ANOVA tests (followed by Tukey HSD tests) and Pearson Chi-squared tests (followed by the calculation of odds ratios). When comparing quantitative response variables among groups, such as total land area, number of on-farm activities, or number of thin months, we used the former; for comparing categorical response variables among groups, such as binomial variables about the practice of specific agricultural activities (Yes/No), we used the latter. Spearman correlations (r_s) were used to assess the association between some variables (e.g., number of edible crops and number of thin months). We held focus groups and data interpretation workshops, to triangulate with our preliminary findings from quantitative analysis. Focus groups that resulted in participants creating agricultural calendars were especially helpful in understanding seasonal patterns of food insecurity to compare with survey results. Insights from field notes, informal conversations with farmers and results interpretation workshops also helped us to interpret survey results.

(*footnote continued*)
carefully determined plan (Gerlicz et al., 2018); we do not assume that this is the case, and we use the term as an analytical category.

4. Results

4.1. Household characteristics and on-farm diversification

4.1.1. Livelihood strategies groups and demographic characteristics

As shown in Table 1, farmers who reported having coffee and no other key activities (Group 1 - G1) constituted 25.1% of all farmers in the sample, while farmer households combining coffee with staple crops made up the biggest group (Group 2 - G2), representing 53.3% of all households. Respondents who reported practicing beekeeping in addition to coffee (Group 3 - G3) or having all key livelihood activities (Group 4 - G4) represented 11.4% and 10.2%, respectively, of all surveyed households. However, it is important to note that beekeepers were overrepresented in the sample, as mentioned above. In terms of demographic characteristics, we found some differences between the groups. For instance, farmers in G2 had the highest average age (48.7 years) and the least formal education (3.9 years), while the beekeeper groups (G3 and G4) had the youngest respondents (G3 = 41.6, G4 = 43.7) and the highest level of formal education (G3 = 6.6, G4 = 5.9). Farmer households in G1 tended to have the smallest household size (4.8 members).

4.1.2. Landholdings and coffee

Farmer households managed, on average, 8.7 ha of land – including both agricultural land and forested areas – with landholdings ranging from 1.4 to 41.0 ha. The land was distributed, on average, in 3.5 plots/land areas with some plots located in the close proximity to the house and others further from the homestead (some taking up to 3 h to reach).

We did not find differences among the groups ($F(3, 155) = 0.40$; $p = 0.75$) in terms of land area, although producers in G4 had, on average, slightly more land than other groups (9.7 ha). Farmer households reported having an average of 6.0 ha under coffee production, and producing 40.2 *quintales* of coffee in total (1 quintal = 57.5 kg of parchment coffee). The land area under coffee is above average in Mexico (CEDRSSA, 2018) and some other parts of Chiapas (Soto-Pinto et al., 2000). Using a Tukey HSD test, we found significant differences between G1 farmers who had the largest land areas dedicated to coffee (7.1 ha on average), and G2 farmers who reported the least hectares under coffee (5.4 ha on average) ($p = 0.05$). Similarly, Tukey's HSD test showed that farmers in G1 produced the most coffee average in total (56.3 quintales), whereas farmers in G2 had the lowest average total coffee production (30.1 quintales) ($p < 0.01$). Farmers in G1 had the highest percentage of respondents who had renovated their coffee plots following the most recent coffee leaf rust outbreak (90.5%), while the G2 had the lowest proportion (74.2%).

4.1.3. Staple crops

Farmers producing maize or beans (G2 and G4) had on average 1.4 ha of land reserved for growing these staple crops. However, we estimate that the average land area under production was considerably smaller, as average land included plots that were fallow or rented to other farmers during the time of the survey. The survey responses show that staple crop production is an activity that is typically learned from parents or grandparents at an early age; many farmers noted that they had been growing staple crops "their whole lives". We also found that many farmers in G1 and G3 had abandoned staple crop production within the past 10 years. In G1, 43.9% of the producers said they had stopped growing staple crops, while for G3 the result was 21.1%. These findings are consistent with two other studies conducted with CESMACH farmers (Fernandez and Méndez, 2018; Baca et al., 2014). When asked about the reasons for abandoning this activity, the most common explanations were the high workload required to maintain staple crops, time constraints, and lack of adequate land. Some farmers specifically mentioned that they had converted their *milpas* into areas for coffee cultivation.

4.1.4. Beekeeping

Beekeeping for honey production is a relatively new activity among CESMACH farmers, unlike most other on-farm activities, and is practiced on a relatively small scale. On average, honey producers had been practicing beekeeping for five years, and were managing approximately 20 beehives. Many farmers said they had initiated beekeeping due to a project through CESMACH (sponsored by Heifer International or Food 4 Farmers), or a governmental program. The data shows that beekeeping is less time-intensive than coffee production: farmers reported working approximately five days per month in apiculture, while coffee occupied an average of 20 days per month. Additionally, beekeeping shows potential for being an economically important activity for the farmers. More than 36.4% of the honey producers considered apiculture "economically more attractive" than coffee. In the non-beekeeper groups, 9.5% (G1) and 15.0% (G2) said they had tried beekeeping within the past 10 years, but had abandoned the activity due to lack of technical assistance, increased workload, and/or health risks (e.g., allergies).

4.1.5. Characteristics of other livelihood activities

Our findings show that farmer households managed a variety of activities on their farms. In addition to coffee, farmers reported having an average of 4.1 productive activities. Excluding beekeeping and staple crop production as productive activities, we found differences between the number of on-farm activities among the groups ($F(3,163) = 29.8$, $p = 0.03$). A Tukey's HSD test showed some evidence that farmers in G4 (3.6 ± 1.1) were managing more on-farm activities than farmers in G1 (3.0 ± 1.1, $p = 0.09$) and in G3 (2.8 ± 1.1, $p = 0.06$).

As Table 2 illustrates, nearly all households (98.2%) had fruit trees, and 87.4% of the respondents reported raising poultry. A Pearson Chi-squared test showed that the proportion of farmers raising poultry ($\chi^2(1) = 16.3$, $p < 0.01$) or farm animals ($\chi^2(1) = 4.3$, $p = 0.04$) differed between groups growing staple crops (G2 and G4) and those who were not (G1 and G3). The former were over seven times (7.2) more likely to raise poultry (95% CI: 2.5–20.8, $p < 0.01$) and over two times (2.2) more likely to have farm animals than the latter (95% CI: 1.0–4.6, $p = 0.04$). Maize is commonly used to feed farm animals and poultry, so its production may provide an advantage for raising poultry or farm animals, but we assume there are also other factors affecting farmers' decision to raise these animals. The least common activities of the activities listed in the survey were aquaculture and livestock (6.0% and 13.8%, respectively).

Table 2
On-farm diversification activities per group.

	Livelihood strategy groups									
	Group 1		Group 2		Group 3		Group 4		All	
% of households										
Beekeeping	0.0		0.0		100.0		100.0		21.6	
Vegetables	78.6		78.7		52.6		82.4		76.0	
Staple foods	0.0		100.0		0.0		100.0		63.5	
Poultry	76.2		95.5		68.4		94.1		87.4	
Farm animals (pigs, rabbits)	14.3		31.5		31.6		52.9		29.3	
Livestock (cows, horses)	7.1		14.6		15.8		23.5		13.8	
Fruit trees	100.0		96.6		100.0		100.0		98.2	
Aquaculture	7.1		5.6		10.5		0.0		6.0	
Other	1.9		9.0		0.0		5.9		8.3	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Number of on-farm activities (excluding all key activities)	3.0	1.1	3.3	1.0	2.8	1.1	3.6	1.1	3.2	1.1
Number of on-farm activities (total, exc. coffee)	3.0	1.1	4.3	1.0	3.8	1.1	5.6	1.1	4.1	1.3

Labor and land were associated with livelihood diversification. We found a positive correlation between the total number of on-farm activities and the number of productive adults (15–64 years) in the household ($r_s = 0.3$, $p < 0.01$). Moreover, there was a positive correlation between the number of on-farm activities and total hectares of

land managed by the household ($r_s = 0.2$, $p < 0.01$).

4.2. Income

4.2.1. Sources of cash income

Coffee farmer households earned cash income from varying sources, as shown in Table 3. In addition to coffee, farmers reported having an average of 3.4 income sources. Other studies from coffee regions in Mesoamerica have reported similar results (Morris et al., 2013; Baca et al., 2014; Caswell et al., 2016; Perfecto and Vandermeer, 2015). Coffee excluded, farmers had an average of 1.1 on-farm and 1.0 off-farm sources of income, as well as 1.3 income streams through different types of benefits, such as conditional cash transfer programs (e.g., *Prospera* for low-income families with children) and payments for ecosystem services (PES) schemes. It is notable that different types of benefits form part of the income portfolios of the vast majority of farmer households (86.2%), and many respondents listed benefits among the three most important income sources. As noted elsewhere, government subsidies are an important source of additional income for smallholder farmers (Jaffee, 2014; Robles Berlanga, 2011). The most commonly reported sources of income were cash transfers/agricultural subsidies (81.1%), PES schemes (46.2%), sale of animals or animal-based products (35.6%), off-farm agricultural labor (29.6%), and small businesses (21.9%).

4.2.2. Sufficiency of income

As illustrated in Fig. 3, farmers combining beekeeping with staple crop production (G4) had the highest probability of perceiving their income as 'sufficient', while the G2 farmers showed the lowest probability, although this was not statistically significant. Our findings suggest that the probability increases for all groups as the number of on-farm sources of income increases (Fig. 3). The trend is similar but slightly weaker when all sources of income are taken into account. To further test the role of beekeeping in terms of income sufficiency we compared beekeepers (G3 and G4) to non-beekeepers (G1 and G2). 55.6 % of the beekeepers perceived their income as sufficient, 19.4 % more or less and 25.0 % not sufficient, while the same percentages for the non-beekeepers were 33.6 %, 17.6 %, and 48.9 %, respectively. Using a Pearson Chi-squared test we found that beekeepers appeared to perceive their income as sufficient more frequently than farmers who did not practice beekeeping (G1 and G2) ($\chi^2(2) = 7.3$, $p = 0.03$). Fig. 4 shows differences between all groups. It is important to note that although our results imply that beekeeping may increase earnings, it could indicate the inverse; farmers with a higher income might be more inclined to invest in a new activity like beekeeping; therefore, we cannot suggest a causal relationship between beekeeping and income.

Table 3
Income-related variables.

	Livelihood strategy groups									
	Group 1		Group 2		Group 3		Group 4		All	
	mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Number of sources of income (excl. coffee)	2.6	1.3	3.4	1.7	3.4	1.5	4.6	1.8	3.4	1.7
On-farm (excl. coffee)	0.6	0.9	1.1	1.2	1.5	0.7	2.2	1.5	1.1	1.2
Off-farm (wage labor, business)	0.8	0.8	1	0.9	0.9	1.3	1.2	0.8	1	0.9
Benefits (governmental programs, PES)	1.2	0.6	1.4	0.6	1	0.8	1.2	0.9	1.3	0.7
% of households with coffee as the only on-farm source of income	57.1		37.8		0		5.9		35.3	

Although income-diversification is common among the producers, coffee remains the main source of agricultural income for many farmer households. Our findings show that 35.3% of farmers reported coffee as the only source of agricultural income. The proportion of farmers who did not sell other agricultural products in addition to coffee differed among the groups ($c\chi^2(3) = 23.4$, $p < 0.01$), with G1 having the highest proportion of coffee-dependent households. The probability of relying solely on coffee as a source of agricultural income were 2.1 times greater for G1 than for G2 (95% CI: 1.0–4.3, $p = 0.06$), and 10.0 times greater than for G4 (95% CI: 2.0–49.4, $p < 0.01$).

Our findings suggest that some on-farm activities may be more relevant for household consumption than for generating cash income. For example, while 96.2% of households have fruit trees, only 18.9% of farmers reported selling fruit. Also, a relatively small percentage of farmer households growing vegetables, corn or beans received cash income from their produce (11.2%, 12.3% and 21.7%, respectively). Our qualitative data from informal conversations with farmers and results interpretation sessions suggests that the sale of agricultural products, such as vegetables and fruits, is more common than the survey results imply. Sales of vegetables and fruit tend to be small and sporadic, which may explain why more farmers did not report these as 'sources of income' (see Gerlicz et al., 2018). Some farmers mentioned that they barter excess agricultural products with family and community members, and use these (especially fruit) for feeding coffee pickers during the harvest.

In addition to beekeeping, we found some evidence that landholdings and the volume of coffee production were associated with income sufficiency. Our results show that income sufficiency tended to increase as the volume of coffee produced ($r_s = 0.2$, $p < 0.01$), land under coffee ($r_s = 0.1$, $p = 0.09$) and the total farm size ($r_s = 0.1$, $p = 0.11$) increased. We did not observe an association between income sufficiency and the number of on-farm activities that farmers were managing.

4.3. Food security

4.3.1. Prevalence of seasonal food insecurity

Seasonal food insecurity was common among the interviewed coffee farmer households, with 71.9% of all respondents reporting at least one month of food scarcity. On average, farmers suffered 2.5 thin months per year with some participants reporting up to 8.0 months, as shown in Table 4. These findings are similar to other studies reporting thin months among the CESMACH farmers. Baca et al. (2014) found that farmers experienced, on average, 2.5 months of food insecurity, while the findings by Fernandez and Méndez (2018) showed an average of 2.7 months (or 1.6 months, if including farmers who did not report thin months). Our results also concur with findings from a study in Northern Nicaragua, where farmers experienced, on average, 3.2 months of food insecurity in 2010 (Bacon et al., 2014).

Table 4
Food-security-related variables.

	Livelihood strategies									
	Group 1		Group 2		Group 3		Group 4		All	
	Mean	sd	mean	sd	mean	sd	mean	sd	mean	sd
Number of thin months	2.8	2.3	2.6	2.1	2.6	2.2	1.3	1.5	2.5	2.1
Number of months of corn supply	n/a		6.7	3.3	n/a		5.8	3.5	6.5	3.4
Number of edible plant species on-farm	23.1	9.7	22.2	8.1	19.2	10.2	27.3	9.5	22.6	9

Almost half of the participants experienced food insecurity from August through October, but in general, the thin months extended from June to December (see Fig. 5). As shown in Fig. 5, thin months overlap with the rainy season and corn/coffee pre-harvest periods, when household savings from previous coffee sales along with maize and bean reserves become depleted. The rainy season also affects the road conditions, which may hamper physical access to markets for food. Moreover, this is the time when staple food prices peak, especially corn, which increases the financial pressure on the families. Similar patterns have been observed in other regions where coffee is the main source of income, and maize and beans constitute important staple foods (Morris et al., 2013; Bacon et al., 2014; Fernandez and Méndez, 2018) .

4.3.2. Type of on-farm diversification influences prevalence of thin months

Some evidence exists that the duration of seasonal food insecurity varies among the groups ($F(3,163) = 2.2$, $p = 0.09$). A Tukey's HSD test revealed that farmers combining coffee with staple food production and beekeeping (G4) experienced fewer months of seasonal food insecurity (1.3 ± 1.5) than farmers in G1 (2.8 ± 2.3, $p = 0.07$), and G2 (2.6 ± 2.1, $p = 0.08$). We did not find an association between the number of on-farm activities and the number of thin months ($r_s = 0.04$, $p = 0.59$), which suggests that specific activities, such as staple food production, may have a stronger impact on food security than the level of diversification. Additional data are needed to better understand the contributions of staple food production to food security. In the survey, only 27.4% of the coffee farmers in G2 and G4 said that their maize production was sufficient to cover their annual consumption; this production covered only 6.5 months, on average. However, we did not find evidence of an association between the number of months of corn supply and the number of thin months ($r_s = -0.08$, $p = 0.32$) (see Fig. 6).

4.3.3. Income sufficiency, landholdings, and coffee production associated with fewer thin months

Our findings suggest that there is an association between the number of thin months and the level of income sufficiency. We found differences in the number of self-reported thin months among farmers perceiving themselves as 'income sufficient', 'non-income sufficient', and 'more or less income sufficient' ($F(2,164) = 4.5$, $p = 0.01$). A Tukey's HSD test revealed that the largest difference was between 'income sufficient' and 'non-income sufficient' farmers ($p = 0.01$), with the former reporting an average of 2.0 months of seasonal food insecurity and the latter 3.1 months.

We also found that as total farm size, land under coffee, and volume of coffee produced increased, the number of thin months reported by the participants decreased ($r_s = -0.2$, $p < 0.01$; $r_s = -0.2$, $p = 0.02$; $r_s = -0.2$, $p = 0.02$ respectively). Other studies from coffee lands in Mesoamerica have found a similar association between farm size and self-reported thin months (Baca et al., 2014; Bacon et al., 2014). Moreover, an increase in these same assets (total farm size, land under coffee, and volume of coffee) was associated with a higher perceived income sufficiency, as discussed in section 4.2.2. We did not find evidence of an association between the number of sources of income and the number of thin months or between the number of on-farm income sources and thin months.

4.3.4. Thin months and agrobiodiversity

On average, coffee farmers cultivated, hosted, and foraged around 22 different edible plant species on their land. Farmers in G4 reported a higher average of on-farm edible plants, when compared to the other groups of farmers ($F(3,163) = 2.6$, $p = 0.05$) (see Table 4). All farmers reported having wild greens on their land, such as nightshade (*Solanum americanum,* n = 161), correlon (*Solanum spp.* n = 149), chipilin (*Crotalaria longirostrata,* n = 122), and amaranth leaves (*Amaranthus spp.,* n = 117). These greens are nutritionally important due to their high Vitamin A and iron content. Other common species included citrus (e.g., orange, lemon, grapefruit; n = 151), avocado (*Persea americana*, n = 130), mango (*Mangifera indica,* n = 104), pacaya (*Chamaedorea tepejilote,* n = 143), and banana (*Musa spp.,* n = 142). As mentioned above, trees provide multiple functions to coffee farmers, including shade for coffee trees, fruits for self-consumption, wood for cooking, timber for building, and nectar for bees.

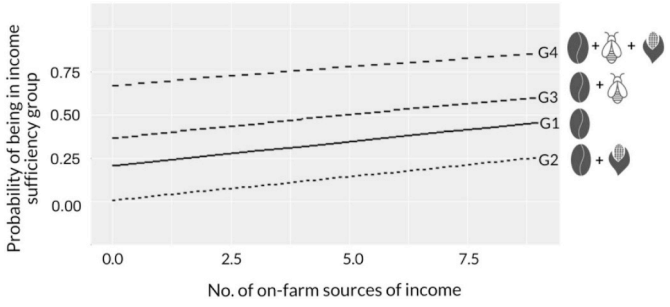

Fig. 3. Probability of perceiving income as sufficient by group as the number of on-farm sources of income increases.

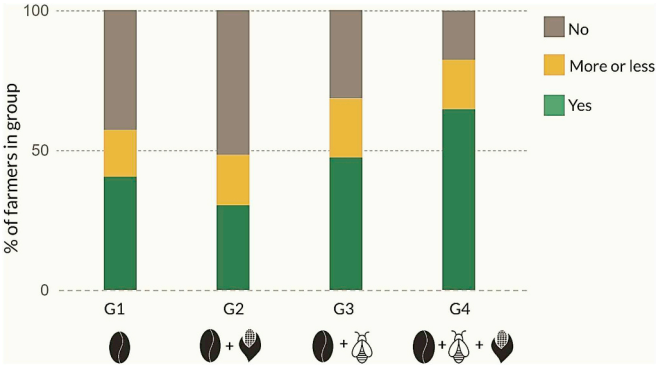

Fig. 4. Perception of the sufficiency of income by group.

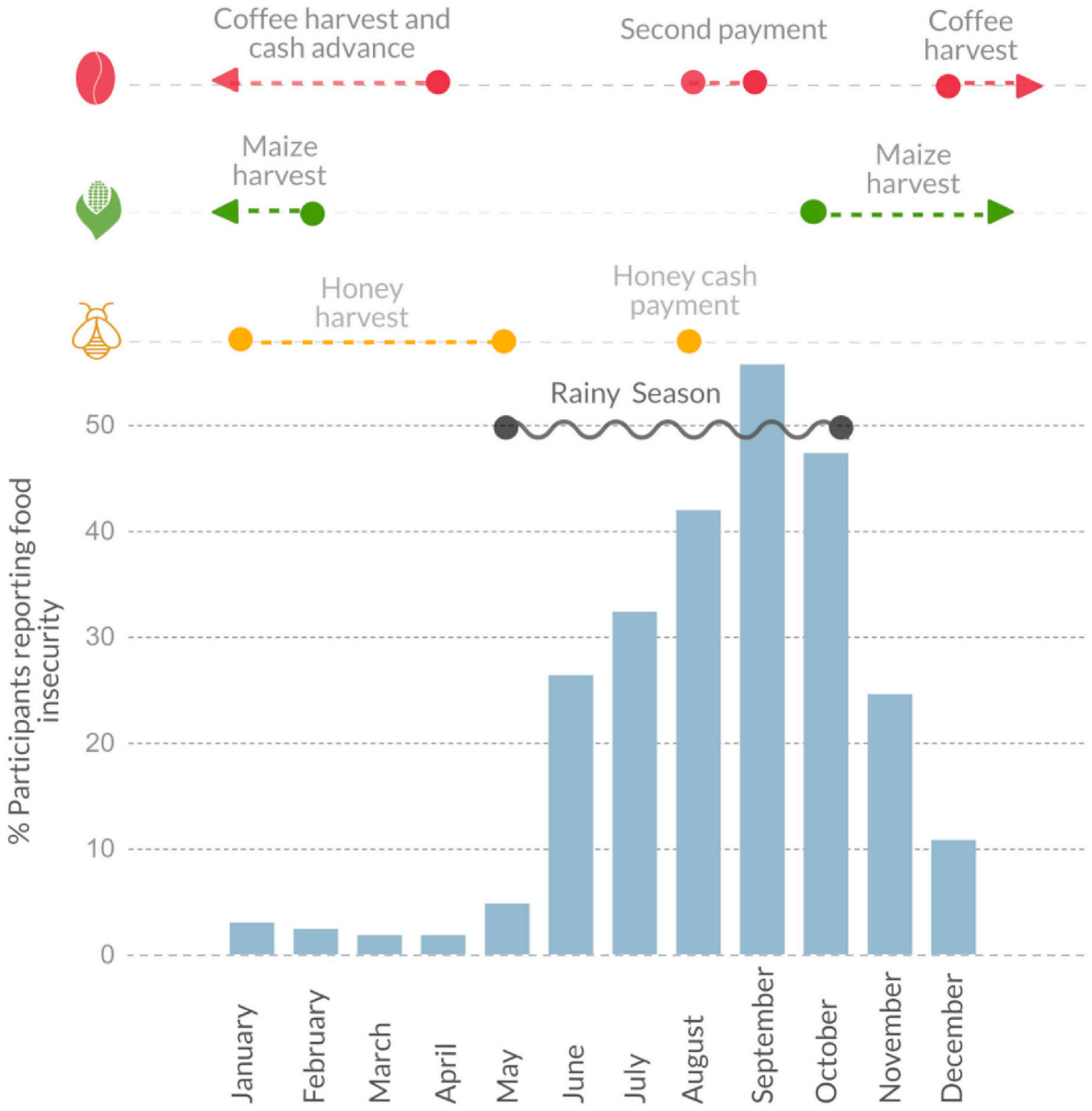

Fig. 5. The thin months occur during the rainy season and when the maize storage has been depleted. In some years, coffee and maize harvest overlap, creating competing labor demands. Honey cash payments arrive at critical moments, helping farmers to cope with the thin months.

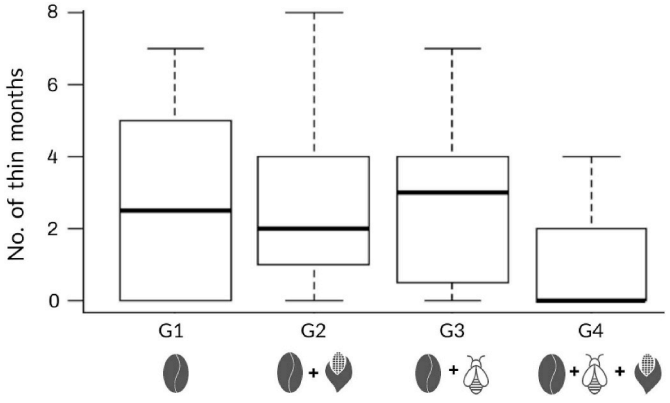

Fig. 6. Farmers practicing *milpa* and beekeeping (G4) experienced fewer thin months than farmers in the other groups.

In addition to the wild greens, other cultivated vegetables stood out in the survey. For example, chayote (*Sechium edule,* n = 147) and squash (*Cucurbita sp.,* n = 77) were frequently mentioned as local recipies utilize parts of the whole plant besides the fruit. For example, *chayote* and squash's vine shoots and squash flowers and seeds can be consumed, providing food before and after their fruits are ripe. Roots and tubers were also frequently reported, especially taro (*Colocasia esculenta*, n = 102) and radish (*Raphanus raphanistrum*, n = 72). Finally, multiple varieties of beans (*Phaseolus vulgaris)*, corn (*Zea mays*) and chili (*Capsicum annuum*) were mentioned by farmers growing these crops. However, we did not find a strong negative correlation between the number of on-farm edible plants reported by farmers and the number of self-reported thin months, as hypothesized (r_s = 0.04, p = 0.61). We believe this could be a consequence of the data collection methods (see Discussion).

5. Discussion and policy implications

5.1. Coffee remains the most important economic activity

Our findings indicate that while CESMACH coffee farmer households were generally diversified, coffee remained the most important economic activity. On average, farmers had one other agricultural source of income in addition to coffee, and more than 30% had no other on-farm sources of income, which points to the relative importance of coffee (and potentially non-farm sources of income) as a source of revenue. A study from CESMACH indicates that around 70% of farmers' income comes from the sale of coffee (Baca et al., 2014), providing further evidence of the central role of this cash crop for the farmer households. This dependency on coffee reflects the contextual factors that moved coffee from being an economic supplement to a mainstay for many Mexican households, leaving coffee-dependent farmers more vulnerable to the various shocks and stressors that affect the crop (Jaffee, 2014).

Previous studies have shown that a relatively low number of additional agricultural income sources can reflect either a long-term plan to specialize on coffee, or a risk-averse strategy to avoid potentially risky investments in new activities (see Tucker et al., 2010). Our field experience suggests that it can also result from various types of obstacles to market access for alternative agricultural products, or not having access to information about alternative crops. Additionally, coffee production as a component of self-identity is a relevant consideration, as it can serve to motivate farmers to improve their practices instead of choosing to diversify (Hausermann, 2014; Bielecki and Wingenbach, 2019). Whatever the motivation may be, specialization in coffee could be an increasingly risky strategy, considering projected impacts of climate change on coffee production (Imbach et al., 2017) and the volatility of international coffee prices (Jaffee, 2014).

5.2. Farmer characteristics influence the level and type of livelihood diversification

Our findings suggest that land (natural asset) and labor (human asset) are important resources for on-farm diversification. We found that households with larger landholdings and/or more productive workforce (adults between 15 and 65 years) tended to practice, on average, more agricultural activities on their farms. Although land availability does not necessarily translate into ability to benefit from it (see Ribot and Peluso, 2003), access to land seems to open opportunities for agricultural diversification, possibly at a lower risk than for land-constrained farmers (Tucker et al., 2010). Access to land may be limited due to various factors, such as membership status in the *ejido* (Morett Sánchez and Ruiz, 2017).

Our findings further point to tradeoffs in resource allocation. Households who reported not having other key activities in addition to coffee (G1) tended to have a smaller household size and fewer adults (15–65 years) than other groups, which suggests that these households may have less workforce to allocate toward alternative livelihood activities in addition to coffee. Farmers who discontinued growing staple crops also referred to competing resource demands, listing labor, time, and land constraints among the main reasons for abandoning the activity. In informal conversations and during the participatory data analysis sessions, some producers explained that households with less family labor found it difficult to allocate time for both coffee and staple food production, and tended to give preference toward cash crop production.

When looking at individual productive activities, we found that CESMACH farmers were most commonly engaged in activities that tend to require relatively low asset investments, and can be managed in coffee plantations or in-home gardens (i.e., fruit trees, poultry, and vegetables). The less common activities (i.e., aquaculture, livestock and beekeeping) appear to coincide with barriers to entry such as a need for more labor, specialized skills, financial resources, and/or suitable land. These findings align with other studies pointing to the importance of different types of asset building/consolidation for creating opportunities for livelihood diversification (Gerlicz et al., 2018; Bielecki and Wingenbach, 2019). This may be particularly important in a state that suffers from high levels of poverty and marginalization (CONAPO, 2015). CESMACH's beekeeping initiative offers an example of the positive effect of NGOs providing technical assistance and equipment to support farmers' engagement in the activity.

5.3. Different livelihood strategies have different effects on food and livelihood security

Coffee farmers growing corn and/or beans (G2) experienced, on average, fewer months of food scarcity than farmers who did not produce staple crops (G1 and G3), although they were generally more food insecure than farmers who produced honey in addition to coffee and staple crops (G4). These results point to the importance of staple food production for food security, echoing findings from several other studies (Isakson, 2009; Morris et al., 2013; Fernandez and Méndez, 2018). However, only a quarter of the households were producing enough maize to meet the households need for the whole year, which may be a result of low yields or the fact that self-produced maize is often used to feed coffee pickers and farm animals. Whatever the reason, many households would need to produce more staple crops to be fully self-sufficient. Due to potential trade-offs in the allocation of land and labor, this option may not be possible for all households.

In terms of income security, farmers combining all key activities (G4) were more likely to perceive their income as sufficient than other groups, whereas farmers in G2 showed the lowest probability of perceiving their income as sufficient. Our qualitative data suggest that beekeeping is an important factor in the relative success of having all key activities. Income from honey complements coffee-related income and, due to the timing of the payment for the product, provides an important source of revenue during the most critical months of food and income shortages (see Fig. 4). However, we need additional data to understand why many farmer households in G2 were not able to generate an income that was sufficient for meeting the basic household needs, or why many farmers in G3 reported experiencing several months of food insecurity, on average, even though they reported being relatively income sufficient.

5.4. Planned and associated biodiversity can help to improve food security

In addition to a variety of managed food crops and fruit trees, a number of wild plants were available in farmers' land, often growing in coffee plots under the canopy of shade vegetation. As many coffee plots are in the buffer zone of El Triunfo Biosphere Reserve, the richness of the associated biodiversity is connected to the vicinity of this protected area. Although we did not find an association between crop species richness and thin months, results from other studies imply that the diversity of edible plants make an important contribution to the food security of farmer households and help cope with seasonal food insecurity (Bacon et al., 2014; Baca et al., 2014; Fernandez and Méndez, 2018). For instance, Fernandez and Méndez (2018) found that wild leafy greens that are rich in micronutrients were part of coffee farmer households' regular diet. However, there are some socio-cultural barriers to consuming wild plants, as some people consider them 'food for the poor' or 'backward'. For this reason, despite their nutritional qualities and cultural tradition, many people do not report them as part of their 'preferred diet'. This offers an opportunity for the cooperative and other initiatives to support a re-valuing and increased awareness of these plants as important sources of local, nutritious food.

5.5. Implications of our study

Our findings suggest that a combination of both market-oriented (i.e., coffee and honey) and subsistence activities (i.e., *milpa*) can have a stronger impact on food and income security than the production of subsistence food or commercial agricultural products alone. However, our analysis on livelihood assets shows that this type of strategy may not be accessible (or attractive) to all farmer households. This underscore the importance of: (1) identifying alternative diversification pathways that are accessible and compatible to different types of farmers who have different resources and interests; and (2) supporting farmers and their organizations to strengthen assets that can enable access to suitable diversification alternatives. To enable this, improved access to credit is essential for opening new opportunities (Robles Berlanga, 2011; Morris et al., 2013; Donovan and Poole, 2014). In addition, interventions that provide support to capacity building, technical assistance, and improved market access have been shown to help farmers to adopt new productive activities (Tucker et al., 2010).

We concur with literature that highlights the diversification of agricultural sources of income as an important strategy for reducing dependency on a single crop and enhancing resilience (Amekawa, 2011; HLPE, 2019). Our findings suggest that beekeeping for honey may be a good alternative for income diversification that can help to reduce dependency on coffee and boost household economy during the critical months of income and food scarcity. However, it is important to note that honey as a commodity is also subject to price volatility, and could increase farmers' vulnerability to price shocks. During the time of writing this paper, the price paid for a kilogram of honey by *Miel Real del Triunfo* was estimated to be around 30 $MXN, whereas in the past year it was 43 $MXN (personal communication, June 2019). Value added beehive products or stronger local markets could potentially help farmers to decrease vulnerability to price fluctuations (see Guevara and Romero, 2016; Altieri, 2009).

Our study raises some concerns about the future of staple food production. While more than 60% of the farmers in the study reported producing staple crops, over the last 10 years many farmers decided to stop growing corn and/or beans. These shifts can be understood in the context of NAFTA, where policy changes affecting maize production are designed to "support non-profitable farmers to transition to other crops and activities" (Keleman et al., 2009 p. 56). The abandonment of *milpa* also reflects a "tension between intensification and diversification" in a neoliberal economic system that is generally hostile to smallholder producers (Jaffee, 2014, p. 167).

Considering the importance of staple crops for Central American diets (Isakson, 2009; Bacon et al., 2014; Fernandez and Méndez, 2018), a tendency towards the abandonment of staple food production is likely to have negative consequences on farmer households' food security. Effects of this will be especially severe in years when coffee harvest fails, coffee prices plummet, or corn prices increase (Bacon et al., 2014; Morris et al., 2013). Additional side effects from these shifts will potentially lead to loss of landrace varieties of maize and beans, and traditional knowledge (see Isakson, 2009). Government, state, NGO, and community initiatives that support households to enhance staple crop production for consumption could have a positive impact on the food security of these households (see Isakson, 2009; Appendini and Quijada, 2016). Successful examples include community seed banks to conserve local varieties, and innovative distribution systems to maintain maize and/or bean prices, access and availability (Bacon et al., 2014).

5.6. Research limitations and future research

We used household surveys as a tool to get a 'snapshot' of farmers' livelihoods. These data allowed us to characterize diversification strategies among CESMACH farmers, identify associations and trends, and refine research questions for the continuation of our PAR process. We are fully aware that these types of surveys have limitations. For instance, they are ineffective for capturing motivations and meanings behind livelihood decisions, or the dynamic and multiscalar nature of livelihoods (Creswell, 2014). While survey data support the identification of connections and tendencies between livelihood activities, assets, and outcomes, surveys alone are limited in describing causality between these elements (Creswell, 2014).

The livelihood strategy groups that guided our research were the result of a careful qualitative analysis of existing literature and our field experience. We also wanted to respect the interests of our PAR partner CESMACH, which we believe will contribute to the 'actionability' of our results (Méndez et al., 2017). Moreover, we wanted to avoid data dredging to reduce the chances of observing false positive results that can arise from re-categorizing and retesting data. However, we recognize that other categorizations (or typologies) would have been possible, and could have generated different kind of results on livelihood strategies and outcomes. Additionally, we are aware that the relatively small number of farmers in G3 and G4, as compared to G1 and G2, can be problematic in terms of making statistical inference.

We used crop species richness and MAHFP as proxies for assessing agrobiodiversity and food security. However, we are aware that crop species richness is a superficial indicator of food availability and accessibility because it may not relate directly to the quantity of food available for consumption. Similarly, MAHFP is a qualitative proxy for food accessibility and does not speak to other dimensions of food security, such as dietary quality. Moreover, the indicators rely on self-reported data, which is dependent on the memory or respondents, and are affected by the seasonal timing of the survey.

Livelihoods are fluid and dynamic, and an array of factors operating at different scales affect farmer households' livelihood portfolios/strategies (Ellis, 2000). These issues have been taken into account, as we continue with the next phases of our PAR process, where we will work with a smaller subset of farmers to deepen our understanding about farmer households' resources, motivations, livelihood portfolios, and outcomes. We will also seek to better understand the gendered nature of livelihoods (see Radel, 2012). In addition, our team will continue integrating agroecological principles and livelihood approaches to the study of diversification in smallholder coffee systems (Amekawa, 2011; HLPE, 2019).

6. Conclusions

The results from this study provide further evidence that diversification could be an important agroecological strategy for strengthening livelihoods and improving the food security and sovereignty of coffee farmers. This is particularly important considering that in our study, more than 70% of farmer households reported experiencing food insecurity, and many farmers perceived their income as insufficient to meet the basic needs of their households. Our findings also show that a variety of factors regulate the effects of diversification on farmers' wellbeing, calling for conservative, non-generic conclusions. Contextual social, economic and ecological factors affect the ability of farmers to start a new livelihood activity and diversify their livelihood portfolio, while the characteristics of the activities, or strategies, determine the direction and magnitude of the livelihood benefits. Further studies exploring socio-ecological characteristics, decision-making processes, and structural aspects are needed to identify sustainable livelihood strategies that could enhance coffee farmers' food and livelihood security, and to find leverage-points for diversification interventions. These types of studies are increasingly important given the dynamic nature of smallholder coffee livelihoods, which require assessing realities that are constantly changing. International coffee markets continue to provide unfavorable conditions for smallholder farmers, and recent climate change scenarios point to the need to rapidly adapt to changing growing conditions. We concur with other authors that collaborative and participatory initiatives, which build bridges among farmers,

academics, policy-makers, and the coffee industry, could lead to more sustainable livelihood outcomes for coffee farmers.

Declaration of interest statement

Authors have no competing interests to declare.

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CRediT authorship contribution statement

Janica Anderzén: Conceptualization, Methodology, Investigation, Validation, Formal analysis, Writing - original draft, Writing - review & editing. **Alejandra Guzmán Luna:** Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft, Writing - review & editing. **Diana V. Luna-González:** Formal analysis, Writing - original draft, Writing - review & editing, Visualization. **Scott C. Merrill:** Validation, Formal analysis, Writing - original draft, Writing - review & editing, Visualization. **Martha Caswell:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Project administration, Funding acquisition. **V. Ernesto Méndez:** Conceptualization, Methodology, Validation, Data curation, Writing - original draft, Writing - review & editing, Supervision, Funding acquisition. **Rigoberto Hernández Jonapá:** Conceptualization, Methodology, Investigation, Resources, Writing - original draft, Project administration. **Mateo Mier y Terán Giménez Cacho:** Conceptualization, Methodology, Writing - original draft.

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