frontiers | Frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 18 August 2022
doi: 10.3389/fsufs.2022.810840

Toward Food Sovereignty: Transformative Agroecology and Participatory Action Research With Coffee Smallholder Cooperatives in Mexico and Nicaragua

Alejandra Guzmán Luna[1,2], Christopher M. Bacon[3], V. Ernesto Méndez[1,2], María Eugenia Flores Gómez[3,4], Janica Anderzén[1,2], Mateo Mier y Terán Giménez Cacho[5], Rigoberto Hernández Jonapá[6], Misael Rivas[7], Henry Alberto Duarte Canales[8] and Álvaro Nicolás Benavides González[8]*

[1] Agroecology and Livelihoods Collaborative (ALC), Department of Plant and Soil Science, University of Vermont, Burlington, VT, United States, [2] Gund Institute for Environment, University of Vermont, Burlington, VT, United States, [3] Department of Environmental Studies and Sciences, Santa Clara University, Santa Clara, CA, United States, [4] Community Agroecology Network, Santa Cruz, CA, United States, [5] Departamento de Agricultura, Sociedad y Ambiente, El Colegio de la Frontera Sur (ECOSUR-CONACYT), San Cristóbal de Las Casas, Mexico, [6] Campesinos Ecológicos de la Sierra Madre de Chiapas (CESMACH), Angel Albino Corzo, Mexico, [7] Promotora de Desarrollo Cooperativo de Las Segovias (PRODECOOP), Estelí, Nicaragua, [8] Universidad Nacional Agraria, Managua, Nicaragua

OPEN ACCESS

Edited by:
Alexandros Gasparatos, The University of Tokyo, Japan

Reviewed by:
Miguel Altieri, University of California, Berkeley, United States
Georgina McAllister, Coventry University, United Kingdom

***Correspondence:**
Alejandra Guzmán Luna
alejandra.guzman@conacyt.mx

Specialty section:
This article was submitted to Social Movements, Institutions and Governance, a section of the journal Frontiers in Sustainable Food Systems

Received: *08 November 2021*
Accepted: *16 June 2022*
Published: *18 August 2022*

Citation:
Guzmán Luna A, Bacon CM, Méndez VE, Flores Gómez ME, Anderzén J, Mier y Terán Giménez Cacho M, Hernández Jonapá R, Rivas M, Duarte Canales HA and Benavides González ÁN (2022) Toward Food Sovereignty: Transformative Agroecology and Participatory Action Research With Coffee Smallholder Cooperatives in Mexico and Nicaragua. Front. Sustain. Food Syst. 6:810840. doi: 10.3389/fsufs.2022.810840

The challenges that coffee smallholder livelihoods face suggest the need to move beyond incremental changes in production. Transformative agroecology offers a potential approach to guide systemic change to achieve food sovereignty among coffee smallholders and cooperatives. This work aims to understand the extent to which diversification practices among coffee smallholders can contribute to a transformative agroecology, and to what extent, participatory action research (PAR) projects may support related transformative processes. The PAR projects described in this paper took place over 3 years with participants associated with two smallholder cooperatives in Mexico, and Nicaragua. After establishing long-term partnerships among cooperatives and universities, we used a PAR approach to guide a mixed methods study that included 338 household surveys, 96 interviews, 44 focus group discussions, and participant observation during farmer-to-farmers exchanges. We found that, although coffee-producing households in both study sites report several diversification activities, more than 50% still face some period of food scarcity each year. In our reflections with farmers and staff from the participating cooperatives, that are also included as co-authors in this study, we conclude that coffee smallholders and cooperatives in both locations are in the early stages of developing a transformative agroecology, as a path toward food sovereignty. Several leverage points to achieve this include land access, native seed conservation, cultural attachment to certain diversification practices, and traditional diets. Some of the more significant challenges to advancing a more transformative agroecology are the prioritization of coffee as a crop (i.e., coffee specialization), and dependency on coffee income. Our PAR project also aimed to contribute to achieving change in the

prevailing system through 1) capacity building with community facilitators/promoters, 2) co-creation of questions and knowledge relevant to the strategic planning by coffee cooperatives, 3) sharing farmer-to-farmer pedagogies across territories, and 4) the co-production of popular education material. We conclude that diversification remains an important agroecological strategy for smallholder commodity producers, as a way of achieving food sovereignty. Most of all, we find that achieving diversification is not a linear process, as there are many trade-offs, feedback loops, obstacles and opportunities that should be considered through long-term and collective approaches.

Keywords: livelihoods, agroecological diversification, seed sovereignty, land access, farmer-to-farmer, traditional diets

INTRODUCTION

The processes of neoliberalization in the coffee sector of Latin America, initiated in 1989, resulted in the closure of national institutes that oversaw technical training and coordinated marketing with smallholder coffee producers, among other activities (McCook, 2017). This trend exacerbated existing drivers of food insecurity, such as food price fluctuations, unsustainable land and water management, pre-existing social vulnerabilities, and precarious livelihoods (Johansson et al., 2016). Despite improvements in some regions, smallholder coffee producers continue to experience various negative socio-economic and climatic impacts (Jaffee, 2014). In addition to these existing challenges, the recent COVID-19 pandemic has exposed new vulnerabilities in the food system (Altieri and Nicholls, 2020; Gliessman, 2020). Stronger theoretical and empirical research is needed to understand, communicate, and contribute to transforming agrifood systems and bringing us closer to solving these persistent challenges (Adger et al., 2013). Furthermore, there is a need to move beyond incremental changes toward through transformative processes (De Schutter, 2011), which are not limited to minor adaptations, but reduce vulnerability and build pathways toward food sovereignty and more dignified livelihoods (La Vía Campesina, 2015; Anderson et al., 2019).

As an alternative to these multiple threats and conditions that leave rural populations exposed and vulnerable, a growing number of scientists, farmers, social movement leaders and some politicians are recognizing and promoting agroecological principles for transformation, with a strong focus on diversity and diversification (IPES Food, 2016). Transformative agroecology can be an approach for redesigning food systems toward achieving food sovereignty, seeking to also achieve ecological sustainability, and economic and social justice in the process. Through transdisciplinary, participatory, and action-oriented research, agroecology links science, practice, and movements focused on transforming food systems (Méndez et al., 2013; Gliessman, 2016).

Diversification is an important principle within agroecology-based transitions. Diversification helps to reduce risks, improve soil fertility, optimize productivity, generate alternative sources of income, and improve diets (Gliessman, 2015). Many studies show that agroecological diversification strengthens farmers' resilience to different shocks such as hurricanes (Holt-Giménez, 2002), coffee price declines (Bacon et al., 2014), long-term drought (Bacon et al., 2017), or access to land (Sauer, 2020). However, there remains a lack of published empirical research on important issues affecting the benefits and challenges of diversification as a means of strengthening food sovereignty. In a context where different types of stressors intersect, more research is needed to better understand the limitations and/or contributions of diversification as part of agroecological transformative processes and its relationships to food sovereignty. This study aims to fill this gap in the literature.

There are several reasons why smallholder-based coffee systems in Mesoamerica are ideal to study transformative agroecology processes, with an emphasis on diversification and through Participatory Action Research (PAR). First, shaded coffee systems are an example of diverse agroecosystems that tend to conserve higher levels of biodiversity, generate higher amounts of ecosystem services and be more resilient to disturbance, than less diverse coffee plantations (Jha et al., 2011; Perfecto and Vandermeer, 2015). Second, studies in coffee systems show that in addition to coffee, smallholders often manage diversified farms that contribute to food security and income, including milpa plots (i.e., corn, beans, and associated crops)[1], home gardens (for vegetables, backyard animals, and fruit trees) and apiaries for honey production (Soto-Pinto et al., 2000; Bacon et al., 2014; Jaffee, 2014; Anderzén et al., 2020), all contributing to food sovereignty. Third, there is a long history of PAR with smallholder coffee farmers in Mesoamerica, which has focused on different aspects of diversification (Bacon et al., 2005, 2008, 2017; Bacon, 2010; Méndez et al., 2010a; Caswell et al., 2012; Fernandez and Méndez, 2018; Anderzén et al., 2020). Fourth, coffee is a complex export-oriented cash crop, which is linked to traditional small-scale agriculture and to a large-scale value chain that involves over 100 million people globally (Tucker, 2011). Fifth, coffee systems have pioneered innovations that advance sustainability in coffee-growing communities (Jaffee, 2014). Finally, there are strong peasant and/or indigenous community-based organizations and cooperatives with whom the research team has relationships to support long-term research.

[1]The *Milpa* is an Indigenous agricultural system originating in Mesoamerica that involves intercropping of several crops, usually different combinations of different varieties of corn, beans and squash (Gliessman, 2015).

In this paper, we report some of the major insights generated through a four-year PAR process in partnership with local organizations in Mexico and Nicaragua. This PAR process sought to co-create knowledge and develop agroecological strategies, based on diversification, to manage high environmental risk, changing market conditions, and other structural factors. Our work addressed two key objectives, as follows. The first objective was to analyze and document different diversification pathways and assess the extent to which they were part of transformative agroecological processes, which contribute to food sovereignty. The second was to examine the role of PAR itself, which is often seen as central to enabling food sovereignty in transformative agroecology processes. Specifically, this work was driven by the following research questions: 1) to what extent do current diversification activities contribute to transformative agroecology that advances food sovereignty in two coffee regions of Nicaragua and Mexico? 2) how can PAR support smallholder diversification with cooperatives, as part of transformative agroecology? 3) what are the obstacles and opportunities for smallholder coffee cooperatives to use diversification as part of processes focused on food sovereignty and transformative agroecology?

CONCEPTUAL APPROACH

This section presents the theoretical pillars that inform our research and how they weave together to shape our conceptual approach. In particular, we draw from and integrate the concepts of 1) food sovereignty, 2) transformative agroecology, and 3) participatory action research (PAR).

Food sovereignty is the collective path toward the development of autonomous food systems, which stand in opposition to a neoliberal and neo-colonial model characterized broadly by plantation-based and large-scale industrialized monocultures (Chappell et al., 2013; Grey and Patel, 2015). Food sovereignty is a precondition to genuine food security, which also addresses the social and political control of the food system (La Vía Campesina, 1996; Patel, 2009). Some of the guiding principles for food sovereignty identified in the Nyéléni declaration[2] (2007) (Schiavoni, 2009; European Coordination European Coordination Vía Campesina, 2018) are to value food providers, by 1) honoring and supporting all their identities and their livelihoods; 2) supporting food providers to have control over their territory and the natural resources on it (i.e., land, water, seeds, livestock, and fish); 3) building food sovereignty on local knowledge, skills, and nature; and 4) rejecting technologies that undermine them (i.e., genetic engineering). In that regard, seed sovereignty and agrobiodiversity[3] are key components for achieving food sovereignty (Kloppenburg, 2014; García López et al., 2019). In ecological terms, agrobiodiversity (as well as on-farm diversification established and managed through the use of agroecological principles), may reduce the use of external inputs, attract pollinators, enrich, and protect the soil, reduce water consumption and transpiration, and increase the quality and amount of the harvest (Ponisio et al., 2015; Isbell et al., 2017). Agroecology has been broadly recognized as an approach with high potential to achieve food sovereignty (Jansen, 2015; La Vía Campesina, 2015; Martínez Torres and Rosset, 2017; Bezner Kerr et al., 2019; Altieri and Nicholls, 2020).

Although plurality is a key element of agroecology, we consider it especially important to highlight the transformative component of our approach, especially in a context in which agroecology is at risk of being stripped of its political content (Giraldo and Rosset, 2017). In that sense, transformative agroecology can be a synergistic strategy with other political and social goals (i.e., gender equity or agrarian reforms) that are the basis for processes that seek to achieve food sovereignty. For the purposes of this paper, we will focus on the role of transformative agroecology processes in achieving food sovereignty.

To better characterize transformative agroecology, we identified 24 indicators (also referred to as elements, parameters, or principles) through an extensive review of the literature (La Vía Campesina, 2015; Gliessman, 2016; Anderson et al., 2019; Biovision, 2019; FAO, 2019; Galab et al., 2019; HLPE, 2019; Hernández et al., 2020). Following the objectives of this study, we ranked and organized the indicators into four deeply interconnected dimensions, as follows: 1) environmental and productive, 2) economic, 3) socio-political and 4) food sovereignty (**Table 1**). Beyond the different dimensions and indicators, **Table 1** also outlined in which phase of the research process (Phase 1 or 2), data for each indicator was collected (Section Data Collection).

In this work, we emphasize on-farm diversification as a food sovereignty indicator and an integral component of agroecology (Altieri et al., 2015). In fact, as diversification can have a strong impact on farmers' diets, it can be considered one of the most important agroecological principles for household nutrition (Bezner Kerr et al., 2021), and thus a key element of food sovereignty. In that regard, we differentiated between two forms of on-farm diversification. The first includes diversified farms conducting certain agricultural activities motivated primarily by cultural and traditional reasons. For instance, one study found that Zapotec indigenous households in Mexico continued to grow traditional maize varieties even when the mean total production costs exceeded the market price of maize by 400% (Chappell et al., 2013). The second is a process of diversification in which households add new strategies into their "portfolio of activities" as a proactive or reactive measure (Ellis, 2000). These often involve agricultural activities that are promoted by external actors, including governmental or nongovernmental organizations.

The last theoretical pillar is agroecology's strong linkages to PAR, which is also deeply rooted in Latin America (Rosset et al., 2020; López García et al., 2021). The link between agroecology and PAR can constitute a virtuous cycle with transformative potential (Levidow et al., 2014; Méndez et al., 2017; Sevilla Guzmán, 2017; Anderson et al., 2019; Rosset et al., 2020). Méndez et al. (2013) summarized these linkages in common principles between PAR and agroecology, which include empowerment of local communities, context dependency, contributions to positive local change, deepening of long-term relationships, and

[2]Created with the participation of more than 500 social movement leaders from nearly 80 countries.

[3]Expresses the number of species and their abundance in the agricultural plots.

TABLE 1 | Dimensions and indicators of transformative agroecology in coffee socio-ecological systems.

Dimension	Indicators	Data sources by phase (P1 or P2)
1. Environment and productivity	Landscape connectivity***	P2: interviews, farm mapping; participant observation
	Water management and access**	P1: surveys; P2: interviews, focus groups; participant observation
	Resilience to climate change and extreme weather events**	P2: surveys, focus groups, focus groups
	Synergies and recycling**	P2: surveys, focus groups; participant observation
	Pest Management*	P2: surveys, farmers' exchanges
	Animal welfare*	P2: focus group, farmers' exchanges
	Soil Health*	P2: surveys
2. Economic	Financial empowerment and solidarity economy***	P2: surveys, focus groups, farmers' exchanges
	Labor force***	P1: surveys P2: surveys; participant observation
	On-farm income diversity***	P1: surveys P2: surveys, interviews, focus groups, farmers' exchanges
3. Socio-political	Responsible governance***	P2: interviews, farmers' exchanges; participant observation
	Ability to challenge and transform structure of power***	Farmers' exchanges, participant observation
	Impact on policies plus producer and producer-consumers links***	Participant observation
	Awareness and analysis of structural and historical context*	P2: farmers' exchanges; participant observation
4. Food sovereignty[a]	Co-creation of knowledge***	P2: interviews, focus groups, farmers' exchanges; participant observation
	Agro/diversity***	P2: surveys; participant observation
	Seed sovereignty***	P2: Focus groups, farmers' exchanges; participant observation
	On-farm diversity***	P1: surveys P2: surveys, farm mapping
	Traditional diet attachment***	P2: surveys, interviews, focus groups, farmers' exchanges; participant observation
	Ability to cope with food scarcity**	P1: surveys P2: surveys, farm mapping, interviews; participant observation
	Short and fair food chain distribution**	P2: surveys, interviews; participant observation
	Dietary diversity**	P2: surveys, farm mapping, focus groups; participant observation
	Agricultural practices that are culturally meaningful*	P2: farm mapping, interviews, focus groups, farmers' exchanges; participant observation
	Intergenerational and gender equity*	P2: surveys, interviews, focus groups, farmers' exchanges; participant observation

[a]*Including social and cultural indicators from other frameworks; *denotes lower relevance for the specific indicator; **denotes average relevance for the specific indicator; ***denotes high relevance for the specific indicator.*

incorporation of diverse voices and knowledge systems. PAR processes can also influence systems of agricultural products and input exchange among different users and consumers, as well as networks with various actors involved in markets, agroecological practices, farmer organizations, and/or allied NGOs, or "agroecological lighthouses", representing iconic cases that can inspire others (Anderson and McLachlan, 2015; Mier y Terán Giménez Cacho et al., 2018; Nicholls and Altieri, 2018). Finally, PAR can be a driving force to question and highlight elements that communities were not aware of and generate alternatives in the face of different inequities.

METHODOLOGY

Study Site

Here we introduce some of the structural and historical features of the two cooperatives with whom we partnered in this study: 1) Campesinos Ecológicos de la Sierra Madre de Chiapas (CESMACH) in southern Mexico, and 2) the Promotora de Desarrollo Cooperativo de Las Segovias (PRODECOOP) in northwest Nicaragua (see **Figure 1**).

In previous decades, agrarian reforms provided land to smallholder and farmer organizations that were institutionalized as cooperatives in Central America, or *ejidos* and agrarian communities in Mexico[4] (Bacon, 2010; Jaffee, 2014; McCook, 2017). Agrarian reforms implied national land redistribution through a variety of processes. Notwithstanding this historical favorable condition in terms of land access, the contemporary crises that coffee producers are experiencing has its roots in the neoliberalization that began in the region in the late 1980s (Bacon, 2010). Its beginning was marked by the collapse of the International Coffee Agreement in 1989, which regulated exports and prices (Jaffee, 2014; McCook, 2017). In the following years, governmental institutions that provided technical training, credit, and that controlled quality, sales, and export of coffee were dismantled (Bacon, 2010; Méndez et al., 2010b; Jaffee, 2014; McCook, 2017). That was the case of INMECAFE in Mexico and UNICAFE in Nicaragua. These changes meant that "an entire sector of peasant producers was exposed to the effects of a deregulated market (...) over the next 3 years, due to the 70 percent drop in the prices, the small producers of coffee were plunged into poverty, indebtedness and even bankruptcy" (Jaffee, 2014: 59). This context led to the surge of many cooperatives that organized smallholder coffee producers, allowing them to access better markets, quality control, and technical training. The demand for quality coffees with "sustainability certifications" (e.g., organic or Rainforest Alliance), mainly by consumers in the United States and Europe (McCook, 2017), have favored international interactions with coffee grower organizations. As a result, international Non-Governmental Organizations (NGOs), buyers, and certifiers replaced the role of governmental agencies in providing technical training, guaranteeing minimum prices, coordinating exports, and financing development projects

[4]Collective land tenure assigned by the state to a group of farmers who demanded it. This was possible in the context of the agrarian reform that took place between 1934 and 1992 (Morett-Sánchez and Cosío-Ruiz, 2017).

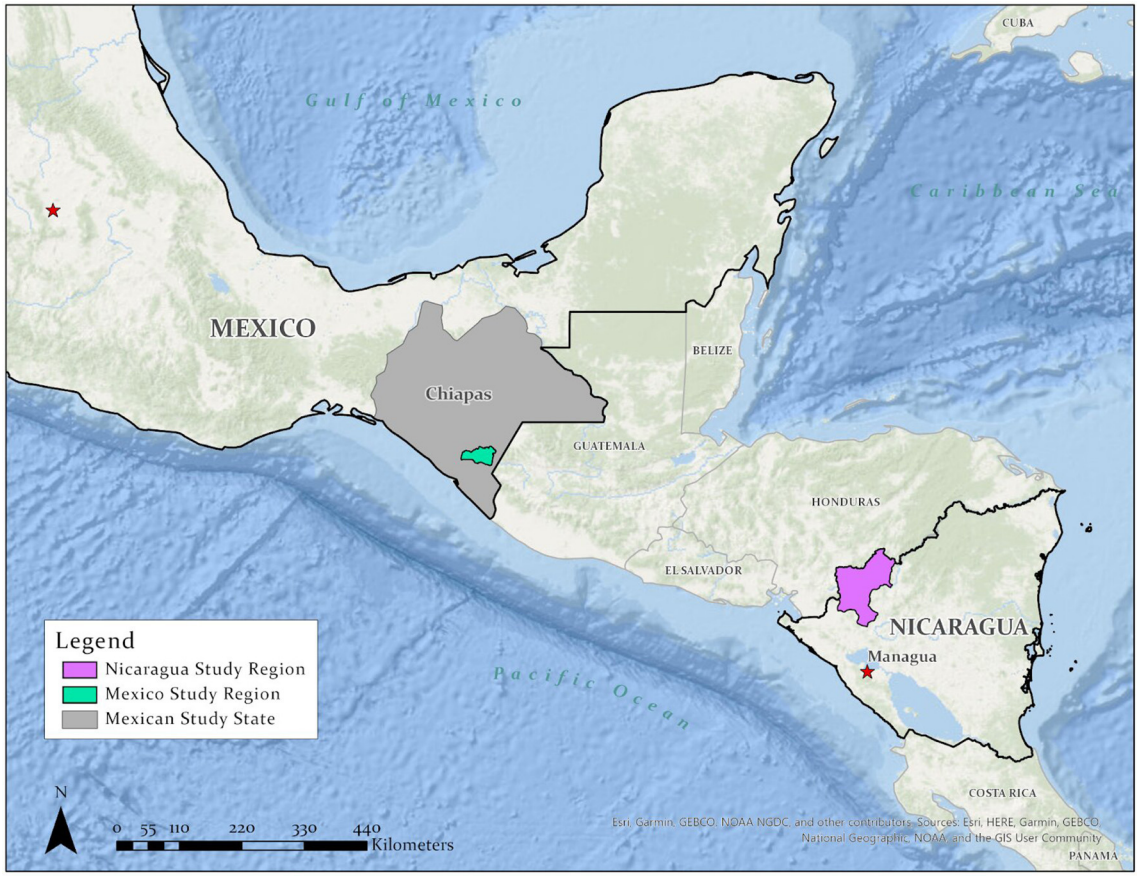

FIGURE 1 | Location of CESMACH (Mexico) and PRODECOOP (Nicaragua). Created by Emma McCurry, Santa Clara University.

with cooperatives. These relationships could be a double-edged sword for organizations, as they could also generate dependent relationships.

Beyond their common structural context, both cooperatives have features that have defined their path toward food sovereignty. Key to this analysis is that they both have a history with institutions and projects that promote diversification.

CESMACH is a coffee cooperative in Mexico founded in 1992 that currently has 689 members, of which 30% are women. Most of its members are part of *ejidos*, distributed in 46 communities, located in the northern side of the Sierra Madre de Chiapas Mountain range in southern Mexico. CESMACH is positioned within the buffer zone of the "El Triunfo" Natural Protected Area (Fernandez and Méndez, 2018), a biodiversity hotspot with an abundance of wild foods that grow in the forests and managed plots. By 2000, the cooperative had registered its trademark as "Café Campesino", and in 2001, it obtained its Fair Trade (FLO-International) and organic (CERTIMEX – IMO control) certifications.

CESMACH has always expressed a commitment to the social wellbeing of its members. Since the early history of the cooperative, they have promoted projects to support sustainable agriculture, family health, nutrition, housing, and food security. All of this has been done with the support of diverse institutions, including governmental (e.g., CONABIO), NGOs (e.g., Heifer International, Food 4 Farmers, Edhuca), solidarity buyers (e.g., Equal Exchange) and international universities following PAR principles (e.g., University of Vermont). Some of the main achievements in this regard have been obtaining a women-inclusive registered trademark called Café Femenino (2006) and also establishing Miel Real del Triunfo (2019), a smaller and parallel cooperative to process and sell honey.

PRODECOOP is a coffee cooperative union in Nicaragua founded in 1993. It integrates 38 affiliated grassroots cooperatives made up of 2,300 member families, of which 28% are women (PRODECOOP, 2020). The organic and conventional production units are located in three departments in northern Nicaragua that contain three mountain ranges running east to west with topographical variation between ∼800 to 1,600 m above sea level (Kelley et al., 2018). PRODECOOP members obtained land tenure in the 1980s agrarian reform, during the 1990s and early 2000s (Bacon et al., 2017). PRODECOOP has developed sophisticated quality control and trained professional staff to market their smallholders' coffee to premium organic, fair trade, and specialty markets.

PRODECOOP's long-term commitment is to improve the quality of life of its members and promote cooperative development in the Segovias region. PRODECOOP started to invest in farm diversification as a key strategy to eliminate seasonal hunger, launching their Food Security and Sovereignty Program (SSAN). This initiative began with a diagnosis in 2010, through which an action plan with project initiatives and activities emerged. These integrated the gender policy and community-based action research approach in partnership with local and international universities following PAR principles (i.e., Universidad Nacional Agraria and Santa Clara University), farmers' movements, and NGOs (i.e., Community Agroecology Network (CAN), based in California). Another important element is capacity building, where farmer leaders of on-farm diversification experimentation and farmer promoter networks are the backbones of all technical assistance in coordination with nine agricultural extension agents. This motivated family participation, increasing from 30 to 1,500 families involved in Good Agricultural Practices on Diversification (GAPD) over the last 11 years.

Participatory Action Research Partnerships

In 2016, researchers and practitioners[5] joined PRODECOOP and CESMACH to design the project "Assessment of Diversification Strategies in Smallholder Coffee Systems of Mesoamerica". PAR and shared methodologies (i.e., criteria for selecting participants; surveys, interviews, and focus groups) were important components of the project from the beginning. This included collective planning and coordination with in-country teams (including local researchers and community facilitators/promoters), cooperative leadership and farmers to define specific goals, design and implement research tools, validate and share results, and define next steps for research and action.

In CESMACH, we worked with five community facilitators (young cooperative members or sons or daughters of members), and the cooperative-based project coordinator (a biologist/agroecologist). In Nicaragua, which had an established longer-term PAR process (Bacon, 2015), the dialogue was carried out with 14 community promoters, and two agroecologists/technical assistance teams. The selection of facilitators/promoters and assistance teams was carried out according to the cooperatives' criteria for hiring personnel, based on their regulations and as a way to contribute with their local governance. Although facilitators/promoters were part of each phase of the project, their leadership in designing research tools, managing focus groups, and making decisions grew throughout the process, with a change being particularly noticeable for female promoters. This led to group reflections and adjustments to finalize research tools, methods, program implementation, community validation, co-authorship, and dissemination of findings for different audiences.

[5]Researchers came from the Agroecology and Livelihoods Collaborative (ALC) at the University of Vermont (UVM), Santa Clara University (SCU), and the Community Agroecology Network (CAN) in the USA, El Colegio de la Frontera Sur in Mexico (ECOSUR), and the Universidad Nacional Agraria (UNA) in Nicaragua.

Data Collection

We used a variety of research methods and instruments throughout the PAR project. In Phase 1 (P1; early 2017), we conducted a survey with 167 households in Mexico and 171 in Nicaragua, with the objective of getting an overview of farmer households' livelihoods, including characteristics of on-farm diversification, food security, and sources of income. For an analysis of this data the interested reader is referred to Anderzén et al. (2020) and Bacon et al. (2021). In Mexico, the households were selected with the support of the cooperative leadership, from five groups (30 farmers from each group) representing different types of diversification: 1) beekeepers, 2) farmers with milpa plots, 3) farmers who had participated in diversification projects, 4) farmers participating in specialty coffee initiatives, and 5) farmers who had not participated in any diversification projects. A similar set of criteria was used for Nicaragua.

In Phase 2 (P2; late 2017-2019), we worked with 50 households (in each site) who represented different livelihood diversification strategies. We carried out farm mapping (46 in Mexico; 50 in Nicaragua), interviews (46 in Mexico; 50 in Nicaragua) about farmers' motivations and background in diversification activities, and household surveys. The surveys were conducted monthly for over a year, focusing on the division of labor in diversified farms, food production and consumption, as well as seasonal sections related to diversification activities, and climate change. We also conducted several focus group discussions (18 in Mexico; 26 in Nicaragua) with the Phase 2 participating households (adult men, women and teenagers). These covered various topics (e.g., beekeeping, milpa systems, food security and sovereignty, agricultural calendars, gender equity), and used participant observation as a method for deepening our understanding of the project themes (on-farm diversification, food security, climate change resilience and gender equity). The focus group discussions also included a farmer-to-farmer component as they were led by the local facilitators/promoters, and typically involved an action element, such as diversification activities training or sharing experiences. All the data was collected by the project team (facilitators/promoters, ALC-UVM, USC, UNA students, and CAN staff).

In parallel, a capacity-building and mutual learning process among researchers, cooperative staff, and facilitators/promoters continued. This included frequent meetings that addressed a variety of topics, such as aspects of PAR and human development. We also carried out two cross-site learning exchanges (in Nicaragua, 2018 and in Mexico, 2019) with farmers, scholars, cooperative leaderships, and the participating NGOs. Those exchanges provided concentrated opportunities for sharing that highlighted the richness of comparing experiences and exploring new ideas. In addition to following community-based and participatory principles (Méndez et al., 2017), all research was conducted after receiving approval from the relevant University Institutional Review Boards.

Data Analysis

During this 4-year project we collected a substantial amount of quantitative and qualitative data. However, in this paper we focus primarily on those findings relevant to answer our research questions (see Section Introduction). In that regard we use descriptive statistics and qualitative data from transcribed interviews and focus group discussions to complement a more interpretive argument about the role of farm diversification, cooperatives, and PAR in transformative agroecology.

The quantitative survey data was exported, cleaned, and preliminary results were shared and discussed with respondents during the focus group discussions, as well as with cooperative staff/promoters. Descriptive statistics and *T*-tests are calculated in Excel spreadsheets. To define the role of on-farm diversification in the process of achieving food sovereignty, we follow the ranked indicators presented in **Table 1** (Section Conceptual Approach).

RESULTS

Several key findings responded to the overarching objective of how current diversification activities contribute to transformative agroecology for advancing food sovereignty, and the role of PAR in the process. Section Food Sovereignty and Transformative Agroecology Elements presents some comparative findings between the two cases, and Section Cooperative-Specific Observations delves more into some context-specific highlights.

Food Sovereignty and Transformative Agroecology Elements

Our study has confirmed that member farmers of both cooperatives manage diversified farms, consisting of farm animals and various crops, in addition to coffee (**Table 2**). Our initial survey (Phase 1) showed that fruit trees were the most common diversification strategy in both study sites, followed by poultry and vegetables. Another important strategy was milpa/basic grains (either in diversified milpa plots or in small scale monocultures of corn or beans), which was present in more than half of the households (Mx∼63%; Ni∼55%). Although the percentage was higher in the Mexican case, we saw a trend of simplifying the milpa system to corn/bean monocrops in both sites. Livestock as an important income source was much more prevalent in Nicaragua.

In terms of food security, 72% of CESMACH respondents in Mexico reported experiencing at least 1 month of seasonal food insecurity (or lean months)[6] in the year prior to the survey (**Table 2**). The average number of lean months reported across the 159 surveyed households (including those reporting zero months), was 2.5 months. The average number of lean months for those households that reported experiencing at least 1 lean month was 3.5 months per year (SD = 1.6). Approximately 50% of the 171 survey respondents from PRODECOOP (Nicaragua) reported at least one lean month in the year before the survey. The mean number of lean months reported across all households was 1.6 months per year (SD = 2.1), which is significantly lower than the mean in Mexico. The smallholders reporting at least one lean month share one important similarity between study sites, in that their average amount of lean months is 3.2 months per year at the Nicaragua site (SD = 1.9) and 3.5 months per year (SD = 1.6) at the Mexico site (**Table 2**). In both study sites, the rainy season coincides with the most severe experiences of lean months (**Figure 2**), exacerbated by delays in receiving the second payment of the coffee harvest. For Fairtrade coffee, a portion of the payment for the crop is paid upfront, with the balance, including the price premiums, paid later in the year. However, **Figure 2** shows that this income does not imply an instant relief from the lean months. In contrast, relief from the lean months coincides with 1) a peak in local fruit consumption in the Mexican site, 2) honey harvest in the Nicaraguan site, and 3) the beginning of the staple crop harvest (i.e., corn and bean) in both countries.

In particular, the cultivation of milpa plots is a significant expression of seed sovereignty in Mexico. In our interviews

TABLE 2 | Engagement in diversification, farm characteristics and prevalence of food insecurity for study cooperatives.

Engagement in diversification activities in the P1 survey (% of households)		
	CESMACH, Mexico ($n = 167$)	PRODECOOP, Nicaragua ($n = 171$)
Fruit trees	98	99
Milpa/basic grains	∼63	∼55
Poultry	88	78
Vegetables	65	74
Livestock	15	38
Farm animals (pigs, rabbits)	30	∼34
Beekeeping	22	19
Farm characteristics		
	CESMACH, Mexico ($n = 159$)	PRODECOOP, Nicaragua ($n = 171$)
Mean farm size (ha)	8.7 (5.7)	5.7 (6.8)**
Farm area under coffee (%)	74% (22)	52% (36)**
Experience of food insecurity		
	CESMACH, Mexico ($n = 167$)	PRODECOOP, Nicaragua ($n = 171$)
Experience of at least one lean month (% of households)	72%	50%
Mean number of lean months for all households (months)	2.5 (2.1)	1.6 (2.1)**
Mean number of lean months for households with >0 lean months (months)	3.5 (1.6)	3.2 (1.9)

***$p < 0.05$ or lower, ***$p < 0.01$; Parentheses denote standard deviation.*

[6]The experience of lean months is an indicator of seasonal hunger. It indicates the number of those months during which the food produced on-farm has run out, and households face difficulty purchasing additional food. Common coping mechanisms include the consumption of less preferred food, borrowing money to buy food, and sometimes skipping meals or going to bed hungry (Bacon et al., 2014).

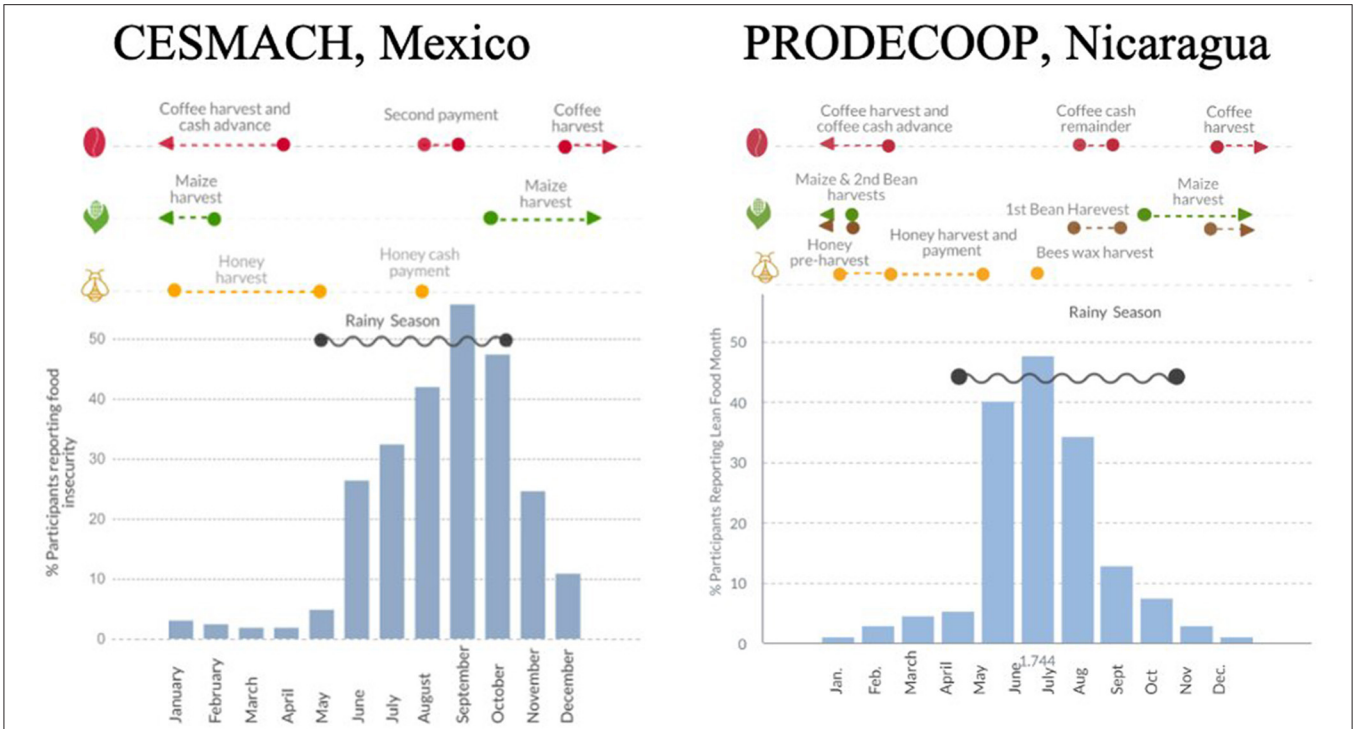

FIGURE 2 | Key moments in the agriculture and cooperatives cycles, as well as lean months. Left graph was published in Anderzén et al., 2020, p. 42. Right graph data came from 171 Household Surveys Northern Nicaragua, 2017 and Focus Groups (Bacon et al., 2021).

and participant observation, many of the coffee smallholders cultivating milpa plots reported using one or several native and creole varieties[7] of corn and beans, either in a traditional milpa system or a simplified system. Through interviews, focus group discussions and Phase 1 surveys, we identified thirteen corn and seven bean varieties that farmers associated with specific features, such as increased yield, adaptation to local climatic conditions, preferred altitude, and specific food uses. In contrast, some farmers mentioned that native and creole varieties do not grow well without agrochemical input or that they produce lower or even no yield. These varieties are also considered as a cultural inheritance with important cultural meaning. Moreover, our data suggest that these landraces may increase the adaptive capacity of the household to climate variability, as one Mexican farmer pointed out during a focus group discussion:

> *There are seeds that are specialized to withstand cold, heat, weather, and so on. Yes, to dedicate myself to planting corn seeds appropriate to face climate change* (*Male farmer*).

Participant observations and collective reflection showed that key seed sovereignty activities in the Nicaragua study location included households with an active participation in seed saving, as well as the maintenance and exchange of vegetative plant material, such as tree cuttings. These tree cuttings can be used in live fences, yuca or cassava root trellises (*Manihot esculenta*), starts for bananas and plantains *(Musa spp.),* and others. After learning from the *Campesino-a-Campesino* Program's innovative community-based seed banks during several farmer exchanges (for more details see Bacon et al., 2014), the smallholders affiliated with PRODECOOP and the rural assistance staff started promoting the establishment of seed and vegetative material "banks" (or "Bancos Vivos") for *in-situ* agrodiversity conservation. By the time of writing this article the cooperatives have undertaken this activity for over 10 years. In addition, there is farmer-led experimentation for the identification of seeds that are resistant to the impacts of climate change.

Diversification activities (and their implementation) are highly dynamic in relation to the landscape and seasons. In the Mexico site, and based on the farm maps drawn by 46 households, we found that most plots, including coffee agroforestry systems, were home to various edible species and/or farm animals. These species provided a wide variety of nutrients to household members, and contributed to the diet of seasonal workers during the harvesting season. In addition, home gardens typically contained a mix of vegetables and fruit trees along with poultry or pigs. Most coffee plots, as agroforestry systems, contained fruit trees and various types of wild food, such as mushrooms and vegetables, which are collectively important food sources during the lean months.

In the Nicaragua site, the maps drawn by cooperative members revealed significant spatial dispersion between households and farm plots, with many farmers managing coffee

[7]We refer as native to seeds from the Americas, and creole as seeds that although not native to the Americas, have undergone adaptation (García López et al., 2019).

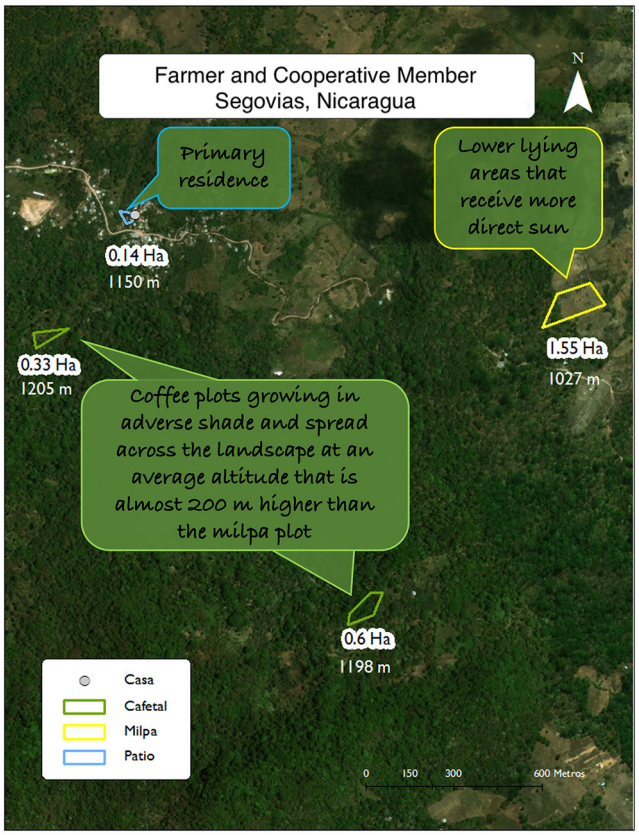

FIGURE 3 | Spatial distribution of productive plots of one farmer in PRODECOOP, Nicaragua.

plots at higher altitudes. These plots can be located >5 km from the household and the lower altitudes of the milpa plots. Although there are no frost zones, the low-lying mountains of the study areas exhibit significant microclimatic variability, and farmers can use different locations to accommodate this high diversity of crops (see **Figure 3**). For instance, beekeepers in the study sites described how they move hives during the year, according to flowering plant availability at different altitudes.

Regarding agrobiodiversity, in the Mexican site, monthly household surveys reported a wide range of edible species. Domesticated species included multiple species of roots (5), vegetables (16), flowers (5), aromatic plants (13), fruits (31), and animals (7). In addition, for wild edible species, households also reported multiple species of vegetables (24), fungi (16), and animals (16, including insects, birds, and mammals). In the Nicaraguan site, households reported several maize (31) and bean (37) varieties. Ten of the varieties of basic grains are handled exclusively by "milpera" women. Families integrated these crops in their plots either for home consumption or for sale. Home gardens are one of the most important agricultural activities, where all family members participate, and with 5–15 crops grown per household. Although progress has been made in the preservation of fruit seeds, spices, tubers, and vegetables for home garden cultivation, there is still an external dependence on vegetable seeds. It is important to point that many families have a strong interest in learning more about vegetable seed preservation.

There were many similarities between the smallholders surveyed at both study sites, as well as considerable variation within each site. The farms surveyed in Mexico averaged 8.7 ha in size, which was significantly larger than the 5.7 ha of average total farm area in the Nicaraguan site (**Table 2**). It is also important to note that the average total farm area dedicated to coffee production was higher for the farms surveyed in Mexico compared to those in Nicaragua (74% average coffee cover in Mexico vs. 52% in Nicaragua). This suggests that although the surveyed farms in both locations may contain a similar number of crop species, when comparing plant diversity per unit area, Nicaraguan farms contain more species.

Finally, coffee remains a key source of agricultural income in both sites. In Nicaragua, most farms <10 ha reported coffee as their primary income source (82%), while in Mexico 35% of all producers reported coffee as the only source of agricultural income. This shows a relatively high specialization focus by these farmers on coffee production for income generation. Furthermore, in both study sites, coffee production is largely dependent on family labor.

Cooperative-Specific Observations

In Sections CESMACH, Mexico—PRODECOOP, Nicaragua, we discuss some of the specific features of each cooperative, according to their importance for achieving food sovereignty. In this sense the sections below reflect the needs and interests of the cooperative partners, and the intrinsic PAR characteristics that are site- and context-specific. This makes it impossible to completely replicate the methodologies, or fully compare findings and PAR impacts between the two cooperatives.

CESMACH, Mexico

Smallholders' Motivations for Diversifying

When asked how diversification activities started within the cooperative, most smallholders mentioned that they started growing certain crops or raising animals through their own initiative. Conversely, the adoption of diversification approaches driven by external support (i.e., NGOs or government funding) was less prevalent. Our Phase 1 survey showed that the production of fruit (from trees), poultry, vegetables, and milpa plots are the four most common on-farm diversification activities, and typically started by farmers themselves (> 87%) rather than through external projects or government programs (<18%). Furthermore, smallholders reported that personal enjoyment was one of the reasons for engaging in these diversification activities. Another motivation for these activities was consuming organically or naturally produced food because they are healthier for people and nature. As one farmer said in an interview: *"That's why we think of health, not of business"* (*Male farmer*).

We argue that these farmer-initiated, on-farm diversification activities for diet improvement and personal enjoyment can be interpreted as food sovereignty-oriented motivations. This

is because they are rooted in households' cultural and environmental conditions, traditional production systems and agrobiodiversity, as well asself-sufficiency. However, other households reported discontinuing the production of poultry, vegetable, and milpa plots in the last 10 years. Among the main reasons for abandoning these activities (either temporarily or permanently) were their high labor requirements, lack of access to sufficient land, or a desire to focus more on coffee production (i.e., increase specialization). Our observations, focus group discussions, and interviews pointed to multiple feedbacks among diversification and production activities. Among others things, they enhanced dietary diversity, which also strengthened food sovereignty.

Origin of Locally Consumed Food

Our monthly surveys identified the high dependency of the surveyed households on purchased food. In particular, rice, cookies, and pasta were among the most commonly purchased types of food reported for all months. This is often low-quality and highly processed food, with high sugar or sodium content. However, following purchased food, self-produced food was most commonly consumed between September and March. This aligns with harvest season for staple crops. Wild edible species (e.g., plants, fungi, insects, other animals) were the second most commonly consumed type of food between April to August, which aligns with a decline in access to purchased food during the rainy season.

This high consumption of self-produced food or food harvested from the wild highlights their potential to help households achieve food sovereignty, while also exposing the vulnerability that high dependence on purchased food can bring. For example, this vulnerability can be particularly significant in a context where roads usually close and communities become easily isolated during the rainy and hurricane season.

Cultural Attachment to Milpa Systems

The cultivation of milpa plots can have a synergistic or antagonistic effect on food sovereignty, depending on the context. For instance, although there is a tendency to simplify the traditional milpa systems to include fewer crops, smallholders acknowledge the many advantages that continuing farming milpa plots can have. These included finding edible wild species in their milpa plots or including other edible crops such as chayote (*Sechium edule*) or camote (*Ipomea spp.*) to "*help the corn grow better*", as a farmer noted in an interview. Some of the interview respondents also suggested that the bean leaves in milpa plots can protect the soil and provide livestock feed after the harvest.

We also observed a strong cultural attachment to milpa systems. Some smallholders explained during the interviews that they grow corn "*only for the fresh corn cob*". In this sense, farmers continue growing corn so their families may enjoy eating it as a snack for some days during the year. It is interesting to note that for some of those smallholders, producing this delicacy implies walking as much as 6 h round-trip once a week, to cultivate small milpa plots (usually <0.5 ha), since the best land closer to home is usually reserved for coffee production.

Only a quarter of the surveyed households were producing enough maize to meet their needs for the whole year. However in some interviews it was suggested that other agricultural activities beyond coffee were important for food consumed within households, including the output of milpa plots that can act as a buffer to annual changes in the diet, and thus represent an important element for achieving food sovereignty. For example, as expressed by a farmer during focus group discussion with farmers that had milpa plots:

> *"Now, gentlemen coffee growers, (...) the detail is, you cook your money and see if that's going to fill you up- (...) it's the truth, we have land to plant, and we buy, and a farmer can not only live from a product, but the farmer lives from different types, not just coffee.* (*Male farmer)"*

PAR Contributions to Food Sovereignty

PAR principles were followed in every activity carried out by CESMACH members. However, the outcomes of the implementations of those principles are hard to measure, especially in the short-term. We identified the capacity-building of community facilitators and the development of popular education tools as the strongest PAR contributions to a transformative agroecology process.

The community facilitators' training focused on three different themes that were treated during three-day monthly sessions: 1) Coffee value chains, which traces the process of the coffee crop from the farm to the cup (e.g., agricultural practices, cupping/coffee appreciation, processing); 2) PAR and research approaches (e.g., livelihood diversification, coffee agroecosystems, food security and sovereignty, climate change, gender equity); and 3) human development (e.g., personal experience with gender dynamics, self-esteem, skill-building). Facilitators had the opportunity to attend national and international conferences and courses about agroecology, food sovereignty, and gender equity. Overall, during the 4-year PAR process, we witnessed personal and professional growth in each of the facilitators, who have also become leaders and advocates for participatory processes, agroecology, and diversification.

In regard to popular education, we (researchers, community facilitators, and a visual designer) created three tools to guide collective reflections to achieve transformative agroecology and food sovereignty (see below for description). The first draft of each tool was created through focus group discussions replicated in three communities. These activities were led by the facilitators, with the support of researchers or CAN staff, and were undertaken as workshops using craft materials (e.g., color papers or drawings) with all the participants. The researchers integrated the three tool drafts for a follow-up validation process with CESMACH's leadership, facilitator team, and (at least) two other communities. Finally, the designer put together the validated tools drafts, which were reviewed one more time with the cooperative's leadership, facilitator team, and researchers, until a consensus was reached.

The first tool was the Nourishment Plate (**Figure 4**), which was developed to outline the most frequently mentioned cultivated or wild local food consumed among CESMACH

FIGURE 4 | The Chiapas Highlands Nourishment Plate education tool that highlights the most common local food resources reported by CESMACH households. Created by Daniela Gallardo Olimón.

member households. Another tool was an agricultural seasonal circular calendar that included all activities that families carry out for coffee production, milpa plot cultivation, and beekeeping, separated by productive activity. Through these tools, we initiated rich and useful discussions to assist decision-making on production issues at the household, community, and cooperative levels.

PRODECOOP, Nicaragua

Smallholders' Perspectives on Diversification and Food Sovereignty

In a series of interviews, PRODECOOP smallholders expressed why diversification is important to them. Most respondents (70%) mentioned that diversification practices help them increase agricultural output from their land. All of the certified organic farmers also reported that diversification practices have environmental benefits. Approximately 72% of these diversification activities began through farmers' own initiative, whereas 15% were linked to a project and 5% to cooperative membership.

Farmers also suggested that diversification activities can help improve their households' food security, save money on food purchases, improve soil fertility by using green manure, and reduce the risk of crop loss after environmental and economic livelihood shocks. Many of these elements also contribute to their sense of autonomy and food sovereignty. For example, as one farmer expressed:

> *"We faced the 2014 drought, which was tremendous, but we, the family farmers, managed it. We preserved soils and had diversified our crops.… [Although] the corn yields were very little, we could rely on the Musaceae [bananas and plantains], the root crops, we thus did not hinder the food part... On the farm, you are going to see the live barriers, and up to 3 or 4 crops, because [we] know how to associate well, in ways that do not compete for light (...). This Canavalia is sown as a cover crop for the summer period, then when the new sowing season starts, you cut it and leave it on the fields*" (Male Farmer).

This quote from a coffee producer, who also maintains a milpa plot, reveals their use of agroecological knowledge to establish and maintain intercropping systems, live fences, and cover crops.

The coffee smallholders of PRODECOOP also demonstrated a strong cultural and material attachment to milpa systems, perhaps with greater importance given to bean production. About half (56%) of the smallholders maintained milpa plots, and farmers prioritized self-consumption of both corn and beans. Corn was primarily consumed within the household, as only 11% of the surveyed smallholders reported selling it in 2017. Conversely 30% reported selling either the culturally preferred Nicaraguan red chili beans or the black beans, usually to external markets.

As illustrated in **Figure 3**, farmers also diversified the location of their plots, since many of these plots are spread across the landscape. One farmer explained the importance of arranging crops in ways that reduces the distance from their homes, allowing thus to invest more care and labor for agricultural activities.

> *"In the* first *place, [I decided to diversify in order] to have more crops closer to home. In the second place for taking more care of them - what we have nearby is easier to care for, because every day we are seeing them, and if they are far away, we cannot go visit the crops every day"* (Female farmer).

Linking Agrobiodiversity to Food Security, Dietary Diversity, and Land Access

The survey analysis found that across all PRODECOOP respondents some variables are correlated with household dietary diversity. Specifically, we found that on-farm crop diversity correlates with measures of household dietary diversity as measured by the weekly consumption of major food groups (coefficient $= 0.09$, $p < 0.001$). These findings suggest the importance of producing multiple crops for household consumption, although it is also likely that some of the crop diversity (e.g., citrus for sale) also contribute to income generation, which is in turn used to purchase more diverse foods. Furthermore, we have documented a strong relationship linking farm size (even slightly larger farms among these smallholders) and higher incomes to fewer lean months per household.

Positive Effects of Affiliation to PRODECOOP

Affiliation to PRODECOOP, as a cooperative union, generated benefits to member households such as technical assistance for organic coffee production and better coffee prices from sales to specialty, Fairtrade, and organic markets. PRODECOOP also used Fairtrade coffee roasters and development assistance organizations to channel aid to the smaller farmer cooperatives, helping them secure buildings, gain knowledge on agroecology, and establish community-based grain and seed banks. In the past 25 years, PRODECOOP has offered legal, technical, and political agency to help secure individual and collective land titles for affiliated cooperatives and smallholders. This was done within a challenging national neoliberal context and local preferences that often favored privately held property rights. PRODECOOP also has a history of female leadership in key staff positions (e.g., general manager, head of exports) and an innovative gender promotion program. This program prioritizes women's empowerment through training and support for human rights, women's economic development, reproductive health, youth leadership, and reducing violence against women.

DISCUSSION

Contribution of Diversification to Food Sovereignty

Below we offer an overview highlighting some key elements of the diversification practices adopted by households in each cooperative. In particular, **Table 3** summarizes the contributions and challenges that diversification offers for food sovereignty in each of the study sites.

In the Mexico case study, our monthly survey, observations, and collective reflections suggest that the lean months reported by households affiliated with CESMACH do not always reflect a scarcity of food, but rather a change in diet. In other words, there is a reduction of regular availability of purchased food coming

TABLE 3 | Contributions and challenges to food sovereignty due to diversification practices.

CESMACH, Mexico	PRODECOOP, Nicaragua	Common elements
- Experience of lean months may reflect a change in diet	- Diversification practices are integral to agroecological farm management	- Farmers own relatively large parcels of land
- Cultural attachment and long-term engagement to a diversified farming system	- Diversification increases local resilience and reduces water stress	- Strong potential to achieve seed sovereignty
- Wild food perceived to be "food of the poor", rather than nutritious or healthy food	- Long-term engagement with diversification efforts, and women and youth capacity building	- Corn cultivation and beekeeping are two important income sources with cultural meaning
- Families struggle between engagement in the global coffee value chain and the achievement of food sovereignty	- Current PAR processes started in 2009	

from outside the communities. Yet, this does not necessarily imply that the quantity of food is lower than normal. In fact, the availability of wild and cultivated food during those lean months increases (see Section Smallholders' Motivations for Diversifying). As the facilitators' coordinator noted: "It is possible that during lean months, families are having even a healthier diet because they are consuming natural food that grows on their plots". In contrast, the use of these seasonal wild food resources is not common in Nicaragua.

There are complex complementarities between on-farm diversification and transformative agroecology for food sovereignty. On the one hand, previous analysis revealed that farmers combining coffee with milpa (traditional or simplified) reported fewer lean months than farmers without these two key activities, especially if they also practiced beekeeping (Anderzén et al., 2020). Farmer motivations appear as cultural values attached to the farming systems (e.g., for milpa), and in the prevalence and diversity of fruit trees in almost all of the households. In that regard, milpa is a traditional system that, beyond the ecological and nutritional complementarity between the species, is the foundation of the Mesoamerican diet and an expression of a historical process of biocultural co-evolution (Toledo and Barrera-Bassols, 2020). Motivations are rooted in the long-term linkages between farmers' livelihoods and the cultivation of milpa plots, as well as vegetables and poultry for self-consumption, healthier food, or enjoyment (see Section Smallholders' Motivations for Diversifying). This reflects the cultural attachments to certain diets that appear as resistance toward industrial food, However, it should be noted that one of the disputed areas in this regard is the perception of wild foods as "food of the poor" (as some participants described them during focus group discussions), rather than nutritious or healthy. Similar perceptions have been documented in other case studies showing that, although local food sources may be undervalued, it is not enough to replace traditional diets completely (Jenatton and Morales, 2020). All of these elements suggest that CESMACH member families cannot be reduced to agricultural micro-entrepreneurs, but rather have various other concerns that enrich how they are attaining their food sovereignty and reproducing their livelihoods.

In sum, on-farm diversification responds to a historical process for CESMACH member families. As Phase 1 surveys showed some diversification activities were the outcome of projects implemented from external institutions, while others were the continuation of traditional practices. This includes a relationship with coffee as a commodity[8] and engagement with external projects, which can sometimes be in tension with the strengthening of CESMACH governance. It is in this context that CESMACH member families play a political role moving between participation in the global coffee value chain and achieving food sovereignty.

In the Nicaraguan case study, although the process of achieving food sovereignty for PRODECOOP members still has some way to go, it has advanced significantly and benefited greatly from a long organizational process that goes beyond coffee production and commercialization (e.g., incorporation to the *Campesino-a-Campesino* program, and establishment of community based seed banks). In productive terms, rather than reducing diversification to "increasing the number of activities", it is closer to integral agroecological farm management (soil, agrobiodiversity, intercrops, live fences, cover crops), mimicking ecological processes inside the plot, and (potentially) at the landscape scale (see Section Food Sovereignty and Transformative Agroecology Elements). This is a major element that has increased the resilience of local households to severe water stress during seasons also characterized by high food insecurity (Bacon et al., 2021), which compromised local food sovereignty. According to the surveyed households some specific outcomes of this agroecological diversification are the increase of food security, diet diversity, and environmental benefits. This may be reflected on the fact that, overall, the respondents in the Nicaraguan site reported on average 1.6 lean months per year, which is lower than what has been reported in previous studies in the Mesoamerican region, including PRODECOOP (Caswell et al., 2012; Bacon et al., 2017). On the other hand, 2017 was considered a "good year" in terms of rainfall and harvests. Furthermore many of the households that were in the initial population identified for sampling have engaged in diversification activities, while their average total farm area is also slightly larger than those included in similar samples (Bacon et al., 2021). Additional potential explanations for the differences

[8]CESMACH's position within a global value chain makes it possible for farmers to contact international organizations that usually promote diversification activities.

seen here, include the longer term engagement of PRODECOOP with diversification efforts, when compared to the relatively recent efforts within CESMACH.

The food sovereignty achievements of PRODECOOP members reported in this work have been the outcome of a historical process that we can start to describe in 2009, with the beginning of the current PAR process, and in collaboration with key stakeholders such as the Asociación de Desarrollo Social de Nicaragua (ASDENIC) and the *Campesino-a-Campesino* program (Holt-Giménez, 2002). In terms of transformative agroecology, this process and collaboration have contributed to the political dimension, bringing awareness of structural and historical context, specifically documenting challenges and capacities in the cooperative (and its farmers), as well as collective decision making. Related to the environmental and productive dimensions, the process and collaborations yielded specific outcomes, such as seed banks and farmer experimentation approaches. Finally, regarding the food sovereignty dimension, PRODECOOP's strategy also included capacity-building and empowerment of women and youth, as well as the integration of investments into both larger regional cooperative-led grain (corn and bean) storage and re-distribution centers with connections to local centers.

There are complementarities and dynamic tensions in efforts to use PAR and agroecology to support on-farm diversification and advance a transformative agroecology that moves toward food sovereignty. This is especially the case with PRODECOOP, which is essentially a multi-service cooperative union that receives its primary revenue and global recognition through the production and export of Fairtrade coffee. PRODECOOP has not only helped affiliated farmers to produce and sell more coffee but also leveraged millions of US dollars in training and direct investment for diversification, promotion of gender equity, and more. In some cases, this work was also informed by PAR processes, which sought to advance diversification to improve farmer food sovereignty, but there are also dynamic tensions. For example, coffee funds pay cooperative staff salaries, maintain the functioning of the business, and provide access to credit. This could reduce the cooperative's interest to invest significant funds away from coffee.

As common elements for food sovereignty, previous research that focused on measuring food sovereignty in different geographical contexts and scales (Binimelis et al., 2014; Jones et al., 2015; Ruiz-Almeida and Rivera-Ferre, 2019; Hernández et al., 2020), agrees that indicators must be context-dependent and multidimensional. In this sense, our work, as developed through our PAR process, coincides with other food sovereignty assessments in terms of the general dimensions (e.g., traditional knowledge, local production and consumption, degree of famer autonomy *vs.* dependence), as well as specific indicators (e.g., food access, seed sovereignty, and the diversity and use of crops grown on the farms).

Land access is a key factor in attaining food sovereignty (La Vía Campesina, 1996; Sauer, 2020). In that regard, and as an outcome of historical processes in both countries, farmers at both sites own relatively large parcels of land (on average 8.7 ha and 5.7 ha per family in Mexico and Nicaragua, respectively) compared with other coffee areas in Mesoamerica. For instance, in the Los Altos region of Chiapas, Mexico the reported total amount of land per family was 1.0–3.2 ha (Pérez Pérez and Villafuerte Solís, 2019), while in western El Salvador it was between 0.7 and 3.7 ha per family (Méndez et al., 2010a). Thus, in terms of access to land, we consider that CESMACH and PRODECOOP member families have considerable potential to achieve food sovereignty.

Another common element is the potential to achieve seed sovereignty. In CESMACH, according to our observations, seed care has been carried through informal and small-scale processes, something that is reflected by several varieties at this site. Seed conservation seems to be pursued mainly by the elderly, while the youth are linked with the simplification of milpa systems and increased dependency on purchased food. In PRODECOOP, *in situ* seed conservation can support the achievement of seed sovereignty through training in seed conservation, PAR, and other techniques, as well as some validation of the technology for participatory breeding (Bacon, 2015). All these efforts have been made in collaboration with CAN.

The similarity among the smallholder families that experienced at least one lean month in both location (See **Table 2**), suggest that future work could prioritize the design of integrative food security and sovereignty strategies with those households reporting >3 lean months per year. In contrast, corn harvest implies a local and important food resource for those families that grow it. We also observed that beekeeping has the potential to become an important income source for some households, which may help alleviate seasonal food insecurity. However, the number of coffee smallholders that engage in beekeeping activities is relatively small (**Table 2**), while both the honey harvest and price vary from year to year (see also Anderzén et al., 2020).

Diversification activities in both study sites were mostly self-initiated (87% in Mexico and 72% in Nicaragua). Those activities imply the permanence of traditional activities, such as milpa, poultry, and fruit trees, three of the most relevant food production strategies. In terms of innovative activities at both sites, we found that beekeeping has the highest potential to strengthen food sovereignty. In Mexico, our findings suggest that families carrying out beekeeping and milpa, in addition to coffee, can generate higher income and experience fewer lean months. In Nicaragua, beekeeping was linked to a high dietary diversity score. This provides further evidence of the positive contributions of beekeeping to food security and rural livelihoods in the global south (Potts et al., 2016; Kassa Degu and Regasa Megerssa, 2020).

Contribution of Diversification to Transformative Agroecology and Food Sovereignty

The most important contribution of diversification to transformative agroecology is that it goes beyond the number of productive activities, and rather represents a broader strategy that incorporates and harmonizes ecological conditions, local/fair markets, and reproductive labor to achieve gender

equity and local governance (La Vía Campesina, 2015; Anderson et al., 2019; FAO, 2019; Gliessman, 2019; HLPE, 2019).

Evidence suggests that the combined effect of experiences, research, and dialogue has influenced many cooperatives and smallholder organizations in Mesoamerica to recognize the limits of depending on a single crop, which has in turn influenced them to diversify (Toledo, 1993; Bacon et al., 2005; OSALA (Observatorio de Soberanía Alimentaria y Agroecología), 2011). The processes of CESMACH and PRODECOOP outlined in Section Results represent examples of how the inclusion of diversification strategies has promoted transformative agroecology at the cooperative level. These organizations have chosen to invigorate and promote food sovereignty among its members, in part by having aligned political and social relations among its associates. In addition, the study cooperatives have strengthened their organizations by prioritizing the wellbeing of their members and investing in securing healthy and culturally appropriate food for members' households. Other cooperatives in the region have also used diversification as an approach toward achieving food sovereignty and transformative agroecology. For instance, the Mexican Cooperatives Union Tosepan[9] is currently working toward achieving food and cultural sovereignty, based on diversification activities that include coffee, pepper, and honey, within landscapes that contain more than 200 useful species (Toledo, 2005).

The multiple on-farm activities observed among the member smallholders were found to depart, to some degree, from practices maintained over generations. This suggests transformative and multidimensional potential of these strategies by directly supporting food sovereignty. Such examples include covering basic needs (e.g., overcoming months of food insecurity), building seed sovereignty, questioning the control and governance of the global coffee value chain (or specific dependencies), and caring for local identities. Seen this way, diversification practices can represent a concrete expression of a transformative agroecology, driven mainly by the people themselves, but also facilitated to further its potential by the cooperatives, and supported by the PAR process and associated allies. This has been documented in other similar processes (see Mier y Terán Giménez Cacho et al., 2018; Hernández et al., 2020).

PAR Contributions to Diversification as Part of Transformative Agroecology

Drawing on the strong organizational structure of the study cooperatives, the use of agroecology and PAR helped to involve the cooperative leadership and youth on work related to learning activities, diversification practices, and in some cases, food sovereignty. These concepts also resonated with smallholder households as expressed in workshops and interviews. It is worth noting that the cooperatives we collaborated with during this 4-year project are in different moments in their journey of achieving food sovereignty and engaging in PAR processes. On the one hand, CESMACH is in an early-stage of this journey and our research showed how, as part of the PAR process, investing in facilitators' capacity-building and farmer pedagogies (e.g., popular education tools, facilitator-led focus groups) was the best way to scale transformative agroecology practices and awareness. On the other hand, PRODECOOP, was at an advanced stage of this journey with more than a decade-long engagement. Our research showed in this case how PAR and capacity building following farmer pedagogies, can generate tangible outcomes with direct positive impacts on food sovereignty (e.g., seed banks, reduction of lean months experienced).

Overall, we see the value of PAR in the transformative agroecology process mainly in two aspects. First, it generates inputs and evidence for the collective acknowledgment of vulnerabilities (e.g., lean months, high consumption of industrial food) and leverage points (e.g., traditional knowledge, edible wild food) to move toward food sovereignty. Second, the established collaborations can act to catalyze other important processes (e.g., capacity building, *campesino-a-campesino* networks), as well as to amplify farmer voices (Bacon, 2010).

A pervasive challenge for PAR and agroecology is how to maintain such processes in the long-term, including how (and in what role) do the external actors stay involved (Méndez et al., 2017). This is a key question that the research teams examine as they continues working with the cooperatives beyond the project reported in this paper. From a research perspective, the critiques of PAR point to it as being expensive, taking too much time, and not yielding sufficient academic outcomes (e.g., peer-reviewed publications). Our experience informs us otherwise, suggesting that more effort needs to be invested to attain a more intentional and detailed documentation of finances and outcomes in these long-term processes. Keeping track of ecological and social processes requires time, and we are working on incorporating the use of agroecological principles in forthcoming work exploring the possibility of better integrating them into PAR processes (Caswell et al., 2021), with the objective of generating both scholarly and practical outcomes.

Obstacles and Opportunities of Diversification as Part of Food Sovereignty Efforts

The realities faced by smallholders are deeply complex and dynamic, and the path toward food sovereignty is highly site-specific. This makes it hard to identify obstacles or opportunities that are universally applicable across smallholder contexts. Moreover, historically, farming communities have shown their potential of turning obstacles into opportunities in diverse ways. However, the bigger challenge for food sovereignty, in the context of smallholder coffee cooperatives, is linked to the high profitability of coffee, as most households prioritize coffee production over other agricultural activities (Vera et al., 2021). This specialization toward coffee production implies the diversion of land, labor, and time to generate coffee income. This creates some tensions with the archetypical tendency of smallholders toward self-provisioning (van der Ploeg, 2010), which aligns with food sovereignty. The high rates of purchased

[9]This group was constituted by Nahua and Totonaca Indigenous populations in 1977, has been supported by a group of scholars, and later received help from governmental and non-governmental organizations (Toledo, 2005; Tosepan, 2017).

food among surveyed households showed a dependency on external food suppliers, as a result of reducing the volume of self-produced food.

In addition, some particular aspects of smallholder coffee production, such as the high reliance on family labor and its gender dynamics, are some of the biggest challenges facing diversification in an agroecological transformative context (Machín Sosa et al., 2010; Jaffee, 2014; Bezner Kerr et al., 2019; Anderzén et al., 2020). However, we were not able to address these key issues with the necessary depth and complexity in this study, and this would thus require further attention in future studies.

In contrast, for these households, the biggest opportunity to reach food sovereignty is through the considerable size and quality of their available land. Such resources are "*the main defining elements of the peasant and include water, animals, and timber, among other resources heritable to the next generation*" (van der Ploeg, 2010: 3). Another important component of food sovereignty is the fact that the current diversification activities within "diversified farms" (i.e., traditional and culturally-relevant activities) and diversification (as novel activities) provide an opportunity to incorporate and mix new knowledge and skills with traditional ones. This is a key characteristic of transformative agroecology (Anderson et al., 2019). Farmers have maintained diversified production in both the Mexico and Nicaragua sites for generations, and the expansion of coffee production has been important in the emergence of agroecological diversification processes (Perfecto and Vandermeer, 2015). This accumulated local and indigenous knowledge is one of the reasons why most diversification initiatives arise from within the cooperatives, rather than from other development projects.

Another opportunity for achieving food sovereignty is the local attachment to traditional diets. This dietary preference contributes in multiple ways toward diversification that protects agrobiodiversity and native seeds, agroecological practices, and landscapes (Brush and Perales, 2007; Tamburini et al., 2020). Finally, and probably the most important opportunity to advance food sovereignty is leveraging the social fabric of both cooperatives. The development and joint implementation of collective strategies has been broadly recognized as a requirement for alternative and transformative projects (Mier y Terán Giménez Cacho et al., 2018; Anderson et al., 2019). In this sense the collective strategies coordinated under the two study coffee cooperatives have facilitated access to capacity-building, local empowerment (particularly for youth and women), and long-term alliances.

CONCLUSIONS

In this study, we viewed diversification practices in a transformative agroecology framework that focused on increasing its impact on food sovereignty. Along these lines, maintaining and increasing agrobiodiversity is an important diversification strategy, and a key component of achieving food sovereignty at the household level. This is linked to the high ecological complexity found in coffee plots, milpa plots, home gardens, and the broader landscape.

We observe that both study cooperatives in Mexico and Nicaragua are on a transformative agroecology pathway by using diversification to achieve food sovereignty. However, this represents a long-term process that requires constant adaptation. In our experience, a key element for the development of this process is smallholders' knowledge and learning exchanges between households and cooperatives. Through the 4-year project summarized in this paper we have witnessed various experiences that confirm other findings in the literature, including the relevance of food and seed banks, and the importance of ecological complexity and productivity of other crops within coffee plots. However, in accordance with the idea that there are no universally-applied recipes in agroecology, but rather there are guiding agroecological and PAR principles, our most important lesson for the cooperatives is to invest in the knowledge and capacity-building of their members These are, in a way, seeds within the organizations that support their internal potential to find their own ways toward transformative agroecology. Finally, scholars that embrace a PAR approach, as we do, can contribute as allies toward the generation of relevant knowledge that is useful to support the collective decisions of smallholders.

DATA AVAILABILITY STATEMENT

All relevant data is contained within the article. The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Boards at University of Vermont and Santa Clara University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

AG and CB: conceptualization, methodology, investigation, validation, formal analysis, writing—original draft, and writing—review and editing. VM: conceptualization, methodology, investigation, formal analysis, and writing—review and editing. MF: methodology, investigation, validation, formal analysis, and writing—original draft. JA: methodology, investigation, validation, formal analysis, writing—original draft, review. MM: formal analysis, writing—original draft, and review. RH, MR, HD, and ÁB: methodology, investigation, and validation and writing—review. All authors contributed to the article and approved the submitted version.

FUNDING

The project Assessment of Diversification Strategies in Smallholder Coffee Systems (No AF 1507-086: No FDNC Engt 00063479) was supported under the Thought for Food Initiative of the Agropolis Foundation (through the Investissements d'avenir programme with reference number

ANR10-LABX-0001-01), Fondazione Cariplo and Daniel and Nina Carasso Foundation. AG was supported by the Gund Institute for Environment, at The University of Vermont. CB received additional support from Santa Clara University Office of the Provost, Dean of Arts and Sciences, Center for Arts and Humanities, and the Environmental Justice and Common Good Initiative.

ACKNOWLEDGMENTS

We want to express our deepest gratitude to the CESMACH and PRODECOOP staff and families, the facilitators and promotors of each cooperative, and the members of our project team -Bruce Ferguson, Rémy Vandame, Luis Mondragón, and Omar Argüello Nájera from ECOSUR, Rose Cohen, Linda Lönnqvist, and Carmen Cortez from CAN, and Josué Daniel Rocha Espinoza from UNA. Additional support from Raul Diaz, Rosario Herrera, and the team at ASDENIC in Nicaragua as well as Universidad Nacional Agraria (UNA). AG also wants to express her deep gratitude to the Journal of Peasants Studies Writeshop, 2021, particularly the Rosa team, for the rich feedback given to a draft of this manuscript. Finally, we would like to thank our funders for making this work possible.

REFERENCES

Adger, W. N., Barnett, J., Brown, K., Marshall, N., and O'Brien, K. (2013). Cultural dimensions of climate change impacts and adaptation. *Nat. Clim. Change* 3, 112–117. doi: 10.1038/nclimate1666

Altieri, M. A., and Nicholls, C. I. (2020). Agroecology: challenges and opportunities for farming in the Anthropocene. *Int. J. Agric. Nat. Resour.* 47, 204–215. doi: 10.7764/ijanr.v47i3.2281

Altieri, M. A., Nicholls, C. I., Henao, A., and Lana, M. A. (2015). Agroecology and the design of climate change-resilient farming systems. *Agron. Sustain. Develop,* 35, 869–890. doi: 10.1007/s13593-015-0285-2

Anderson, C., and McLachlan, S. M. (2015). Transformative research as knowledge mobilization: transmedia, brides, and layers. *Action Res.* 14, 295–317. doi: 10.1177/1476750315616684

Anderson, C. R., Bruil, J., Chappell, M. J., Kiss, C., and Pimbert, M. P. (2019). From transition to domains of transformation: getting to sustainable and just food systems through agroecology. *Sustainability* 11, 5272. doi: 10.3390/su11195272

Anderzén, J., Guzmán Luna, A., Luna-González, D. V., Merrill, S. C., Caswell, M., Méndez, V. E., et al. (2020). Effects of on-farm diversification strategies on smallholder coffee farmer food security and income sufficiency in Chiapas, Mexico. *J. Rural Stud.* 77, 33–46. doi: 10.1016/j.jrurstud.2020.04.001

Bacon, C., Mendez, E., and Brown, M. (2005). *Participatory Action Research and Support for Community Development and Conservation: Examples from Shade Coffee Landscapes in Nicaragua and El Salvador*. ASFS Research Brief 6. Santa Cruz, CA.: Center for *Agroecol. Sustain. Food Syst.* (CASFS), University of California.

Bacon, C., Sundstom, W., Stewart, I., and Beezer, D. (2017). Vulnerability to Cumulative Hazard: Coping with the Coffee Leaf Rust Outbreak, Drought, and Food Insecurity in Nicaragua. *Word Develop.* 93, 136–152. doi: 10.1016/j.worlddev.2016.12.025

Bacon, C. M. (2010). A spot of coffee in crisis: Nicaraguan smallholder cooperatives, fair trade networks, and gendered empowerment. *Latin Am. Perspect.* 37, 50–71. doi: 10.1177/0094582X09356958

Bacon, C. M. (2015). Food sovereignty, food security and fair trade: the case of an influential Nicaraguan smallholder cooperative. *Third World Quart.* 36, 469–488. doi: 10.1080/01436597.2015.1002991

Bacon, C. M., Méndez, V. E., Flores Gómez, M. E., Stuart, D., and Díaz Flores, S. R. (2008). Are sustainable coffee certifications enough to secure farmer livelihoods? The millenium development goals and nicaragua's fair trade cooperatives. *Globalizations* 5, 259–274. doi: 10.1080/14747730802057688

Bacon, C. M., Sundstrom, W. A., Stewart, I. T., Maurer, E., and Kelley, L. C. (2021). Towards smallholder food and water security: Climate variability in the context of multiple livelihood hazards in Nicaragua. *World Develop.* 143, 105468. doi: 10.1016/j.worlddev.2021.105468

Bacon, C. M., Sundstrom, W. M., Flores Gómez, M. A., Méndez, V. E., Santos, R., Goldoftas, B., et al. (2014). Explaining the 'hungry farmer paradox': Smallholders and fair-trade cooperatives navigate seasonality and change in Nicaragua's corn and coffee markets. *Global Environ. Change* 25, 133–149 doi: 10.1016/j.gloenvcha.2014.02.005

Bezner Kerr, R., Hickey, C., Lupafya, E., and Dakishoni, L. (2019). Repairing rifts or reproducing inequalities? Agroecology, food sovereignty, and gender justice in Malawi. *J. Peasant Stud.* 46, 1499–1518. doi: 10.1080/03066150.2018.1547897

Bezner Kerr, R., Madsen, S., Stüber, M., Liebert, J., Enloe, S., Borghino, N., et al. (2021). Can agroecology improve food security and nutrition? A review. *Global Food Secur.* 29, 100540. doi: 10.1016/j.gfs.2021.100540

Binimelis, R., Rivera-Ferre, M. G., Tendero, G., Badal, M., Heras, M., Gamboa, G., et al. (2014). Adapting established instruments to build useful food sovereignty indicators. *Develop. Stud. Res.* 1, 324–339. doi: 10.1080/21665095.2014.973527

Biovision. (2019). Agroecology Info pool – agroecology criteria tool (ACT). Available online at: https://www.agroecology-pool.org/methodology/ (accessed October 28, 2021).

Brush, S. B., and Perales, H. R. (2007). A maize landscape: Ethnicity and agro-biodiversity in Chiapas Mexico. *Agric. Ecosyst. Environ.* 121, 211–221. doi: 10.1016/j.agee.2006.12.018

Caswell, M., Maden, R., McCune, N., Mendez, V. E., Bucini, G., Anderzen, J., et al. (2021). "Amplifying agroecology in vermont: principles and processes to foster food systems sustainability," in *USDA Agricultural Research Service (ARS) Center*. p. 4.

Caswell, M., Méndez, E., and Bacon, C. (2012). *Food Security and Smallholder Coffee Production: Current Issues and Future Directions.* ARLG Policy Brief #1 Burlington, VT: University of Vermont.

Chappell, M. J., Wittman, H., Bacon, C. M., Ferguson, B. G., García Barrios, L., García Barrios, R., et al. (2013). Food sovereignty: an alternative paradigm for poverty reduction and biodiversity conservation in Latin America. *F1000Research*. 2, 235. doi: 10.12688/f1000research.2-235.v1

De Schutter, O. (2011). "Agroecology and the right to food," in *Report presented at the 16th Session of the United Nations Human Rights Council [A/HRC/16/49]*. United Nations Special Rapporteur on the Right to Food.

Ellis, F. (2000). *Rural Livelihoods and Diversity in Developing Countries*. Oxford: Oxford University Press.

European Coordination Vía Campesina. (2018). *¡Soberanía Alimentaria Ya!* Una guía por la Soberanía Alimentaria.

FAO (2019). Food and Agriculture Organization of the United Nations. *TAPE Tool for Agroecology Performance Evaluation 2019 - Process of development and guidelines for application.* Available online at: *www.fao.org/contact-us/licence-request*.

Fernandez, M., and Méndez, V. E. (2018). Subsistence under the canopy: agrobiodiversity's contributions to food and nutrition security amongst coffee communities in Chiapas, Mexico. *Agroecol. Sustain. Food Syst.* 43, 579–601. doi: 10.1080/21683565.2018.1530326

Galab, S., Prudhvikar, P., Sree, R. D., Raju, R., Ravi, C., and Rajani, A. (2019). "Impact Assessment of Zero Budget Natural Farming in Andhra Pradesh - Kharif 2018-19. A comprehensive Approach using Crop Cutting Experiments," in *Center for Economic and Social Studies*. p. 45.

García López, V., Giraldo, O. F., Morales,. H., Rosset, P. M., and Duarte, J. M. (2019). Seed sovereignty and agroecological scaling: Two cases of seed recovery, conservation, and defense in Colombia. *Agroecol. Sustain. Food Syst.* 43, 827–847. doi: 10.1080/21683565.2019.1578720

Giraldo, O. F., and Rosset, P. M. (2017). Agroecology as a territory in dispute: between institutionality and social movements. *J. Peasant Stud.* 45, 1–20. doi: 10.1080/03066150.2017.1353496

Gliessman, S. (2015). *Agroecology: the Ecology of Sustainable Food Systems*. 3rd Edition. Boca Raton, Florida: CRC Press/Taylor and Francis. p. 406. doi: 10.1201/b17881

Gliessman, S. (2016). Transforming food systems with agroecology. *Agroecol. Sustain. Food Syst.* 40, 187–189. doi: 10.1080/21683565.2015.1130765

Gliessman, S. (2019). Editorial: Community-based participatory action research with Agroecology. *J. Sustain. Agric.* 33, 799–800. doi: 10.1080/10440040903303363

Gliessman, S. (2020). Confronting Covid-19 with agroecology. *Agroecol. Sustain. Food Syst.* 44, 1115–1117. doi: 10.1080/21683565.2020.1791489

Grey, S., and Patel, R. (2015). Food sovereignty as decolonization: some contributions from Indigenous movements to food system and development politics. *Agric. Human Values* 32, 431–444. doi: 10.1007/s10460-014-9548-9

Hernández, C., Perales, H., and Jaffee, D. (2020). Without Food there is No Resistance: The impact of the Zapatista conflict on agrobiodiversity and seed sovereignty in Chiapas, Mexico. *Geoforum.* 128, 236–250. doi: 10.1016/j.geoforum.2020.08.016

HLPE (2019). High Level Panel of Experts on Food Security. Agroecological and other innovative approaches for sustainable agriculture and food systems that enhance food security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome. Available online at: https://www.fao.org/fileadmin/user_upload/hlpe/hlpe_documents/HLPE_Reports/HLPE-Report-14_EN.pdf (accessed July 9, 2022).

Holt-Giménez, E. (2002). Measuring farmers' agroecological resistance after Hurricane Mitch in Nicaragua: a case study in participatory, sustainable land management impact monitoring. *Agric. Ecosyst. Environ.* 93, 87–105. doi: 10.1016/S0167-8809(02)00006-3

IPES Food (2016). "*From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems*," in International Panel of Experts on Sustainable Food Systems (IPES).

Isbell, F., Adler, P. R., Eisenhauer, N., Fornara, D., Kimmel, K., Kremen, C., et al. (2017). Benefits of increasing plant diversity in sustainable agroecosystems. *J. Ecol.* 105, 871–879. doi: 10.1111/1365-2745.12789

Jaffee, D. (2014). *Brewing Justice: Fair Trade Coffee, Sustainability, and Survival.* Updated edition. Berkeley, CA: University of California Press. p. 432. doi: 10.1525/9780520957886

Jansen, K. (2015). The debate on food sovereignty theory: agrarian capitalism, dispossession and agroecology. *J. Peasant Stud.* 42, 213–232. doi: 10.1080/03066150.2014.945166

Jenatton, M., and Morales, H. (2020). Civilized cola and peasant pozol: young people's social representations of a traditional maize beverage and soft drinks within food systems of Chiapas, Mexico. *Agroecol. Sustain. Food Syst.* 44, 1052–1088. doi: 10.1080/21683565.2019.1631935

Jha, S., Bacon, C. M., Philpott, S. M., Rice, R. A., Méndez, V. E., and Läderach, P. (2011). "A review of ecosystem services, farmer livelihoods, and value chains in shade coffee agroecosystems," in Campbell, W. B. and López Ortíz, S., Editors, 2011. *Integrating Agriculture, Conservation and Ecoturism: Examples from the Field.* Sacramento, CA: Springer. p. 141–208. doi: 10.1007/978-94-007-1309-3_4

Johansson, E. L., Fader, M., Seaquist, J. W., and Nicholas, K. A. (2016). Green and blue water demand from large-scale land acquisitions in Africa. *Proc. Nat. Acad. Sci.* 113, 11471–11476. doi: 10.1073/pnas.1524741113

Jones, A. D., Fink Shapiro, L., and Wilson, M. L. (2015). Assessing the potential and limitations of leveraging food sovereignty to improve human health. *Front. Public Health* 3, 263. doi: 10.3389/fpubh.2015.00263

Kassa Degu, T., and Regasa Megerssa, G. (2020). Role of Beekeeping in the Community Forest Conservation: Evidence from Ethiopia. *Bee World.* 97, 98–104. doi: 10.1080/0005772X.2020.1825308

Kelley, L. C., Pitcher, L., and Bacon, C. (2018). Using google earth engine to map complex shade-grown coffee landscapes in northern Nicaragua. *Remote Sens.* 10, 952. doi: 10.3390/rs10060952

Kloppenburg, J. (2014). Re-purposing the master's tools: the open-source seed initiative and the struggle for seed sovereignty. *J. Pleasant Stud.* 41, 1225–1246. doi: 10.1080/03066150.2013.875897

La Vía Campesina. (1996). The right to produce and access to land. Availale online at: http://safsc.org.za/wp-content/uploads/2015/09/1996-Declaration-of-Food-Sovereignty.pdf (accessed January 20, 2021).

La Vía Campesina. (2015). *Nyéléni 2015—Declaration of the International Forum for Agroecology*. Nyéléni—forum for food sovereignty.

Levidow, L., Pimbert, M., and Vanloqueren, G. (2014). Agroecological research: conforming—or transforming the dominant agro-food regime? *Agroecol. Sustain. Food Syst.* 38, 1127–1155. doi: 10.1080/21683565.2014.951459

López García, D., Cuéllar-Padilla, M., de Azevedo Olival, A., Laranjeira, N. P., Méndez, V. E., Peredo y Parada, S., et al. (2021). Building agroecology with people. Challenges of participatory methods to deepen on the agroecological transition in different contexts. J. Rural Stud. 83, 257–267. doi: 10.1016/j.jrurstud.2021.02.003

Machín Sosa, B., Roque Jaime, A. M., Ávila Lozano, D. R., and Rosset, P. M. (2010). *Revolución Agroecológica: El Movimiento de Campesino a Campesino de la ANAP En Cuba.* La Habana: ANAP y La Vía Campesina.

Martínez Torres, M. E., and Rosset, P. M. (2017). *Diálogo de saberes: La construcción colectiva de la soberanía alimentaria y la agroecología en La Vía Campesina*. in: Soberanía Alimentaria: un diálogo crítico. p. 147–162.

McCook, S. (2017). "Environmental History of Coffee in Latin America," in *Oxford Research Encyclopedia of Latin American History*. Oxford: Oxford University Press. doi: 10.1093/acrefore/9780199366439.013.440

Méndez, V. E., Bacon, C., Morris, K., and Shattuck, A. (2010a). Agrobiodiversity and smallholder livelihoods: a review and synthesis of ten years of research in central America. *Professional Geograph.* 62, 357–376. doi: 10.1080/00330124.2010.483638

Méndez, V. E., Bacon, C. M., and Cohen, R. (2013). Agroecology as a transdisciplinary, participatory, and action oriented approach. *Agroecol. Sustain. Food Syst.* 37, 3–18. doi: 10.1080/10440046.2012.736926

Méndez, V. E., Bacon, C. M., Olson, M., Petchers, S., Herrador, D., Carranza, C., et al. (2010b). Effects of fair trade and organic certifications on small-scale coffee farmer households in Central America and Mexico. *Renew. Agric. Food Syst.* 25, 236–251. doi: 10.1017/S1742170510000268

Méndez, V. E., Caswell, M., Gliessman, S., and Cohen R. (2017). Integrating agroecology and participatory action research (par): lesson from central America. *Sustainability* 9, 1–19. doi: 10.3390/su9050705

Mier y Terán Giménez Cacho, M., Felipe Giraldo, O., Aldasoro, M.iriam, Morales, H., Ferguson, B. G., Rosset, P., Khadse, A., et al. (2018). Bringing agroecology to scale: Key drivers and emblematic cases. *Agroecol. Sustain. Food Syst.* 42, 637–665. doi: 10.1080/21683565.2018.1443313

Morett-Sánchez, C. J., and Cosío-Ruiz, C. (2017). Panorama de los ejidos y comunidades agrarias en México. *Agríc. Sociedad y Desarrollo* 14, 125–152. doi: 10.22231/asyd.v14i1.526

Nicholls, C. I., and Altieri, M. A. (2018). Pathways for the amplification of agroecology. *Agroecol. Sustain. Food Syst.* 42, 1170–1193. doi: 10.1080/21683565.2018.1499578

OSALA (Observatorio de Soberanía Alimentaria y Agroecología). (2011). *Sociedad Cooperativa Agropecuaria Regional Tosepan Titataniske (Unidos Venceremos).*

Patel, R. (2009). What does food sovereignty look like? *J. Peasant Stud.* 36, 663–706. doi: 10.1080/03066150903143079

Pérez Pérez, E. F., and Villafuerte Solís, D. (2019). *Dilema de los campesinos frente a los imperativos del mercado neoliberal en Los Altos de Chiapas, México*. Estudios Rurales: Publicación del Centro de Estudios de la Argentina Rural.

Perfecto, I., and Vandermeer, J. (2015). *Coffee Agroecology: A New Approach to Understanding Agricultural Biodiversity, Ecosystem Services and Sustainable Development.* Abingdon, UK: Routledge. p. 352. doi: 10.4324/9780203526712

Ponisio, L. C., M'gonigle, L. K., Mace, K. C., Palomino, J., Valpine, P., de, and Kremen, C. (2015). Diversification practices reduce organic to conventional yield gap. *Proc. R. Soc. B: Biol. Sci.* 282, 20141396. doi: 10.1098/rspb.2014.1396

Potts, S. G., Imperatriz-Fonseca, V., Ngo, H. T., Aizen, M. A., Biesmeijer, J. C., Breeze, T. D., et al. (2016). Safeguarding pollinators and their values to human well-being. *Nature* 540, 220–229. doi: 10.1038/nature20588

PRODECOOP (2020). Institutional Website. Available online at: http://www.prodecoop.com/ (Accessed July 15, 2020). Also see Available online at: https://equalexchange.coop/our-partners/farmer-partners/prodecoop

Rosset, P. M., Barbosa, L. P., Val, V., and McCune, N. (2020). Pensamiento Latinoamericano Agroecológico: the emergence of a critical Latin

American agroecology? *Agroecol. Sustain. Food Syst.* 45, 42–64, doi: 10.1080/21683565.2020.1789908

Ruiz-Almeida, A., and Rivera-Ferre, M. G. (2019). Internationally-based indicators to measure Agri-food systems sustainability using food sovereignty as a conceptual framework. *Food Secur.* 11, 1321–1337. doi: 10.1007/s12571-019-00964-5

Sauer, S. (2020). Covid-19, right-wing populism and agrarian struggles in Brazil: Interview with João Pedro Stédile, national leader of the MST–Brazil. *J. Peasant Stud.* 47, 927–43. doi: 10.1080/03066150.2020.1782892

Schiavoni, C. (2009). The global struggle for food sovereignty: from Nyéléni to New York. *J. Peasant Stud.* 36, 682–689.

Sevilla Guzmán, E. (2017). Sobre as perspectivas teórico-metodológicas da Agroecologia. *Redes - Santa Cruz do Sul: Universidade de Santa Cruz do Sul* 22, 13–30. doi: 10.17058/redes.v22i2.9341

Soto-Pinto, L., Perfecto, I., Castillo-Hernandez, J., and Caballero-Nieto, J. (2000). Shade effect on coffee production at the northern Tzeltal zone of the state of Chiapas, Mexico. *Agric. Ecosyst. Environ.* 80, 61–69. doi: 10.1016/S0167-8809(00)00134-1

Tamburini, G., Bommarco, R., Cherico Wanger, T., Kremen, C., van der Heijden, M. G. A., Liebman, M., et al. (2020). Agricultural diversification promotes multiple ecosystem services without compromising yield. *Sci. Adv.* 6, eaba1715. doi: 10.1126/sciadv.aba1715

Toledo, V. M. (1993). *Ecología y autosuficiencia alimentaria.: hacia una opción basada en la diversidad biológica, ecológica y cultural de México*. México: Siglo XXl. p. 118.

Toledo, V. M. (2005). *Potencial económico de la flora útil de los cafetales de la Sierra Norte de* Puebla.

Toledo, V. M., and Barrera-Bassols, N. (2020). La milpa y la memoria Biocultural de Mesoamérica. In A conservação das sementes crioulas: uma visão interdisciplinar da agrobiodiversidade. p. 63–81. Available online at: https://www.researchgate.net/publication/341565901 (accessed July 9, 2022).

Tosepan. (2017). *Antecedentes Históricos De La Organización*. Available online at: https://www.tosepan.com/antecedentes-historicos-de-la-organizacion/ (accessed January 15, 2022).

Tucker, C. M. (2011). *Coffee Culture: Local Experiences, Global Connections*. Abingdon, UK: Routledge. p. 160.

van der Ploeg, J. D. (2010). The peasantries of the twenty-first century: the commoditisation debate revisited. *J. Peasant Studies* 37, 1–30. doi: 10.1080/03066150903498721

Vera, T. S., Rosset, P. M., Moreno, A. S., Méndez, V. E., and Ferguson, B. G. (2021). La milpa: sistema de resiliencia campesina. Estudio de dos organizaciones campesinas en Chiapas. *Región y Sociedad*. 33, e1432. doi: 10.22198/rys2021/33/1432

Conflict of Interest: MF is employed by Community Agroecology Network, RH is employed by Campesinos Ecológicos de la Sierra Madre de Chiapas (CESMACH), MR is employed by Promotora de Desarrollo Cooperativo de Las Segovias (PRODECOOP).

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.