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Climate Resilience Actions and Coffee Households' Food (in)security in Western Honduras

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von
Fernando Rodríguez Camayo

aus
Cali, Colombia

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Referent: Prof. Dr. Christian Borgemeister
Korreferent: Prof. Dr. Julián Ramírez-Villegas

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ABSTRACT

In Central America, particularly in Honduras, coffee production is vital to rural economies. However, extreme weather events such as droughts negatively impact coffee and food production, affecting food security of rural communities. In western Honduras populations suffer from food insecurity and malnutrition, with droughts worsening these conditions. Projections suggest that climate change could reduce the area suitable for coffee production in Central America by more than 50% by 2050. Over the past decade, in Honduras and Guatemala farmers and the coffee industry such as traders, coffee roasters and certification schemes have promoted agricultural practices such as shade trees and improved soil management for better water retention under the approach Climate-Smart Agriculture (CSA) practices. Evidence suggests that CSA has substantial potential to enhance resilience, particularly in terms of food security, productivity, and climate adaptation. However, limited evidence exists regarding whether and how CSA adoption in coffee systems improve food security.

This research examines climate resilience and food security among coffee households in the western part of Honduras, a region where the coffee industry is invested on coffee adaptation strategies.

The main objective is to identify how stakeholders in the coffee value chain understand, address and can improve farmers' resilience to food insecurity under extreme events.

A mixed-methods approach was employed, integrating quantitative and qualitative research methods. Data were collected from a survey of 348 coffee farmers in western Honduras, accompanied by focus group discussions with technicians and farmers, and key stakeholder interviews with coffee sector representatives from US and Europe, certifiers, and experts as well as the local food system actors. Additionally, a systematic literature review was conducted to identify agricultural practices and adaptation options that enhance the resilience of coffee systems to climate variability while improving food security, particularly in Latin America and the Caribbean (LAC).

The main findings reveal that coffee remains the primary source of income for many coffee households, making them vulnerable to fluctuations in coffee prices and food insecurity in the study area. Traders, roasters, households, and some certification scheme representatives often lack a clear understanding of what food insecurity entails. While certification schemes and industry initiatives promote sustainable practices, they often fail to adequately address food security challenges in western Honduras. Climate adaptation strategies in the coffee sector throughout Latin America, including multipurpose agriculture practices, agroecology practices, and regenerative agriculture practices, offer promising solutions for improving both coffee production resilience and household food security.

Local food production plays a critical role in enhancing food security, particularly during crises when external supply food chains may be disrupted. Strengthening connections between local production (including on-farm climate adaptation practices) and local markets is crucial to ensure continuous food availability. This integrated approach not only mitigates the impacts of climate shocks on coffee systems but also fosters resilience within coffee communities.

Without targeted efforts, food insecurity will remain a persistent challenge in coffee-producing regions, undermining the long-term resilience of both coffee systems and farming communities, while also threatening the sustainability of the coffee industry.

KLIMAANPASSUNGSMAßNAHMEN UND ERNÄHRUNGSSICHERHEIT (BZW. -UNSICHERHEIT) VON KAFFEEANBAUENDEN HAUSHALTEN IM WESTLICHEN HONDURAS

Kurzfassung

In Zentralamerika, insbesondere in Honduras, spielt die Kaffeeproduktion eine zentrale Rolle für die ländlichen Volkswirtschaften. Extreme Wetterereignisse wie Dürren beeinträchtigen jedoch die Kaffee- und Nahrungsmittelproduktion und gefährden die Ernährungssicherheit ländlicher Gemeinschaften. Im westlichen Honduras leiden die Menschen unter Ernährungsunsicherheit und Mangelernährung, wobei Dürren diese Bedingungen weiter verschärfen. Prognosen zufolge könnte der Klimawandel die für den Kaffeeanbau geeignete Fläche in Zentralamerika bis 2050 um mehr als 50 % reduzieren.

In den letzten zehn Jahren haben Bauern und die Kaffeeindustrie in Honduras und Guatemala – darunter Händler, Kaffeeröster und Zertifizierungsprogramme – landwirtschaftliche Praktiken wie Schattenbäume und verbessertes Bodenmanagement zur Erhöhung der Wasserhaltekapazität im Rahmen des Ansatzes der Klimaintelligenten Landwirtschaft (Climate-Smart Agriculture, CSA) gefördert. Evidenzen weisen darauf hin, dass CSA ein erhebliches Potenzial zur Stärkung der Resilienz bietet, insbesondere in Bezug auf Ernährungssicherheit, Produktivität und Klimaanpassung. Allerdings gibt es bislang nur begrenzte Belege dafür, ob und wie die Einführung von CSA in Kaffeesystem die Ernährungssicherheit verbessert.

Diese Forschung untersucht die Klimaanpassungsfähigkeit und Ernährungssicherheit von Kaffeeanbauenden Haushalten im westlichen Honduras, einer Region, in der die Kaffeeindustrie in Anpassungsstrategien investiert hat.

Das Hauptziel besteht darin, herauszufinden, wie die Akteure der Kaffeewertschöpfungskette die Resilienz der Bauern gegenüber Ernährungsunsicherheit unter extremen klimatischen Bedingungen verstehen, angehen und verbessern können.

Ein Mixed-Methods-Ansatz wurde angewendet, bei dem quantitative und qualitative Forschungsmethoden kombiniert wurden. Die Datenerhebung erfolgte durch eine Befragung von 348 Kaffeebauern im westlichen Honduras, Fokusgruppendiskussionen mit Agrarberater und Bauern sowie Interviews mit relevanten Akteuren des Kaffeesektors aus den USA und Europa, Zertifizierungsstellen, Experten und lokalen Akteuren des Ernährungssystems. Zusätzlich wurde eine systematische Literaturrecherche durchgeführt, um landwirtschaftliche Praktiken und Anpassungsoptionen zu identifizieren, die die Resilienz von Kaffeesystemen gegenüber Klimavariabilität verbessern und gleichzeitig die Ernährungssicherheit stärken, insbesondere in Lateinamerika und der Karibik (LAC).

Die Hauptergebnisse zeigen, dass Kaffee die primäre Einkommensquelle für viele Kaffeebauern bleiben wird, wodurch diese gegenüber Preisschwankungen und Ernährungsunsicherheit im Untersuchungsgebiet besonders anfällig sind. Händler, Röster, Haushalte und einige Vertreter von Zertifizierungssystemen haben oft kein klares Verständnis davon, was Ernährungssicherheit bedeutet. Zwar fördern Zertifizierungssysteme und Brancheninitiativen nachhaltige Praktiken, jedoch wird das Thema Ernährungssicherheit im westlichen Honduras oft unzureichend berücksichtigt. Klimaanpassungsstrategien im Kaffeesektor in ganz Lateinamerika, einschließlich multifunktionaler landwirtschaftlicher Praktiken, agrarökologischer Ansätze und regenerativer Landwirtschaft, bieten vielversprechende Lösungen zur Verbesserung sowohl der Produktionsresilienz als auch der Ernährungssicherheit von Haushalten.

Die lokale Nahrungsmittelproduktion spielt eine entscheidende Rolle bei der Gewährleistung der Ernährungssicherheit, insbesondere während Krisen, in denen externe Lieferketten unterbrochen sein können. Die Stärkung der Verbindungen zwischen lokaler Produktion (einschließlich klimagerechter landwirtschaftlicher Praktiken vor Ort) und lokalen Märkten ist entscheidend, um eine kontinuierliche Verfügbarkeit von Nahrungsmitteln sicherzustellen. Dieser integrative Ansatz mildert nicht nur die Auswirkungen von Klimaschocks auf Kaffeesysteme ab, sondern fördert auch die Resilienz innerhalb der Kaffeeanbaugemeinschaften.

Ohne gezielte Maßnahmen wird Ernährungsunsicherheit eine anhaltende Herausforderung in Kaffeeanbaugebieten bleiben, die langfristige Widerstandsfähigkeit sowohl der Kaffeesysteme als auch der landwirtschaftlichen Gemeinschaften untergraben und die Nachhaltigkeit der Kaffeeindustrie bedrohen.

DEDICATION

Quiero aprovechar este espacio para agradecer a mis tutores, Tina Beuchelt y Mark Lundy, así como a mis profesores, Christian Borgemeister y Julián Ramírez. También extiendo mi gratitud a colegas y amigos, quienes creyeron en mí y estuvieron apoyándome durante este proceso de aprendizaje.

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Agradezco igualmente a la Universidad de Bonn, en particular al Centro de Investigación para el Desarrollo (ZEF), a la Alianza Bioversity Internatiotal y el CIAT, en especial a los programas de Entorno Alimentario y Comportamiento del Consumidor, y de Acción Climática.

Finalmente, y no por ello menos importante, mi profundo agradecimiento a todas las personas que me apoyaron y guiaron en la fase de campo. Gracias por compartir su conocimiento y experiencia, y por hacer posible esta investigación.

Por las comunidades y personas que apoyaron o fueron parte de esta investigación, están dedicados mis esfuerzos, y espero seguir contribuyendo con mi trabajo al bienestar de las personas que más lo necesiten.

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LIST OF ACRONYMS AND ABBREVIATIONS

4C	The Common Code for the Coffee Community
ABC	Alliance Biodiversity and CIAT
BANASUPRO	Suplidora Nacional de Productos Básicos - Honduras
CA	Centro America – International Road
CENICAFE	Centro de Investigaciones del Café - Colombia
CGIAR	Consultative Group on International Agricultural Research
CIAT	Centro Internacional de Agricultura Tropical – International Center for Tropical Agriculture
CFS	Level Plane of Experts on Food Security and Nutrition of the Committee on World Food Security
CSA	Climate-Smart Agriculture
FAO	Food and Agriculture Organization of the United Nations
FEWSNET	Famine Early Warning Systems Network
FIES	Food Insecurity Experience Scale
FNC	Federación Nacional de Cafeteros de Colombia
FT	Fair Trade
GBM	Gradient Boosting Model
GHG	Greenhouse Gas
HDDS	Household Dietary Diversity Score
HH	Households
IHCAFE	Instituto Hondureño de Café
INE	Instituto Nacional de Estadística
IHMA	Instituto Hondureño de Mercado Agrícola
IRT	Item Response Theory
LAC	Latin American and the Caribbean
MAHFP	Months of Adequate Household Food Provisioning
MLR	Multiple Linear Regression
PPI	The Poverty Probability Index
RA	Rain Forest Alliance
UN	United Nations
WHO	World Health Organization
ZEF	Center for Development Research

1. INTRODUCTION OF THE THESIS

1.1. Background of information

Coffee supports the livelihoods of approximately 25 million people in tropical regions, including vulnerable rural families (Baca et al., 2014; Bacon, 2005; Morel et al., 2019). Despite coffee being one of the most traded commodity worldwide, 80% of the coffee farmers live with on less than USD 1.25 per day (FAO, 2015). In Central America, particularly in Honduras, coffee production is vital to rural economies. However, extreme weather events such as tropical storms, hurricanes, and irregular rainfall patterns negatively impact food production affecting staple crops like beans, maize and vegetables. These climate disruptions also reduce coffee income, exacerbating food insecurity in the region (Harvey et al., 2018). Studies indicate that interannual climate variations have led to reduction of up to 30% in coffee productivity and incomes (Morel et al., 2019).

Honduras, particularly its southern and western regions, suffer from food insecurity and malnutrition, with droughts worsening these conditions. Projections suggest that climate change could reduce the area suitable for coffee production in Central America by more than 50% by 2050, unless effective adaptation and mitigation strategies are implemented to address rising temperatures and water stress (Imbach et al., 2017; Ovalle-Rivera, et al., 2015a). Without these adaptation strategies, poverty and food insecurity may escalate further throughout the region.

Smallholder farmers in Central America often lack the capacity to adapt to climate-related stressors, making them highly vulnerable (Bouroncle et al., 2017; Hannah et al., 2013). In Honduras and Guatemala, 56% of farmers experience recurrent food insecurity, and 36% suffer episodic food insecurity due to extreme climate events (Alpízar et al., 2020). Furthermore, access to and quality of basic services, including extension, inputs and seed markets, water for irrigation, and health care, are well below global standards across rural areas in Central America (Bouroncle et al., 2019; Palma et al., 2020; Ward et al., 2017). Beyond climate events, non-climate stressors such as fluctuating market prices, lockdowns by pandemics or violence and political instability further compound farmers' vulnerability.

1.2. Problem statement

For decades, coffee farmers in Central America, particularly in Nicaragua and the South of Mexico, have been implementing agroecological practices interconnecting coffee production and food availability (Caswell et al., 2014; Fernandez & Méndez, 2019; Putnam, Cohen, & Jaffe, 2016). The promotion of an agroecological approach enhances the resilience of local food systems linking food production and consumers in rural communities (Gliessman, 2016; Gliessman, Friedmann, & Howard, 2019)

Over the past decade, in Honduras and Guatemala farmers and the coffee industry, such as traders, coffee roasters and certification schemes, have promoted agricultural practices such as shade trees and improved soil management for better water retention (Pico-Mendoza et al., 2020; Koutouleas et al., 2022) under the approach Climate-Smart Agriculture (CSA) practices (Bunn et al., 2019; Djufry & Wulandari, 2021; Reay, 2019). CSA aims to achieve three objectives: (i) increasing food security and incomes, (ii) adapting to climate change, and (iii) reducing or removing greenhouse gas (GHG) emissions (FAO, 2021; Lipper et al., 2014). Evidence suggests that CSA has substantial potential to improve farmers' resilience especially at the interface of food security, productivity, and climate adaptation (e.g., Aggarwal et al., 2018; Prestele & Verburg, 2020; Sain et al., 2017).

However, despite its promise, the adoption of CSA remains limited among farmers in middle and low-income countries (Amadu, McNamara, & Miller, 2020; García de Jalón, Silvestri, & Barnes, 2017; McCarthy et al., 2011; Vernooy & Bouroncle, 2019).

This may be due to strong differences between farmers' priorities and CSA offered by supply services (Akhter Ali & Olaf Erenstein, 2017). Furthermore, CSA programs have primarily focused on enhancing crop productivity and the biophysical environment, often ignoring social values, adoption constraints, local context, and food security concerns (Groot et al., 2019; Khatri-chhetri, Aggarwal, Joshi, & Vyas, 2017; Long, Blok, & Poldner, 2016; Westermann, Thornton, & Förch, 2015).

Little evidence exists to date on whether and how CSA adoption improves food security of farmers' households, particularly in Central America, where knowledge gaps persist regarding suitable adaptation strategies for farmers' specific vulnerability conditions and food security (Donatti et al., 2019).

This study aims to bridge this knowledge gap by exploring suitable adaptation strategies tailored to the specific vulnerabilities of coffee farmers in western Honduras.

1.3. Scope of the thesis

This research examines climate resilience and food security among coffee households in the western part of Honduras, a region where the coffee industry is invested on coffee adaptation strategies. The study focuses on the stakeholders within the coffee value chain who collaborate with coffee farmers and their cooperatives to implement climate resilience practices. Three main dimensions are addressed to understand the current state of coffee households with this context.

(1) Coffee Households' Characteristics and Coping Mechanisms: This dimension explores demographic variables, poverty levels, and food insecurity status among smallholder coffee farmers. It also examines their coping mechanisms in response to these challenges in 2019.

(2) Local Food System Dynamics: This dimension investigates the structure and resilience of the local food system in coffee-growing communities, particularly in response to external shocks between 2019 and 2020.

(3) Stakeholder Perceptions and Actions: This dimension examines how key coffee value chain stakeholders, including cooperatives, traders, roasters, and certification organizations, address climate variation and food security.

This study does not evaluate the effectiveness of specific CSA practices adopted by coffee farmers, or the direct influence of certification schemes on household well-being. A mixed-methods approach was employed, integrating quantitative and qualitative research methods. Data were collected from a survey of 348 coffee farmers in western Honduras, accompanied by focus group discussions with technicians and farmers, and key stakeholder interviews with traders, coffee roasters, industry representatives from the US and Europe, certifiers, and experts. Additionally, a systematic literature review was conducted to identify agricultural practices that enhance coffee system resilience and food security in Latin America and the Caribbean (LAC).

1.4. Objectives

1.4.1. Main objective

To identify how stakeholders in the coffee value chain understand, address and can improve farmers’ resilience to food insecurity under extreme events in western Honduras.

1.4.2. Specific objectives

The specific objectives of this thesis were defined as follows and each objective correspond to separate chapter of the thesis:

- To understand the suitability of CSA practices promoted by the Honduran’ coffee sector in addressing the food security coffee households’ strategies under climate stress,
- To examine how coffee households respond under an extreme event and how their local food system changed,
- To identify climate resilience actions promoted by the coffee sector, including certification systems, traders, and coffee roasters, that could improve food security in coffee households.

1.5. Study area

Honduras has a population of nearly 10 million inhabitants, with 48% living below the national poverty line with less than USD 6.85 per person/day in 2019 and 14.6 % of the population suffering moderate to severe food insecurity (World Bank, 2020). The study focuses on western Honduras, specifically the departments of Ocotepeque, with a population of 175,001 inhabitants in 2023 (INE, 2023), and Copan with nearby municipalities such as Corquin, Pacayas, Las Capucas (Fig. 1). The study region has a wide range of elevations, stretching from 800 meters above sea level (m.a.s.l) to 2,400 m.a.s.l. The highlands in the region are part of the Guisayote Forest Reserve, which converges with farmers’ vegetable plots and coffee farms. The dry season is between December and February. Livelihoods in this region depend on the cultivation of beans, coffee, maize, vegetables, livestock, off-farm labor, and remittances (FEWSNET, 2014). The local economy is highly reliant on coffee, given the concentrated focus of critical services such as input provision, technical assistance, transportation, and banking specifically tailored to coffee cropping (CIAT, 2018). In the study I specifically targeted households engaged in coffee farming, recognizing coffee as the primary livelihood source within this regional context. Notably, the region is characterized by the presence of numerous coffee farms, organized into cooperatives. The central hub for commercial activities, including supermarkets, a diverse array of shops, and the sole public food market, is situated in San Marcos and Corquín. In contrast, villages generally feature smaller grocery stores, illustrating a nuanced economic landscape.

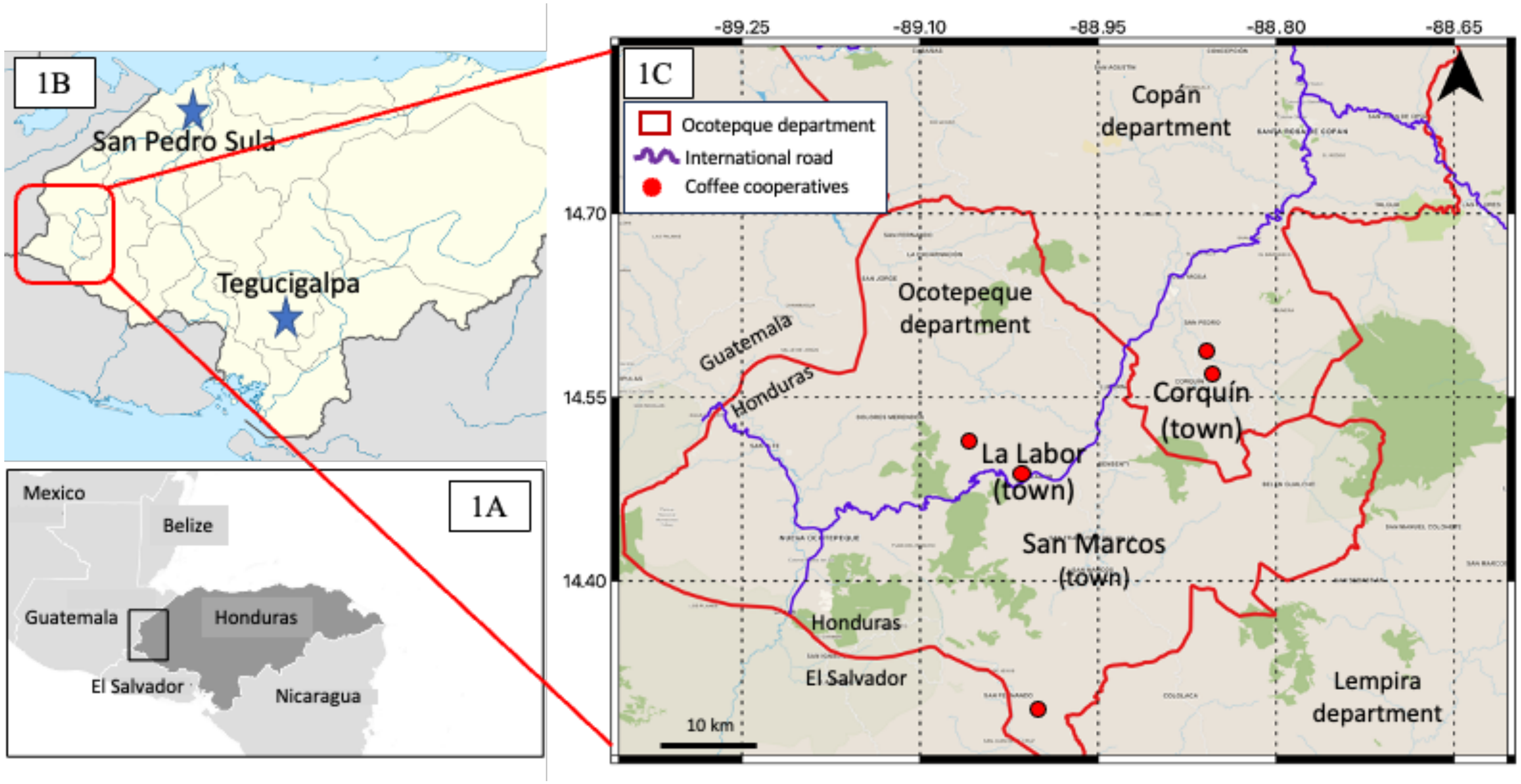

Figure 1.1. Study is in Honduras. 1 (A) Location of Honduras in Central America; the black square highlighting the western part of Honduras; (B) the red square represents the coffee cultivation in Ocotepeque department and in the south of Copán department, the blue stars represent principal cities of Honduras; (C) the area of study, with the red points representing the location of coffee cooperatives (three located Ocotepeque department and two located in the municipality of Corquín, department of Copán) and around them the coffee farming households.

2. UNDERSTANDING COFFEE FARMERS' POVERTY, FOOD INSECURITY AND ADAPTIVE RESPONSES TO CLIMATE STRESS. EVIDENCE FROM WESTERN HONDURAS

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Abstract

Central America faces significant vulnerability to climatic variations. In recent years, national and international organizations have promoted climate-smart agricultural (CSA) to help coffee farmers adapt to climate change. However, limited scientific evidence exists regarding the appropriateness of these strategies in mitigating vulnerability. This study aims to understand the suitability of CSA practices promoted by Honduras' coffee sector in addressing the needs and vulnerability of coffee-farming households. We integrated quantitative and qualitative methods, to understand how coffee farmers' poverty levels, and food insecurity status are associated with their dependence on coffee income, demographic characteristics, prevailing stressors, and the responses from farmers and value chain stakeholders. Multiple linear regression and machine learning techniques examine these relationships. Data from a survey of 348 coffee farmers in western Honduras, along with key stakeholder interviews and focus group discussions, inform our analyses. Results indicate that households' poverty levels and food insecurity are associated with being more dependent on income from the coffee production than from other income sources. Most CSA-related efforts focus on maintaining or enhancing the coffee production, such as introducing grasses or shrub trees, but do not explicit address food security concerns among smallholders. However, around 50% of the smallholders are food insecure. Coffee households report climate hazards, pests and diseases, and low coffee prices as key problems, which are associated with crop losses, income instability, and food insecurity. Our

[1] Rodriguez-Camayo, Fernando and Ramirez-Villegas, Julian and Borgemeister, Christian and Lundy, Mark and Giraldo, Norma and Beuchelt, Tina, Understanding Coffee Farmers' Poverty, Food Insecurity and Adaptive Responses to Climate Stress. Evidence from Western Honduras. Climate Risk Management, Volume 49, 2025. ISSN 2212-0963. Available at https://doi.org/10.1016/j.crm.2025.100735. or https://www.sciencedirect.com/science/article/pii/S221209632500049X

findings suggest that broadening the scope of coffee CSA practices to include food security and income stability could better support smallholder resilience.

2.1. Introduction

Coffee supports the livelihoods of about 25 million people in tropical regions, including vulnerable rural families (Baca et al., 2014; Bacon, 2005; Morel et al., 2019). Despite coffee being the most traded commodity in the world, 80% of the coffee farmers live with on less than USD 1.25 per day (FAO, 2015). In Central America, including Honduras, where coffee production is vital for rural economies, extreme weather events such as tropical storms, hurricanes, and irregular rains have had negative effects on production, income, and food security (Harvey et al., 2018). Morel et al. (2019) reported up to 30% reductions in coffee productivity and incomes from interannual climatic variations. Food insecurity and malnutrition, especially among the most vulnerable population, have worsened because of the droughts in the southern and western regions of Honduras. Climate change is projected to reduce the area suitable for coffee in Central America by more than 50% by 2050, unless adaptation and mitigation strategies are implemented to address rising temperatures and water stress (Imbach et al., 2017; Ovalle-Rivera, et al., 2015a). Without adaptation strategies, this reduction in suitable land could worsen food insecurity and poverty throughout the region.

Central American farmers often lack the capacity to adapt to climate-related stressors, rendering the region highly vulnerable (Bouroncle et al., 2017; Hannah et al., 2013). In Honduras and Guatemala, a recent study found that 56% of farmers faced recurrent food insecurity and 36% experienced episodic food insecurity due to extreme climate events (Alpízar et al., 2020). Furthermore, access to and quality of basic services, including extension, input and seed markets, water for irrigation, household use and health, are well below global standards across rural areas in Central America (Bouroncle et al., 2019; Palma et al., 2020; Ward et al., 2017).

Over the past decade, Honduras and Guatemala have promoted climate-resilient agricultural practices (Bunn et al., 2019; Djufry & Wulandari, 2021; Reay, 2019). Climate-smart agriculture (CSA) addresses three pillars: increasing food security and incomes, adapting to climate change, and reducing or removing greenhouse gas (GHG) emissions (FAO, 2021; Lipper et al., 2014). A growing body of evidence suggests that CSA has substantial potential to improve farmers resilience, especially at the interface of food security, productivity, and climate adaptation (e.g., Aggarwal et al., 2018; Prestele & Verburg, 2020; Sain et al., 2017). Yet, evidence shows so far limited adoption of CSA especially in smallholder contexts in middle- and low-income countries (Amadu, McNamara, & Miller, 2020; García de Jalón, Silvestri, & Barnes, 2017; McCarthy et al., 2011; Vernooy & Bouroncle, 2019). This may be due to strong differences between farmers' priorities and CSA offered by supply services. (Akhter Ali & Olaf Erenstein, 2017). Furthermore, CSA programs have primarily focused on enhancing crop productivity and the biophysical environment, often ignoring adoption constraints, local context, social values, or food insecurity (Groot et al., 2019; Khatri-chhetri et al., 2017; Long et al., 2016; Westermann et al., 2015). Little evidence exists to date on whether and how CSA adoption improves food security of farmers' households, particularly in Central America, where knowledge gaps persist regarding suitable adaptation strategies for farmers' specific vulnerability conditions and food security (Donatti et al., 2019).

This study aims to understand the suitability of CSA practices promoted by the Honduran' coffee sector in addressing the food security coffee households' strategies under climate stress, we aim to answer the following questions:

- How do coffee farmers' poverty and food security conditions vary with respect to demographic characteristics, climate and non-climate hazards and income dependency on coffee?
- What are farmers' strategies to reduce food insecurity under climate stress?
- What are coffee value chain actors' strategies to reduce farmers' food insecurity under climate stress?

To address these questions, we conducted a randomized household survey of 348 Honduran coffee farmers to analyze socioeconomic conditions, food insecurity, and poverty levels. In the survey, we also identified the main climate and non-climate stressors affecting coffee producers, and the producer responses to these stressors. We also conducted 55 semi-structured interviews with value chain stakeholders to better understand their responses to climate impacts at the farm level.

Finally, we discuss the results considering existing knowledge on climate adaptation and food security for coffee farmers in the region and elsewhere and draw recommendations for research and practice in climate adaptation for coffee cultivation.

2.2. Materials and methods

2.2.1. Conceptual Framework

The research framework focuses on coffee households and analyzes how different stakeholders—farmers, cooperatives, and buyers—address food insecurity under climate stress. Grounded in Scoones' (1998) sustainable livelihood framework, this study explores how coffee households utilize livelihood strategies and resources to confront food insecurity. It also examines how institutions and organizations influence these livelihoods to improve outcomes such as food security under both climate and non-climate hazards.

This study differs from Scoones' approach by treating the capability to react and implement adaptation and mitigation strategies not as an outcomes (Béné et al., 2016), but as integral components of livelihood strategies and resources. Instead, these actions and strategies are viewed as integral components of livelihood strategies and resources.

Livelihood strategies, such as agricultural intensification/extensification and diversification (e.g., coffee, other crops, animals, off-farm labor and remittances), are employed to mitigate food insecurity from external shocks.

These strategies are shaped by key following livelihood resources:

- Social (e.g., farmers associations,),
- Natural (e.g., elevation, food production, agricultural practices),
- Economic/financial (e.g., credit, savings, income),
- Human capital (e.g., education level, labor, know-how), and
- Physical (e.g., water supply, land, housing).

Institutions and organizations, such as national coffee institutions, buyers, and coffee industry representatives, play a critical role in shaping these livelihood outcomes. They influence livelihood strategies and resource allocation through various actions like climate adaptation practices aimed at addressing climate stress.

Conditions, context, and stressors refer to external factors such as non-climate events (e.g., low coffee prices, pest and diseases), and climate events (e.g., irregular rains, droughts). In combination with livelihood strategies, resources, and the influence of institutions and organizations, these factors have varying implications for livelihood outcomes.

Our definition of food security follows that of the FAO (2006): "*Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.*" We included the food insecurity experiences of coffee households to understand the dimension of food access.

The decision to exclude the dimensions of food use, availability, and stability from our research was due to two factors: the mobility restrictions during the COVID-19 lockdowns, which limited our ability to explore household meal preparation, and the challenges in fully investigating the local food system to assess food availability and stability.

2.2.2. Study area

This study focuses on coffee systems in western Honduras, covering farms located in the departments of Ocotepeque and Copan (Figure 2.1). The livelihoods of farmers in this region depend on the cultivation of coffee and staple crops like bean and maize. The region is an important coffee producer in Honduras, especially for specialty coffee and export to international markets. It has a wide range of elevations, spanning from 850 meters above sea level (m.a.s.l.) to 1,800 m.a.s.l. Coffee is grown across the entire elevational gradient. The coffee farmers' households are situated within the red square (Figure 2.1B). Most of the coffee exporters and the national coffee institutions are based in the main cities of Tegucigalpa and San Pedro Sula (marked with stars in Fig. 2.1B).

Figure 2.1. Study area in Honduras. (1a) Location of Honduras in Central America; The square in western Honduras encloses Copan and Ocotepeque states (1b). Surveyed coffee households are distributed within the red square, and red dots represent the farmers cooperatives close to the villages and local towns. Source: own elaboration based on the Atlas of Honduras (2022).

2.2.3. Coffee household and value chain stakeholder data

We used three methods to collect primary data on household characteristics and adaptation strategies at both farmer and value chain levels: (i) a structured household survey, and (ii) semi-structured qualitative stakeholder interviews and observations.

To select farmers and other stakeholders for data collection, we first identified relevant institutions working on CSA within the target region via a stakeholder mapping. Thereafter we performed a pre-screening process to assess their interest in participating in our research. The pre-screening consisted of an in-person meeting with representatives of each farmers' organization and emails and calls with exporters, national institutions, and non-governmental organizations (NGOs) where we explained the objectives of the research, the nature of the work (i.e., academic research), and the potential relevance of the results for their own purposes. The pre-screening meeting also included explanations about the ethical aspects of the research and addressed any concerns related to conflicts of interest.

The pre-screening resulted in 22 stakeholders interviewed, including representatives of cooperatives (n=5 interviews), coffee exporters (n=3), national institutions (e.g., Honduran Coffee Institute –IHCAFE, n=6), agronomists (n=5), and NGOs (n=3). Lastly, we conducted three focus group discussions: one with several agronomists (n=9) and two others with 12 coffee farmers each (n=24 total). It is noteworthy that the coffee exporters did not explicitly work with CSA due to their exclusive focus on the export process. However, they purchased large volumes of coffee and thus constituted an important player in the coffee value chain. The semi-structured interviews captured perceptions of food insecurity among the coffee farming households, resilience of farmers to climate change and the roles of national coffee sector actors (exporters, national institutions, research centers) to ensure coffee farming households' food security and resilience to climate variation.

The farmer sample for the household survey was drawn from the population of farmers associated with the said five coffee cooperatives. These coffee cooperatives are working on climate resilience strategies with support from national institutions (e.g. IHCAFE) and other members of the coffee sector such as coffee industry representatives and coffee research centers through a project focused on coffee and climate resilience in the region. To draw the sample, we prepared a first list of potential household respondents based on individual membership lists provided by each cooperative. This list was further revised with the support of cooperative leaders and technical assistants, to ensure that only active members of the cooperatives were surveyed. We applied a simple random sampling method with a 90% confidence level and a 5% precision level, stratified by elevation. The elevation strata used were as proposed by CIAT (2017) with two categories related to the impacts of climate change: "remain suitable" for households located between 1,200 and 1,800 m.a.s.l., and "substantial stress or worse" for households below 1,200 m.a.s.l. We surveyed 348 individuals from a total population of 716. We conducted the survey during September and October 2019 using software SurveyCTO®. Data cleaning was performed in STATA to identify duplicates and remove records with missing data or with clearly erroneous answers.

The household survey captured (a) the Poverty Probability Index® (PPI), which is a poverty measurement to characterize households' asset ownership through 10 questions and calculates the probability of living below the poverty line. After accomplishing the survey, the poverty of a coffee household can be calculated by summing the score of answers (from 0 to

100) and using the PPI Scorecard to look-up the poverty likelihood (%) corresponding to the PPI Score related to a poverty line for the country. The poverty probability of a household increases when its PPI score is low and vice versa. We further recorded (b) the Months of Adequate Household Food Provisioning (MAHFP) (Swindale & Bilinsky, 2010), a proxy to measure changes of household food access during a year; and (c) the Household Dietary Diversity Score (HDDS) (FAO, 2010; Swindale & Bilinsky, 2006), which assesses a household's economic access to food and which is calculated by adding up the number of food groups (0 - 12) eaten over the past 24 hours by all households members, where (1) cereals, (2) white tubers and roots, (3) vegetables, (4) fruits, (5) meat, (6) eggs, (7) fish and sea food, (8) legumes, nuts and seeds, (9) milk and dairy products, (10) oils and fats, (11) sweets, and (12) spices, condiments and beverages. The HDDS focuses on dietary diversity, but its scope is limited to only the last 24 hours. We also gathered and then incorporated data on (d) the Food Insecurity Experience Scale (FIES) (Ballard, et al., 2013) into our data collection methods to assess food insecurity levels among coffee households. FIES is based on the household's direct responses to questions about their experiences facing constrained access to food for the previous 12 months. FIES consist of eight questions that were integrated into the structured households survey, covering various aspects of food access such as concern about food security, changes in dietary diversity, to skipping meals or staying without eating for a whole day (Ballard, et at., 2013). These questions are designed to capture the severity of food insecurity experienced by households, with their responses reflecting the extent of their challenges. Therefore, the severity level of food insecurity is considered an unobservable trait, and the experiences reported by households' respondents are closely linked to the FIES question set. Compared to the MAHFP and HDDS, the FIES is a more comprehensive food insecurity indicator. The MAHFP and HDDS measures household food provisioning during the year, therefore measuring availability and access, but not severe levels of food insecurity. Consequently, the more severe a households' food insecurity, the greater the likelihood of reporting associated experiences. Finally, the survey also recorded (e) climate-smart practices applied by farmers; (f) farmers' strategies for food security; (g) extreme events, including climate hazards and non-climate hazards perceived during the last five years; and (h) households' responses to extreme climate events.

Lastly, we conducted three focus group discussions. The first one was with nine agronomists to understand the various climate adaptation practices promoted in the field by the technicians and by any project to which they had participated. The nine interviewed constituted all the agronomists working for the five cooperatives, as well as those that worked directly with NGOs. The other two focal groups were conducted with coffee farmers to understand whether and how climate-smart practices contributed to climate resilience, food security as well as the incentives for adoption of these practices. For the farmer focal group discussions, we drew two random samples of 12 farmers from the household survey sample.

2.2.4. Data analysis

We performed three types of analysis: (1) descriptive analysis of household socioeconomic characteristics, poverty, and food insecurity levels; (2) multiple linear regression for poverty and machine learning techniques for food insecurity, both to understand the relationships with demographic characteristics and stressors; and (3) qualitative analysis of food insecurity perceptions and stakeholder strategies for household food security and climate resilience. For (1) and (2) we used the household survey data, whereas for (3) we used the stakeholder interviews and focus group discussions.

The descriptive analysis described household demographic and socioeconomic characteristics for the entire farmer sample and three coffee income dependency groups. These coffee income dependency groups were determined based on the share of coffee income to total household income. A group termed "diversified" was defined as containing households with coffee incomes below 50% of total household income. A second group, termed "coffee specialized", contained households with coffee incomes between 50% and 75%. The third group, labelled "coffee dependent", was defined to contain households with coffee incomes above 75%. For the whole sample, and for each income group, we calculated the mean value of all relevant demographic and socioeconomic variables.

We analyzed food insecurity we used the data from the eight questions FIES applied: 1) Were you worried you would not have enough food to eat? 2) Were you unable to eat healthy and nutritious food? 3) Did you eat only a few kinds of foods? 4) Did you have to skip a meal? 5) Did you eat less than you thought you should? 6) Did your household run out of food? 7) Were you hungry but did not eat? 8) Did you go without eating for a whole day? The methodology used for analyzing FIES data employs Item Response Theory (IRT), which examines responses to survey or test questions. Specifically, the Rasch model, a component of IRT utilized in analyzing FIES data, aims to improve measurement accuracy and reliability by systematically evaluating response data. This model not only provides a theoretical framework but also includes a set of statistical tools that facilitate interpretation of the responses (Nord, 2014). We applied a probabilistic model, linking unobservable traits with respondents' experiences, following a procedure developed by the United Nations Food and Agriculture Organization (FAO) (Cafiero, Viviani, & Nord, 2018) to assess the prevalence of food insecurity within each households' coffee income dependency groups.

In the descriptive analysis, quantitative categorical types of data were analyzed using percentages, frequency distributions, and cross-tabulation, while quantitative continuous data were analyzed using means, and standard deviations. The Kruskal-Wallis and Fishers' Exact test were used to investigate potential differences in numeric and categorical variables, respectively, among households' coffee income dependency groups. For non-normally distributed variables, the Dunn Bonferroni test was used by pairwise comparison among households' coffee income dependency groups.

The analyses used the household survey data to explain the variability in poverty and food insecurity using climate and non-climate stressors, and household characteristics as explanatory variables. As we were interested in understanding what variables contributed to explaining the variability in poverty (measured by the PPI score) or food security (measured through the weights' percentages resulting from the reported food insecurity experience or not, derived from the FIES questions) across the sample of households, these two were used separately as response variables.

The PPI (continuous) and the FIES (ordinal) scores are variables of different nature; and this necessitated a different type of model. For PPI we therefore used multiple linear regression (MLR) with the following formula:

Equation 2.1 Poverty and its explanatory variables, demographic characteristics and stressors

2.1

$$\gamma(PPI) = \beta o + \beta 1(CCLASS) + \beta 2(FSIZE) + \beta 3(EDUC) + \beta 4(HHSIZE) + \beta 5(HHSEX) + \beta 6(PWATER) + \beta 7(ICLASS_{speci}) + \beta 8(ICLASS_{depen}) + \beta 9(DROU) + \beta 10(LPCOFFEE) + \beta 11(PDCOFFEE) + \beta 12(OHAZARD)$$

Where (Y) is the dependent variable (PPI-Poverty), (β_o) is the intercept, and (β_i) is a slope coefficient of the independent variables. The independent variables were CCLASS (climate impact class; remain suitable, substantial stress or worse), FSIZE (farm size), EDUC (education), HHSIZE (number of household members), HHSEX (sex of the household head), PWATER (availability of piped water in household; Yes/No), ICLASS (income class; diversified, specialized, dependent), DROU (experienced drought; Yes/No), LPCOFFEE (experienced low price shocks; Yes/No), PDCOFFEE (experienced pest and disease shocks; Yes/No), OHAZARD (experienced other hazards; Yes/No).

For food security, we structured the modeling process into a sequential framework, encompassing both the tuning and assessment of models built various classification algorithms. Initially, we transformed the raw score into a binary outcome: food secure, when the raw FIES score was equal to zero, and food insecure when the raw score was greater than zero. Next, we validated the distribution of the food security variable, observing no imbalance among classes. Subsequently, we scrutinized the correlation between dependent and independent variables, revealing an absence of correlation. For the independent categorical variables, we employed the One-Hot Encoding technique to convert them into binary variables suitable for automatic learning models. Furthermore, we partitioned the data, allocating 75% for training and 25% for testing purposes.

The evaluation phase involved four classification algorithms, namely, Logistic Regression, Gradient Boosting Model (GBM), Random Forest, and XGBoost. We fine-tuned and assessed each model using metrics such as Precision, Recall, F1-score, AUC-ROC, and accuracy. To optimize hyperparameters, we conducted a comprehensive search through GridSearchCV, exploring multiple hyperparameter combinations to identify optimal settings that maximized model performance based on the assessed metrics. Additionally, we implemented K-Fold cross-validation to ensure a robust estimation of model performance, mitigating the risk of bias in model evaluation. This strategy provides a thorough exploration of the model's generalizability, enhancing the reliability of our findings.

In these classification models, explanatory variables included all household characteristics collected in the survey, namely, the level of income dependency on coffee, farm size, education level of the household head, number of household members, sex of the household head, and whether the household had piped water. We did not include outmigration of household members because it is likely to be a result, rather than a driver of poverty. Farm size, educational level and household size were all considered as continuous variables, whereas PWATER (Yes/No) and ICLASS (diversified, coffee-specialized, dependent) were both categorical. We also included climate and non-climate hazards and long-term climate change impacts. For the hazards, we explicitly included the three most common ones as reported by the surveyed households, namely, drought (DROU; Yes/No), low coffee prices (LPCOFFEE; Yes/No), and coffee pests and diseases (PDCOFFEE; Yes/No). To account for the rest of the hazards we also included a variable on the occurrence of any other hazard (OHAZARD; Yes/No). For long-term climate change impacts, we used the climate change impact by elevation gradient proposed by CIAT (2018) as a categorical variable (CCLASS) with two classes, i.e., "remain suitable", and "substantial stress or worse". For food security, we also added the PPI score as an explanatory variable, under the rationale that food security is an outcome that arises in part from the household assets and poverty levels (Hyman et al., 2005; Pretty et al., 2003; Saravanakumar et al., 2020).

The metrics for each classification algorithm are summarized in table 2.1. The GBM demonstrated the best performance in precision and F1-score compared to other models. Therefore, GBM exhibits superior generalization capabilities, emphasizing its effectiveness in our modelling process.

Table 2.1 - Metrics assessed for each classification algorithm

Metric	Logistic Regression	Gradient Boosting Classifier	Random Forest Classifier	XGBoost Classifier
Accuracy	0.53	0.57	0.52	0.54
Precision	0.52	0.56	0.52	0.54
Recall	0.73	0.73	0.66	0.63
F1-Score	0.61	0.63	0.58	0.58
AUC-ROC	0.52	0.57	0.52	0.54

Consequently, for food security, we present and discuss results only for the GBM model (Freund & Schapire, 1997; Friedman, 2002). In gradient boosting, the final prediction is the sum of predictions from a series of simpler models (usually decision trees), each of which attempts to correct the errors of its predecessor. The general form of the gradient boosting model can be expressed in the equation 2.2 as:

$$\hat{y}_i = F_M(x_i) = F_0(x_i) + \sum_{m=1}^{M} \lambda \cdot h_m(x_i) \tag{2.2}$$

Where:

- $\hat{y}_i$ is the predicted value for the i-th observation (food insecurity).
- $F_M(x_i)$ is the final model after M iterations (i.e., the combined model after all boosting steps).
- $F_0(x_i)$ is the initial model or baseline prediction (this could be the mean of the target variable across all observations).
- λ is the learning rate, a parameter that controls the contribution of each new tree to the final model.
- $h_m(x_i)$ is the m-th weak learner (e.g., decision tree) that is fitted to the residual error of the previous model.

Each weak learner $h_m(x_i)$ is built to predict the residuals (errors) from the previous iteration:

$$r_i^{(m)} = y_i - F_{m-1}(x_i) \tag{2.3}$$

Where:

- $r_i^{(m)}$ is the residual for the i-th observation after the m-th iteration.
- y_i is the actual observed value of the target variable (food insecurity)
- $F_{m-1}(x_i)$ is the prediction from the model after $m - 1$ iterations.

At each iteration, a new tree is fitted to these residuals:

$$h_m(x_i) = Tree\ (r_i^{(m-1)}) \tag{2.4}$$

A then, the model is updated as:

$$F_M(x_i) = F_{m-1}(x_i) + \lambda \cdot h_m(x_i) \tag{2.5}$$

By summing up these weak learners, each of which refines the model's predictions, the GBM captures the complex, non-linear relationships between the independent variables (e.g., education level, household size, farm size, etc.) and the dependent variable (food insecurity).

For synthesizing perceptions and strategies, we transcribed and analyzed the interviews and focus group discussions using the Atlas.ti software. In Atlas.ti, once the transcription process was completed, we created codes for the various categories and concepts that were relevant to this work. These included concepts such as food insecurity, poverty, but also categories such as perceptions, impacts, and strategies. Once the codes were created, we then mapped segments of the transcribed data to the relevant codes. After this we synthesized the interviews and focus group discussion data into a synthesis narrative on (1) farmers' and other value chain stakeholders' perceptions of household food insecurity, and (2) the stakeholder strategies to address food insecurity and climate-related stress.

2.3. Results

2.3.1. Coffee households' livelihoods, poverty, and food insecurity according to climate and non-climate hazards and households' coffee income dependency groups.

2.3.1.1. Households' description

After data cleaning, 348 households were included in the final dataset. Predominantly, households were male-headed (86%), averaging 3.86 members, operating relatively small farms (3.06 ha on average) at a range of elevations (800–1,800 m.a.s.l.). The age of household heads ranged from 21 to 80 years (average 49 years). Education levels varied, with only 9% having no formal education, 26% attending high school or technical education, and 7% completing a university degree. However, 65% had attended at least secondary school (Table 2.2).

In terms of income sources, households relied on coffee (65%), off-farm labor (18%), external sources (7%), other crops (6%), and animals (4%). Off-farm labor included work at other farms, jobs in coffee cooperatives, and small businesses. External sources encompassed remittances, government cash transfers, or donations. Other crops included staples like beans and maize, while animals referred to cows, pigs, and poultry. Notably, income from forest-related activities was absent due to legal restrictions in Honduras.

Income distribution varied among households, with 37% classified as diversified, 33% specialized, and 29% coffee-dependent. The diversified group balanced incomes from coffee (39%), off-farm labor (34%), external sources (13%), other crops (6%), and animals (6%). The specialized group relied primarily on coffee (68%), followed by off-farm labor (13%), other crops (8%), external sources (6%), and animals (5%). Coffee-dependent households primarily relied on coffee (94%), with minimal contributions from other sources.

Poverty and food insecurity rates were high, with 31% of households living below the national poverty line (Table 2.2). Greater dependency on coffee correlated with a higher likelihood of poverty, with specialized and dependent households being 10% and 12% more likely to be below the poverty line, respectively (Table 2.2). There is a high prevalence of food insecurity, especially regarding quality and diversity of food consumption. The FIES data show only 49% of the surveyed households were food secure, while 51% of households had a level of food insecurity in the last 12 months (Table 2.2). The percentage of food secure households went down from 55% "diversified" to 47% "coffee-specialized" and 43% "coffee-dependent" as the dependency on coffee for income increased. The Rash model, used to analyze the FIES questions, revealed that among households, the prevalence of food insecurity (moderate and severe) was highest in the "coffee-dependent" group at 15%, following the "diversified" group at 5%, and the "coffee-specialized" group at 3%.

Consistent with the FIES results, the MAHFP data show that households in the study area have access to adequate food provisioning for the whole year (mean of 11.8 months), with no significant differences between the three coffee income distribution groups. In the HDDS, we found that the mean for the total sample was 9.33 on the scale from 0 to 12. We also found that the HDDS is lower when households depend more on coffee incomes. The "coffee-dependent" households have a score of 8.8, which means less access to diversified groups of food than the "coffee-specialized" (score of 9.4) and the "coffee-dependent" (score 9.7) ones (Table 2.2).

Table 2.2 Demographic variables of total households and coffee income distribution groups

		Coffee incomes distribution					
Variables	**Total (n=348)**	**Diversified (n=130)**		**Specialized (n=116)**		**Dependent (n=102)**	
			SD		**SD**		**SD**
PPI - Probability to be below of the national poverty line – (%)†	31%	25%*	10.9	34%*	10.9	36%*	12.8
Number of households members (Mean)†	3.9	3.8	1.7	4.1	1.4	3.8	1.2
Age of household head – (Mean)†	47	46*	13.7	50*	13.2	51	13.5
Size of farm (Ha) – (Mean)†	3.1	3.4	2.5	2.7	4.6	3.1	4.6
Household head male – (%)	86%	85%		86%		85%	
Access to clean water (public system)	97%	95%		99%		97%	
The education of the head of household – (%)							
No studies	9%	9%		9%		7%	
Elementary	65%	54%		66%		76%	
Middle	20%	26%		17%		14%	
Higher	7%	11%		7%		3%	
Income distribution – (%)							
HHs incomes with >75% of coffee	29%						
HHs incomes with <75%>50%	33%						
HHs incomes with <50%	37%						

Mean Access to Adequate Households Food Provisioning Months (MAHFP) – (Mean)†	11.8	11.8	0.9	11.7	0.6	11.8	0.9
Low (1–9 months) Moderate (10–11 months) High (12 months)	3% 7% 90%	3% 2% 95%		4% 8% 88%		2% 10% 88%	
Mean Households Dietary Diversity Score – HDDS – (Mean)†	9.3	9.7*	1.5	9.4	1.5	8.8*	1.6
Food access – FIES – (%)							
Food security	49%	55%		47%		43%	
Farm elevation (m.a.s.l.) – (Mean)	1271	1289	191.1	1245	181.6	1276	160.3
Elevation farm groups – (%)†							
Substantial stress (<1,200 m.a.s.l.) Remain suitable and suitable (>1,200 – 1,800 m.a.s.l.)	44% 56%	38% 62%		53% 47%		42% 58%	
Households with a family member migrated in the last five years – (%)	24%	17%		28%		27%	
Households with a family member is thinking of migrating – (%)	7%	9%		8%		9%	

Note: Symbol † indicates non-normally distributed variables. Kruskal-Wallis and Fishers' Exact tests were used to test for statistical differences, * indicate a significant difference between groups, followed by pairwise comparisons based on the Dunn-Bonferroni post hoc test was used for non-normally distributes variables. SD is the standard deviation.

2.3.1.2. Relationships between poverty and food security and climate and other hazards and households' demographic variables.

The MLR model explained 47% of the variance in the PPI score, with level of education and income dependency on coffee, farm size, number of members in the household, and farm elevation as the most important variables (Table 2.3).

Table 2.3 The multiple linear regression results for relation demographic variables, hazards, and poverty (y=PPI)

Variables	Acronym	Coefficients	Standard Error
	Intercept	0.6126	0.08125
HH with coffee incomes			
>50%<75%	ICLASS_Speci	0.0539***	0.02066
HH with coffee incomes >75%	ICLASS_Depen	0.0390**	0.02144
Farm size	FSIZE	-0.0058***	0.00210
The education of the head of HH	EDUC	-0.0250***	0.00663
Sex of the HH head	HHSEX	0.0308	0.02480
HH had piped water	PWATER	0.0004	0.04908
Drought as a hazard	DROU	0.0096	0.02060
Low coffee prices as a hazard	LPCOFFEE	-0.0262	0.02212
Pest and diseases as a hazard	PDCOFFEE	0.0268	0.02076
Number of HH members	HHSIZE	0.0199***	0.00587
Elevation gradient	CCLASS	-0.0002***	0.00004
Any other hazard	OHAZARD	-0.0266	0.02476

Note: *** p>0.01; **p<0.05; *p<0.1 indicates a significant difference

Model results show that education, farm elevation and farm size have a positive relationship with the PPI score; that is, the larger the farm, or the greater the education level or higher the elevation, the lower the probability to be below the national poverty line. The converse relationship is found for the number of household members, with poverty increasing (i.e., PPI score decreasing) with a greater number of households members. Importantly, consistent with the descriptive results shown in Table 2.2, the MLR model shows that poverty increases when the level of income dependency on coffee increases. Overall, therefore, the PPI model results suggest that households with many members, with small farms, limited education, and high dependency on coffee for incomes are more likely to be below the poverty line.

For the food security indicator, the GBM model shows the greatest contribution to explained variance came from the PPI score (Figure 2.2). According to the model, the variables with a high contribution to food security are the following: income dependency of coffee, size of farm, and education level of the household head. The hazards and long-term climate change impacts that the model found important are the low coffee prices, the pest and diseases and droughts (Figure 2.2). It is noteworthy, however, that although the coffee pests/diseases were herein categorized by non-climate events, the technicians and farmers focal groups associated this hazard with the coffee rust disease, caused by the fungus *Hemileia vastatrix*, whose occurrence is highly dependent on weather conditions such as high humidity and high temperatures.

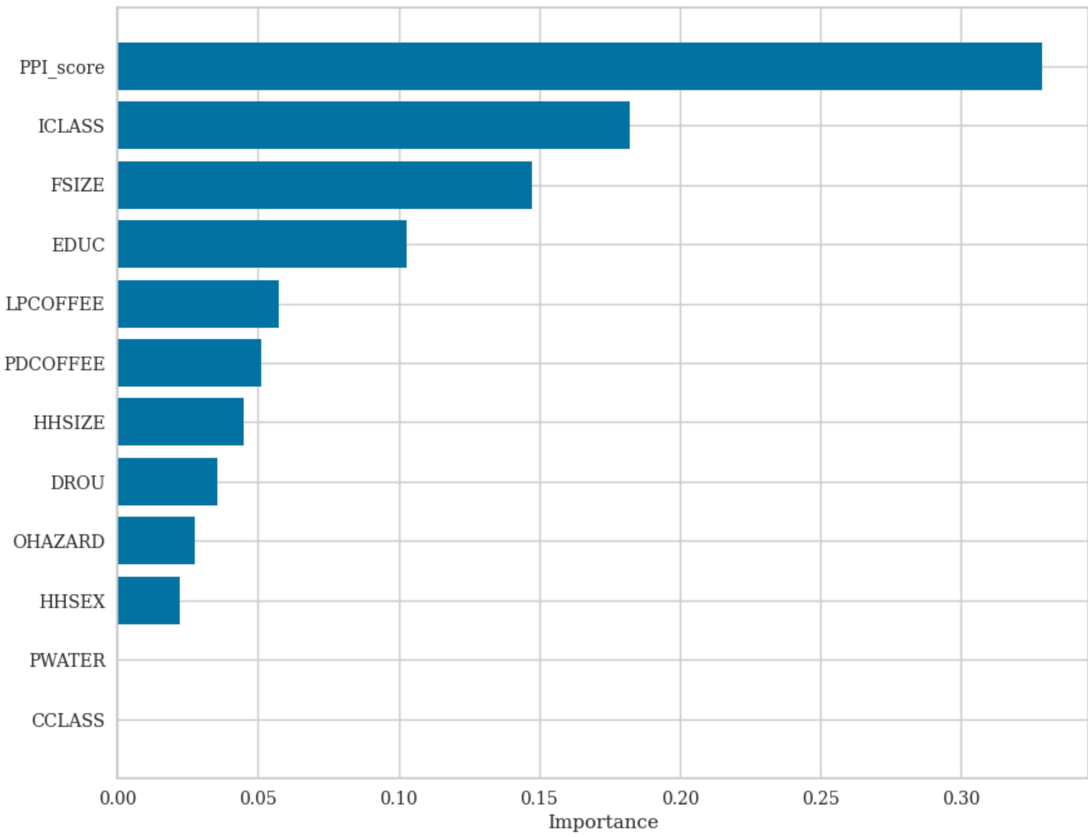

Figure 2.2 Variable importance plot for food security variable using the GBM

Note: The following acronyms stand for the explanatory variables: probability of households to be below of the national poverty line (PPI_score), the level of income dependency on coffee (ICLASS), farm size (FSIZE), education level of the household head (EDUC), number of household members (HHSIZE), sex of the household head (HHSEX), and whether the household had piped water (PWATER). Also, included the three most common ones, drought (DROU), low coffee prices (LPCOFFEE), and coffee pests and diseases (PDCOFFEE), any other hazard (OHAZARD) and elevation gradient (CCLASS).

The regression and classification analysis confirmed the descriptive results that the variability of both the PPI score and the food security indicator (transformed FIES_score) can be partly explained through the coffee income dependency. Other variables also contributed significantly to explaining the variability of the two dependent variables (Table 2.2).

2.3.1.3. Climate and non-climate hazards and their relationship with households

Recognizing the association between climate and non-climate hazards association with poverty and food insecurity, we analyzed the individual hazards by examining their reporting frequency, their relationship with farm- and household-level, and the corresponding household coping strategies.

A total of 233 out of the 348 households reported to have experienced non-climate hazards, from which 60 households reported at least two non-climate hazards, and 11 households reported three non-climate hazards during the last five years. A total of 152 households out of the 348 households reported experiencing climate hazards. From these 152 households, seven reported to have experienced two climate hazards, and one household reported three events over the last five years, for a total of 160 individual climate hazard events reported. The most frequently mentioned non-climate events were coffee pest and diseases (38%), and low coffee prices (23%), whereas the most frequent climate hazard for the households surveyed was drought, with 36% of the households perceiving it in the last five years.

A closer look at the intersection between the most reported climate and non-climate events, i.e., pests and diseases, low coffee prices and droughts, shows the complexity of the interplay between the various hazards to which farmers are exposed, with a considerable proportion having experienced two or more concurrently. Coffee farmers are challenged by drought and pests and diseases (Figure 2.3). The most reported hazards are coffee pest/diseases (38%), drought (36%) and low coffee incomes (23%). At least 32% of households reported two or more of these three events the last five years. A total 76 out of the 348 households (22%) perceived coffee pest/diseases and droughts, and 180 households (52%) perceived droughts or coffee pest/diseases (Figure 2.3). Note that a total of 211 households (60.6% of total) indicated that at least one of the three events affected them.

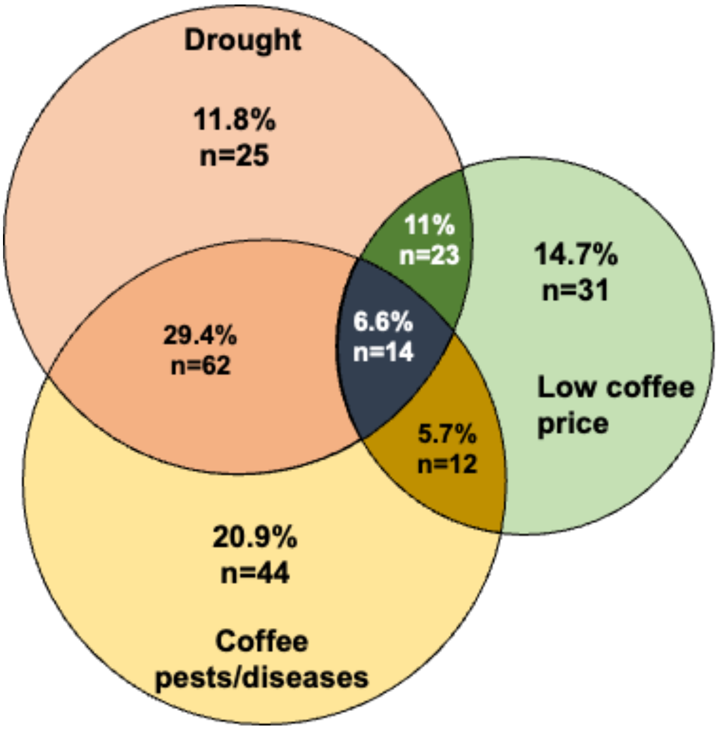

Figure 2.3 Relative distribution of the co-occurrence for the three most frequently reported climate (droughts) and non-climate events (coffee pest/diseases and low coffee prices) as reported by coffee households

The reported coffee households' experiences of the climate events show that these associated mainly coffee yields and food security (Table 2.4). Fifty-three percent (53%) of these households said they noted a reduced coffee yields due to an extreme event in the last five years. Technicians and coffee farmers in focus groups mentioned an extended dry period during the coffee flowering or beyond, reduces the nutrient uptake by coffee plants, causing flower abortion or wilting of coffee trees, resulting in partial or total loss of the next coffee harvest, especially for coffee-dependent households. At least 38% of households reported food insecurity as a main impact of climate events. The food security impacts "Household food reduction" due to climate hazards show a greater perception of such impacts for the coffee-specialized and coffee-dependent income groups (Table 2.4).

Table 2.4 The impact of climate and non-climate events and responses from coffee households

Impacts of climate events 152 households reporting 160 events	**Total (%)**	**Coffee income groups (%)** **Diversified**	 **Specialized**	 **Dependent**
		n=48	**n=64**	**n=40**
Reduction of yields	10	7	3	3
Partial loss of harvest	26	8	14	16
Total loss of harvest	26	8	21	7
Household food reduction	38	15	20	17
Lower incomes	0	-	-	-
Households' responses		**Diversified**	**Specialized**	**Dependent**
Sold assets	0	-	-	-
Accessed to loans or savings	26	1	2	5
Looked for another type of income	5	12	10	14
Somebody of the household migrated for looking a job	0	-	-	-
Adjust the household budget	1	-	-	-
Applied CSA-practices	7	2	3	4
Bought staple food (beans and maize)	1	-	1	1
Planting or renovation of the coffee plantation	8	2	1	7
Others (request support from relatives)	5	1	3	4
Without strategies	47	12	23	31

Impacts of non-climate events		

233 households reporting 300 events	Total (%)	Diversified	Specialized	Dependent
		n=86	n=77	n=70
Reduction of yields	18	7	3	8
Partial loss of harvest	16	6	7	3
Total loss of harvest	23	8	9	7
Destabilization of household income and food reduction	17	5	6	6
Lower incomes	48	19	14	14
Other	6	2	2	2
Households' responses		**Diversified**	**Specialized**	**Dependent**
Sold assets	4	2	1	1
Access to loans or saving	65	24	19	21
Somebody of the household migrated for looking a job	2	0	1	1
Others	1	0.4	0.4	0.4
Renovation coffee trees or pest/diseases management	32	15	9	9
Without strategies	24	7	10	7

The reported non-climate events primarily impact income, total loss of harvest and reduction of yields (Table 2.3). Sixty-five percent (65%) of the 233 households said that they experienced a reduction of incomes or redistribution of household spending (including a reduction of food consumed) due to a non-climate hazard in the last five years. Also, farmers and technicians in focal groups mentioned heavily reduced income from coffee when prices and/or the production dropped (due to pests/diseases). Moreover, farmers must continue to pay back the credits they took to invest in coffee, often carrying over these debts into the following coffee season.

2.3.2. Coffee households' response against the impacts of climate and non-climate events

Despite many households experiencing climate hazards (Table 2.4) nearly half (47%) of those surveyed reported having no response to the impacts of these extreme climate events. Most coffee households recognize the occurrence of a climate event when it hits them, but they lack mechanism to prepare for it.

While coffee households did not report storing of staple food (beans and maize) as a strategy to cope with climate events in the survey, farmers' focus groups indicated that this is a traditional household strategy used during periods of food shortage. The coffee farmers purchase and store staple food (beans and maize) at home according to their financial capacity. According to the interviewed households and the focus group discussions, this strategy is often hindered by low coffee prices, which prevent households from purchasing enough beans and maize to last for the next months.

Only seven percent of households reported implementing CSA practices, such as intercropping before the climate event occurred. According to interviews and focus group discussions, coffee farmers regularly practiced intercropping (planting beans and maize) as part of their livelihood strategies long before the concept of CSA was introduced.

Many farmers and local technicians agree that intercropping coffee with beans and maize is a crucial strategy for responding to climate impacts. However, they did not consider this to be a CSA practice. According to the survey, in response to income reductions due to non-climate hazards such as low coffee prices and pest and diseases, 151 households (50%) used their savings or accessed credits. This strategy helped them pay debts, cover health care cost, purchase food, or pay wages and inputs. Notably, using saving or accessing credit was also the primary strategy households used to cope with climate hazards. In both cases, coffee households used a financial strategy to cope with extreme hazards.

2.3.3. Strategies designed and applied by coffee stakeholders on coffee farms to address climate change.

The interviewed coffee stakeholders have been promoting CSA practices through projects and activities in the field, including coffee farms, experimental research stations, and experimental farms. These efforts are supported by capacity-building through workshops with farmers and local agronomists. These activities aim to enhance the climate resilience capacities of coffee farmers against climate conditions such as high temperatures, heat waves, and prolonged dry seasons (additional data can be found in Online-resource 4).

Farmers reported that the most applied practices include soil management (such as minimum or no tillage), the use of cover crops (avoiding bare soil fallows), the implementation of vegetative barriers with, (e.g., *Dracaena sansevieria*), shade management (e.g., *Cajanus cajan*), and soil cover (e.g., *Brachiaria ruziziensis* grass) between the rows of the coffee trees. Soil management interventions focused on improving water retention and reducing high soil temperatures, such as by using *Brachiaria ruziziensis*. Adoption of these practices is high (Online-resource 4). However, according to experts and local agronomists, note that many of these practices are tied to certification requirements. It remains unclear whether they address farmers' actual climate adaptation needs or whether they are motivated by avoiding price penalties due to not being certified.

During the focus groups farmers explained that some practices are not new to them. Practices such as vegetative barriers with *Yucca gigantea*, soil cover with lemongrass (*Cymbopogon* spp.), as well as intercropping with beans and maize, were already used before the initiation of recent climate projects. With the introduction of new coffee projects, farmers reported adopting additional practices tailored to their specific soil types and local weather conditions. As one farmer expressed,

"*We adopted the practices based on our soil type and local weather, so, the technician brings practices such zacate (grass), avocado tree, or sunflowers, and we chose the most suitable option*" (A coffee farmer, focus group interview, 2020).

Another farmer mentioned,

"*We all adopted these practices because failing to do so could so losing certification and, consequently, the price premium*" (A coffee farmer, focus group interview, 2020).

Some farmers observed that while crops like grasses, introduced through these practices, improve water retention and soil quality, they also required additional labor and competed with coffee plants for nutrients. Coffee farmers expect that these practices will eventually reduce production cost and increase coffee incomes. As one participant remarked, "*The grass retains water and enhances soil quality, but we need to mow it every 30 or 40 days to prevent competition with coffee trees for nutrients*".

Another coffee farmer stated,

"*As these practices are part of the certification, we are hopeful that the certification price premium will increase and we could access a better food*" (A coffee farmer, focus group interview, 2020).

A coffee exporter noted the pressure from the coffee sector on coffee farmers to adopt CSA practices,

"*Sometimes, the technical assistance from international agencies and coffee projects feels like a sales group, trying to convince coffee farmers to adopt practices, they don´t want to.*" (A national coffee exporter, personal interview, 2020).

These perspectives exemplify the coffee farmers' views on the climate resilience practices promoted by projects in the study region. However, these resilience practices are often implemented with a fixed set of technologies and options, without adequate co-design processes involving with the end users, e.g., the farming households. A representative of an NGO from the coffee industry describes the process of selecting CSA-practices in the field.

"We establish a baseline by identifying risks, such as high temperatures, and assessing climate impacts like water stress. With external advisors, we explore various mitigation options such as using grass or forage covers to reduce specific risks. We then conduct trials on farms to test these practices with farmers." (Representative of a coffee industry NGO, personal interview, 2020)

Ultimately, this leads to a top-down technology adoption process that fails to consider of farmers' climate and socioeconomic vulnerability, as well as the adaptation pathways more suitable for them.

Finally, the national institutions, led by the Ministry of Agriculture and Livestock (SAG) provide climate-information services to support agronomic decisions, such as planting times for annual crops and fertilizer management. While the national coffee sector also shares these information services with farmers to guide fertilization timing, it remains unclear how effectively farmers use these services to manage their farms or what specific benefits they derive from them

2.4. Discussion

In our study coffee households of western Honduras with more dependence on coffee incomes are poorer, more vulnerable and food insecure than the households with diversified incomes such as off-farm labor and additional on-farm activities like animal husbandry and other staple crops. Anderzén et al. (2020) reported that Mexican coffee farmers with more diversified strategies tend to have higher incomes and are more food secure than households only involved in coffee cultivation. In that case, however, the households were more focused on on-farm and market-oriented strategies such as honey and coffee (cash flow) and maize and beans (staple food). Similarly, van Asselt and Useche (2022) reported that coffee income dependence for small-scale farmers households in Guatemala has a negative impact on their nutrition due to decreases in food production diversity, and no impact on-farm income. Furthermore, small-scale coffee farmers from Colombia with a strong focus on coffee (farm certification and/or high-quality coffee) may preclude increases in total household incomes as coffee activities demand substantial input in terms of time and labor from family members (Vellema et al., 2015). Despite these challenges, coffee is a very important livelihood strategy for many rural communities in Latin America. In Guatemala for instance, coffee households enjoy better food security and higher incomes than farmers households growing only maize (Lopez-Ridaura et al., 2019). The evidence of this paper from this specific study area, reinforces the structural transformation approach by Timmer, 2014, where the population of developing countries migrate from specialized on-farm strategies to diversify incomes, specially off-farm labour the income increases, and poverty reduces. Yet diversifying incomes is key to improve levels of food security and prosperity. This underscores the importance of understanding the local economy, the income distribution in the target population sufficiently early in the design of agricultural development interventions. Projects and intervention programs should seek to contribute to balancing coffee households' income sources between on-farm strategies such as coffee, other crops and animals, with market-oriented and off-farm strategies like small local business and jobs with better salaries.

Our analysis suggests that households with many members, with small farms, limited education, at lower elevations and high dependency of coffee incomes are more likely to find themselves below the national Honduran poverty line. These households tend to also experience more hazards events, further exacerbating food insecurity and poverty. The combined effects of climate and non-climate hazards such as low coffee prices, pests and diseases (for instance coffee rust), and recurrent droughts, coupled with the unavailability of efficient coping strategies, enhances the vulnerability of such coffee households (Avelino et al., 2015). In general, high climate vulnerability leads to food insecurity and outmigration for coffee households in Latin America (Bacon et al., 2021; Dupre et al., 2022; Harvey et al., 2018; Ruiz et al., 2015).

The majority of the respondents in our study either possessed no coping strategies in the face of climate hazards or had to resort to financial interventions such as using savings, reducing expenses, and/or accessing credits. Lopez-Ridaura et al. (2021) for Guatemala, Honduras, El Salvador, and Mexico, and Harris et al. (2020) for India, reported similar financial strategies for farmers during shocks. Although it is encouraging that there are at least some response strategies, it is likely that there are clear limits to such coping mechanisms. More specifically, the current strategies are unsustainable considering the projected long-term climate changes for Central America which suggest warmer temperatures and increasingly frequent extreme events (IPCC, 2012, 2021; Ruiz et al., 2015).

In our study, although most of the climate-resilience practices provided by the coffee sector are focused on improving coffee tree productivity in the face of climate variability, they do not appear to respond to actual household climate adaptation needs. This reinforces the notion of a disconnect between the needs of end-users of technologies and resilient practices offered by service providers (Akhter & Erenstein, 2017). There are two implications of this finding. First, although it could be in principle an attractive strategy to protect one of the main sources of gross income of households (coffee), the current strategies such as soil management with fodder crops and vegetative barriers do not have a direct effect on improving household food security, prosperity, adaptive capacity, or other farmers' basic needs (also see Groot et al., 2019; Khatri-chhetri et al., 2017; Long et al., 2016; Westermann et al., 2015). Thus, a focus on resilience to improve coffee production alone may not help producers enough to become more resilient to food insecurity and climatic variation. Second, the incentives needed for the adoption of such practices (e.g., certification schemes) create more, rather than less, vulnerability, which ultimately hinders agricultural development (Vellema et, al., 2015). It will remain a topic of future study whether the lack of broader farming and food system focus when promoting climate-smart practices and technologies 'locks' farmers into a maladaptation pathway, preventing them from income diversification.

Therefore, understanding the vulnerability of households with a multidisciplinary view (social, biophysical, and economic) can shed light on the debate around building inclusive climate adaptation strategies for coffee farmers (Donatti et al., 2019), improve the adoption of climate-resilient practices (Amadu et al., 2020; García de Jalón et al., 2017) and climate adaptation policies and programs (Harvey et al., 2018). Building resilience and adaptive capacity should include households needs such as income diversification as well as food availability and food production but designing such necessitates the participation of affected households.

2.5. Conclusions

This study analyzed coffee farmers' food insecurity, poverty, and their exposure and responses to climate and non-climate hazards, aiming to understand whether and how CSA promoted by coffee stakeholders are addressing households' socioeconomic vulnerability and their adaptation needs. Our findings suggest that diversified households, whose income relies more on off-farm labor and less on coffee, tend to have a higher probability of being food secure. Conversely, coffee-specialized and coffee-dependent households are more frequently associated with food insecurity. Current climate-smart agriculture practices promoted by the coffee stakeholders, which primarily focus on improving coffee productivity, appear limited in addressing the broader adaptive needs of households. These findings highlight a potential misalignment between the strategies promoted by coffee stakeholders and the actual requirements of coffee farmers to secure their livelihoods and food security.

Given these findings, a multidisciplinary approach that incorporates the social, biophysical, and economic aspects of household vulnerability may be more effective in addressing food security under climate stress. Policymakers and development practitioners must design inclusive climate adaptation strategies that not only focus on agricultural productivity but also prioritize income diversification and involve the active participation of affected households.

The development practitioners should assess the long-term sustainability of current coping mechanisms to mitigate the risk of maladaptation. It is crucial that future interventions are informed by a deeper understanding of the local context and are designed in close collaboration with the communities they aim to support. Comprehensive and participatory approaches can play a key role in fostering lasting resilience among coffee households in vulnerable regions.

3. LOCAL FOOD-SYSTEM AND HOUSEHOLD RESPONSES TO EXTERNAL SHOCKS: THE CASE OF SUSTAINABLE COFFEE FARMERS AND THEIR COOPERATIVES IN WESTERN HONDURAS DURING COVID-19

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Abstract

The COVID-19 pandemic lockdowns (people confined to home, with movement restrictions) presented an external shock to livelihoods and food systems worldwide, most severely affecting vulnerable households in low-income countries. While evidence is available regarding how COVID-19 generally affected low-income countries, the specific dynamics of local food-system responses and sustainably-certified coffee farm households has not been examined, despite them being usually deemed to be more resilient to shocks. This research examines how local food systems in Honduras changed during lockdowns, how certified coffee households coped with the shock, especially food insecurity, and the potential role of coffee cooperatives in increasing households' resilience under future shocks and stressors. We applied a mixed-methods approach that combined a structured household survey with semi-structured qualitative interviews with 91 households, 6 cooperative representatives, and 18 food-system representatives. We found that coffee-income-dependent households experienced greater food insecurity during lockdown than coffee households with diversified incomes. Before lockdown the local food system was highly dependent on external fresh food from outside the state. Food suppliers changed altered fresh-food procurement strategies, mostly to maintain fresh-food availability at the beginning of the pandemic. However, more than half the interviewed households lacked confidence regarding food security, amid rising food prices and local shortages. Certified coffee cooperatives supported their members by providing food assistance, cash transfers, and credit. Some of these strategies are difficult to maintain where crises are recurrent and that may render households more vulnerable to future extreme events. Rather, coffee cooperatives could diversify and support their members in growing and marketing

[2] Rodriguez-Camayo, F.; Lundy, M.; Borgemeister, C.; Ramirez-Villegas, J.; Beuchelt, T. (2024) Local food system and household responses to external shocks: The case of sustainable coffee farmers and their cooperatives in Western Honduras during COVID-19. Frontiers in Sustainable Food Systems 8:1304484. ISSN: 2571-581X. DOI: https://doi.org/10.3389/fsufs.2024.1304484

additional food crops. This could be a key approach for boosting local food security and strengthening the local food system.

Keywords: Food security, local food systems, resilience capacity, farming households, certified farmers

3.1. Introduction

COVID-19 was the first pandemic over the last century necessitating extreme governmental measures worldwide to reduce its spread. The World Health Organization (WHO) recommended mobility restrictions to reduce the spread of infection during the first wave of COVID-19. These mobility restrictions were introduced in low income countries without any preparation, disrupting food systems, reducing income and employment, and further weakening economies across the world (Swinnen & Vos, 2021).

Evidence regarding how COVID-19 affected food security during and after the lockdown period is growing (Béné, 2020) and is portraying the deficiencies of the current food systems in many countries (Gliessman, 2020). For instance, households in low income countries experienced shocks during the lockdown due to less labor demand and increasing food costs (Béné, 2020). This led to declining household incomes, which affected households' capacity to access food (Erokhin & Gao, 2020; Laborde et al., 2021). Other examples include studies reporting reductions in rural households' access to food (fruit and animal-based foods), and reductions in prices, sales, and incomes for farmers (Harris et al., 2020). Changes in food costs also affected the quality of vegetable consumption from Europe, Asia, Africa, Latin America, and the Caribbean (Jordan et al., 2021). In addition, evidence has emerged regarding supply-chain responses to confront lockdowns. For example, shortening food supply chains between production and consumers was a Central America's strategy to maintain food supply in local communities (Lopez-Ridaura et al., 2021; Tittonell et al., 2021).

Limited attention has been paid to how coffee farming households were affected during the first wave of COVID-19 and responded to this extreme event. In Peru for instance, coffee farmers used financial strategies such as savings and accessed loans to cover household expenses in response to the COVID-19 crisis (Vargas et al., 2021). Reports of negative impacts of COVID-19 on the national coffee sector for Honduras, i.e., small-coffee farmers had low coffee yields for 2020/21 due to lack of labor during lockdown to fertilize coffee plants after coffee harvest March and April 2020), local coffee-traders and exporters (issues related to exporting logistics) (Rios, Ruiz, Bogantes, & Marenco, 2022), also exist in Central America, including Honduras (Fromm, 2022). Likewise, Lara-Arévalo, (2023) provides a general overview related to food supply chains disruptions and its impacts on food availability and accessible from COVID-19 lockdowns in Honduras based on secondary information, but without specific focus on coffee grower, the local food system and their changes food security status.

Many factors likely shaped coffee household responses to the pandemic and its impacts. Foremost, being primary producers tended to lessen impacts in most of Mesoamerica due to their own food production and their ability to engage in local markets (Lopez-Ridaura et al., 2021). Households whose incomes relied more heavily on off-farm sources, such as temporary work in construction or on commercial farms, faced more difficulties during the lockdown (Lopez-Ridaura et al., 2021). In general, more diversified farms are more resilient against market and price volatilities than less diversified ones (Anderzén et al., 2020). Also the level of specialization of coffee farmers to access high quality or certified coffee markets can in some instances reduce available household labor for other activities like own food production (Vellema, et al., 2015). On the other hand, certified coffee farmers (e.g., Fairtrade or organic) are probably in a stronger position to face external shocks because of their better access to credit as well as benefitting from transparent internal accounting procedures, technical assistance, and capacity-building initiatives compared to non-certified coffee farmers (Beuchelt & Zeller, 2011, 2013). Moreover, (C. M. Bacon, 2015; C. M. Bacon et al., 2014) found that members of certified coffee cooperatives in Nicaragua had access to marketing services for various food crops, including fruits, vegetables, beans, and maize, stressing the link between the certification (here Fairtrade) and improved food security and food sovereignty for coffee farmers. Thus, farmers households' income dependency probably played a key role in terms of their level of vulnerability during the lockdowns.

However, the benefits of certification on well-being of coffee farmers in Central America are not always clear-cut. For instance, Jena et al. (2017) and Estrella, et al. (2022) did not find significant differences in total households' incomes from certified (Fairtrade and other certification schemes) and non-certified coffee farms in Nicaragua and Honduras. One possible reason for these discrepancies is that the total amount of certified coffee sold by coffee farmers in Mesoamerica is relatively low due to limited market demand (Méndez et al., 2010; Panhuysen & Pierrot, 2020).

Central America in the past has been repeatedly affected by food insecurity (Alpízar et al., 2020), more recently intensified by seasonal weather fluctuations (inter-annual events) and extreme events such as droughts and storms affect the planting season for beans, maize and vegetables in the region (Harvey et al., 2018). As a consequence, the overall food availability and access decrease, particularly impacting the more vulnerable households in the area (FEWSNET, 2023; Harvey et al., 2018). To better respond to these weather challenges, farmers with certification programs started to adapt and incorporate different agroecological practices such as shade trees and improved soil management for better water retention (Koutouleas et al., 2022; Pico-Mendoza, et al., 2020). Agrobiodiversity as a strategy gives shade in the coffee farms for example and, maybe contributes to food security of coffee households (Fernandez & Méndez, 2019).Within this complex landscape, a particular point of interest lies in comprehending the situation of certified coffee farmers and their food security during the COVID-19 lockdowns.

This research seeks to understand for cooperatively organized, coffee producers a) how the local food system, in which the coffee farmers interact, has changed under COVID-19 mobility restrictions, b) how this change affected the coffee farming households and their food security situation, c) what strategies did farmers implement to maintain their food security, and d) the role coffee cooperatives played in supporting households to increase their food security resilience. Our study specifically concentrated on two certified cooperatives in Western Honduras.

3.1.1. Conceptual framework

We used a food system approach to better understand the effect of mobility restrictions on household food security. Figure 3.1 describes the different stepwise activities of the food system (i.e., production, processing, sale, and consumption) and the various actors involved in each step, as defined by the UN Food and Agriculture Organization's (FAO) High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security (CFS) (Béné et al., 2023; Béné et al, 2016; Ericksen, 2008; HLPE, 2014, 2017). The food system outcomes contributing to food security dimensions such as food access and availability (Ericksen, 2008; Ingram, 2011), and are affected by shocks and stressors (socioeconomic drivers), such as changes in demography or income.

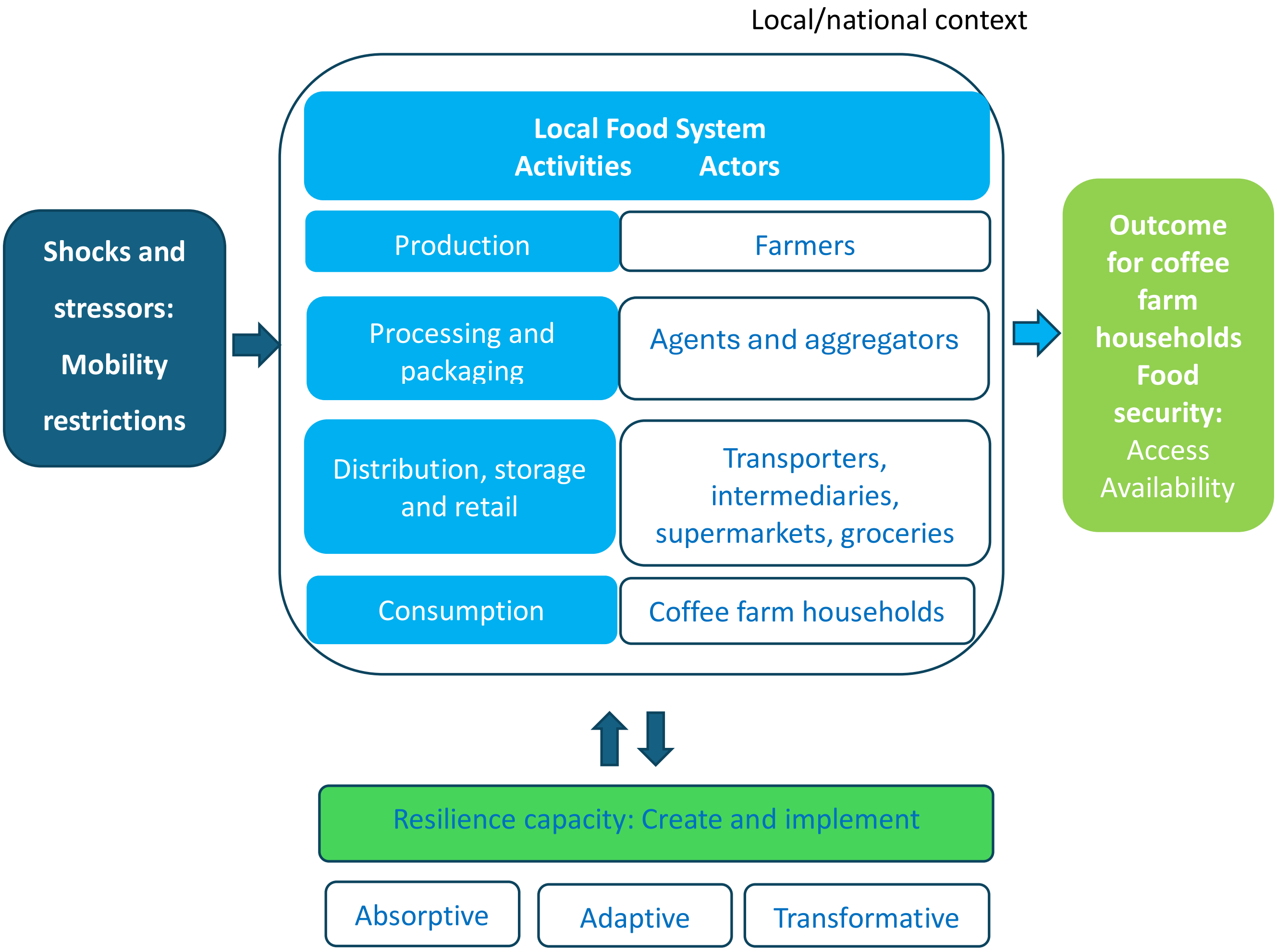


Figure. 3.1 Effects and responses of food security approach under extreme events. Sources: Own illustration based on Ericksen, (2008); Ingram (2011); Béné (2016); HLPE (2014, 2017)

Our definition of food security follows that of the FAO (2006), "*Food security exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.*" We focused on food supply, including local food production, household reserves, and local food markets (availability and access to food). In addition, we included the food insecurity experiences of coffee households to understand the access to food changes before and during the COVID-19 lockdown. The decision to exclude the dimension of food use and stability from our research was influenced by two factors. First, the mobility restriction imposed during the lockdowns limited our ability to explore how households prepared daily meals. Second, the duration of our fieldwork was relatively short, making it challenging to capture the stability of all food security dimensions adequately.

Food systems' resilience capacity refers to their capability to react and implement strategies to increase food security (Béné et al., 2016). The concept of resilience is based on a set of actions and strategies of individuals, households, a community, or a system to confront shocks and stressors. According to the intensity of shocks and stressors, the responses or strategies can be classified as absorptive, adaptive, or transformative (Béné et al., 2012). *Absorptive* capacity refers to individuals, households, and systems that can absorb the negative impacts of mild shocks without compromising livelihoods, positions, or basic needs (Ansah, et al., 2019; Béné et al., 2012). *Adaptive* capacity complements absorptive capacity, meaning that individuals and households can increase changes and adaptations through diversification of households' livelihood activities or access to credit when shocks are moderate (Béné et al., 2012). *Transformative* capacity refers to circumstances in which individuals, households, or systems are impacted by stressors and shocks of a catastrophic and permanent nature (Béné et al., 2012). If absorptive and adaptive strategies are insufficient, individuals or households must make substantial lifestyle and livelihood changes to survive under severe shocks or stressors. Therefore, resilience refers to capacity, rather than outcome (Béné et al., 2016).

3.2. Materials and Methods

3.2.1. Study area

Honduras has a population of nearly 10 million inhabitants of which 48% live below the national poverty line with less than USD 6.85 per person/day in 2019 and 14.6 % of the population suffers moderate or severe food insecurity (World Bank, 2020). Our study area was located in western Honduras, specifically the department of Ocotepeque (Fig. 3.2) with a population of 175,001 inhabitants in 2023 (INE, 2023). The study region has a wide range of elevations, stretching from 800 meters above sea level (m.a.s.l) to 2,400 m.a.s.l. The highlands in the region are part of the Guisayote Forest Reserve, which converges with farmers' vegetable plots and coffee farms. The dry season is between December and

February. The dry corridor, is a region with over for dry months per year (i.e., precipitation below 50 mm) (CIAT, 2018). Livelihoods in this region depend on the cultivation of beans, coffee, maize, vegetables, livestock, off-farm labor, and remittances (FEWSNET, 2014). The local economy is highly reliant on coffee, given the concentrated focus of critical services such as input provision, technical assistance, transportation, and banking specifically tailored to coffee cropping (CIAT, 2018). In our study we specifically targeted households engaged in coffee farming, recognizing coffee as the primary livelihood source within this regional context. Notably, the region is characterized by the presence of numerous coffee farms, organized into cooperatives. The central hub for commercial activities, including supermarkets, a diverse array of shops, and the sole public food market, is situated in the city of San Marcos. In contrast, villages generally feature smaller grocery stores, illustrating a nuanced economic landscape.

The two coffee cooperatives in our study are termed Cooperative A (Coop A) and Cooperative B (Coop B), have requested that we maintain their anonymity for this research. Coop A was established in 2000 and operates in a village within the La Labor municipality, while Coop B was founded in 1999 and is situated in a village near the Mercedes municipality. Both cooperatives acquire the coffee cherry produced by their members. Subsequently, they process the coffee cherries, which involves pulping, selecting, and drying the coffee beans. Following this processing phase, the cooperatives sell the dried parchment coffee to coffee roasters in North America and Europe, facilitated by national exporters. Because both cooperatives hold a Fairtrade certification, they offer specific services to their members such as access to credit, capacity building on agronomic practices and the regulated purchase and sale of coffee. Both farmers' cooperatives have the same organizational structure, constituted by a General Assembly, which is composed of all members, a president elected by the General Assembly, and a management team that represents each administrative area (financial/accounting, technical assistance, operations, and support). According to cooperative representatives, Coop A has 63 members and Coop has 61 members, and all of them hold a Fairtrade and/or organic certification.

The studied coffee households are primarily located in a village 11 km from the town of La Labor and in Mercedes, 18 km from the town of San Marcos. The coffee farms are situated between 900 and 1,800 m.a.s.l. and produce a similar coffee quality.

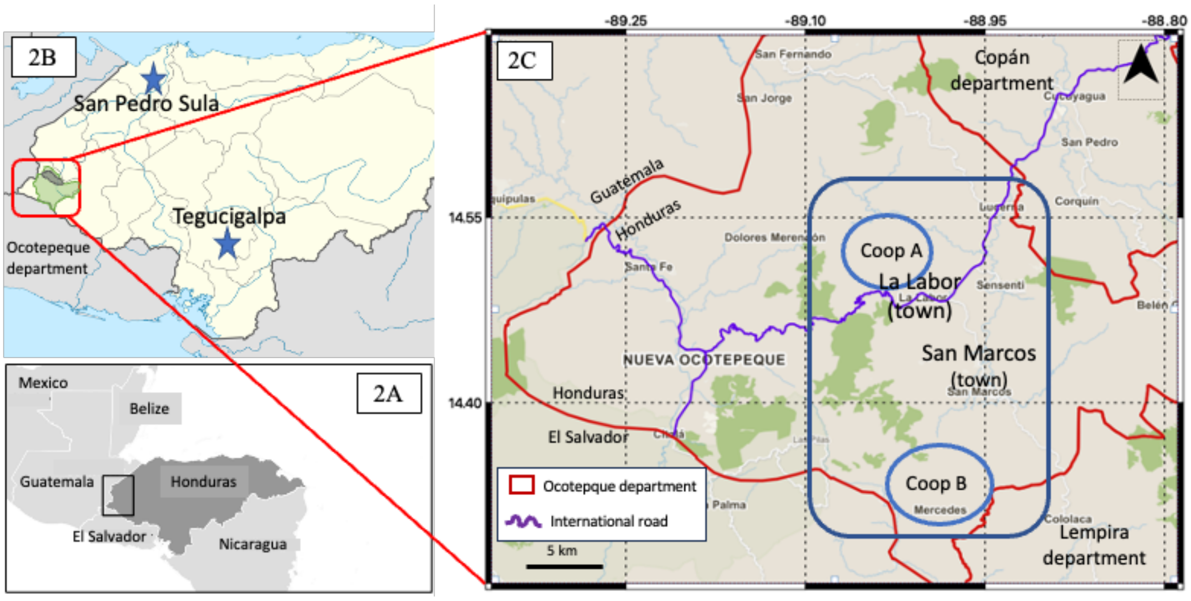


Figure. 3.2. Study area in Honduras. 2A Location of Honduras in Central America; the black square highlighting the western part of Honduras; 2B Area in green represents the current coffee cultivation area in Ocotepeque department, and grey represents low elevation areas (< 1,000 m.a.s.l.); 2C The area with the blue square is the study area, green areas within the blue square represent the Guisayote Forest Reserve; blue circles the location of interviewed coffee cooperatives and coffee farming households. Next to the blue circles represent La Labor (at the top) and Mercedes (in the button), these are the capital cities of the municipalities that share the same name.

3.2.2. Selection of stakeholders and data collection

This research uses a mixed-methods approach, combining a structured household survey with semi-structured, qualitative stakeholder interviews with households, representatives of cooperatives, and other food-system actors, and photograph recording and observation. Data collection took place between May and July 2020. The main national curfew was imposed during March 15–31, 2020, and mobility restrictions within municipalities and between municipalities and states were implemented from April 1 to September 2020 (see Fig. 3.3).

Structured household surveys were conducted in two selected cooperatives that agreed to participate in the research despite the circumstances of COVID-19. Ninety-one households were surveyed, including 40 households from Coop A and 51 households from

Coop B. The survey was conducted in two parts. First, a more extensive household survey that was conducted in 2019, pre-COVID-19, and a second survey (in 2020) with the two cooperatives and households selected for the survey in 2020 represented a subsampled of 91 households of those surveyed in 2019. Focusing on the same coffee households enabled us to compare the households' food insecurity both pre and during the COVID-19 outbreak.

The survey of 2019 was a randomized household survey including two cooperatives from Honduras and 91 farm households. The two cooperatives were selected based on their interest and scope (geographic and certification). The households were sampled by drawing a first list of potential household respondents based on individual membership lists provided by each cooperative. This list was further revised with the support of cooperative leaders and technical assistants, to ensure that only active members of the cooperatives were interviewed. We then applied a simple random sampling method with 90% confidence level and 5% precision level, stratified per elevation (two strata: under 1,200 m.a.s.l., and between 1,200 and 1,800 m.a.s.l.). In the survey we collected data on coffee farmers' livelihoods, poverty through The Poverty Probability Index® (PPI), food security access dimension (Food Insecurity Experience Scale; FIES), and household income diversification (incomes by coffee, crops, animals, forestry, labor off-farm and external incomes), which was conducted in the same study area between September and October 2019. The survey was supported by a technical assistant from each cooperative, who coordinated the appointments with respondents, using a list of cooperative members.

For the 2020 survey, additional criteria to select sub-samples of coffee farmers and cooperatives were: a) coffee households with previous food insecurity data collected, and b) agreed to join to the research, and c) agreed to follow all health security measures from the national government during the research

Cooperative leaders and coffee households helped us to identify the main suppliers of fresh food (vegetables, fruits and staple foods) for farmers, such as grocery shops, supermarkets, (in)formal vendors, and food marketplaces where farmers get the basic food basket. The cooperative leaders scheduled interviews with food suppliers based on the trustworthiness they enjoy among the population. Vendors from the open food market in San Marcos were not included due to availability (i.e., open market closure due to COVID-19 restrictions).

By ethical reason, all participants of these research, coffee households, cooperatives, and local food system actors were anonymized. All surveyed and interviewed stakeholders were included in this study on a voluntary basis. The structured household survey (in 2020) addressed 1) food insecurity (access and availability), 2) food systems (actors and factors) from households perspective, 3) changes in local food systems (the origin of fresh and staple foods) and a list of them before and during lockdown, and 4) coffee farmers' strategies in response to household food insecurity during the lockdown. To estimate coffee households' food insecurity and their prevalence, we used the Food Insecurity Experience Scale - FIES developed by FAO as part of the evolution of the lasted version from the Food Insecurity Access Scale - HFIAS and Latino-America and the Caribbean Food Security Scale - ELCSA (Ballard, et at., 2013). The FIES captures the dimensions of households' food access through eight questions that were integrated into the structured household surveys in 2019 and 2020, which range from being worried about food security, changes in dietary diversity to skipping meals or without eating for a whole day (Ballard, et al., 2013; see also Table 4). The severity level of households' or individuals' food insecurity is an unobservable trait. The experiences associated with household respondents' food insecurity are associated with the FIES question set; thus, the more severe a household's experienced food insecurity, the higher the probability of reporting associated experiences. The survey results are triangulated with the semi-structured interviews applied to households and food system actors regarding food access and availability. The leaders of Coop A agreed to meet with all coffee households that participated in the survey in 2019. The Coop B supported the study with two technical assistants who helped collecting the information (survey). We did a pre-test of the survey with staff of both cooperatives to identify gaps of information, and misleading vocabulary. We conducted the survey in person, utilizing paper forms, and following the cooperatives leaders' recommendation designed it to take no longer than 15 minutes per interview. In total, the survey comprised 28 questions, including 15 with multiple-choice options and 13 with yes/no responses.

Due to the time constraint, unfortunately, we had to exclude important variables such as households' poverty (PPI) during the lockdown. This limited the scope of the analysis of the present study.

The semi-structured interviews were conducted with various local food-system actors (i.e., representatives of food suppliers, such as supermarkets, intermediaries, coffee households, food producers, local groceries, and cooperative leaders (Fig. 3)). For all interviews and surveys, we followed the national health care measurement such as social distancing, mask wearing, conducting interviews only in open areas, cleaning with alcohol our hands before and after each survey interview and avoiding any physical contact.

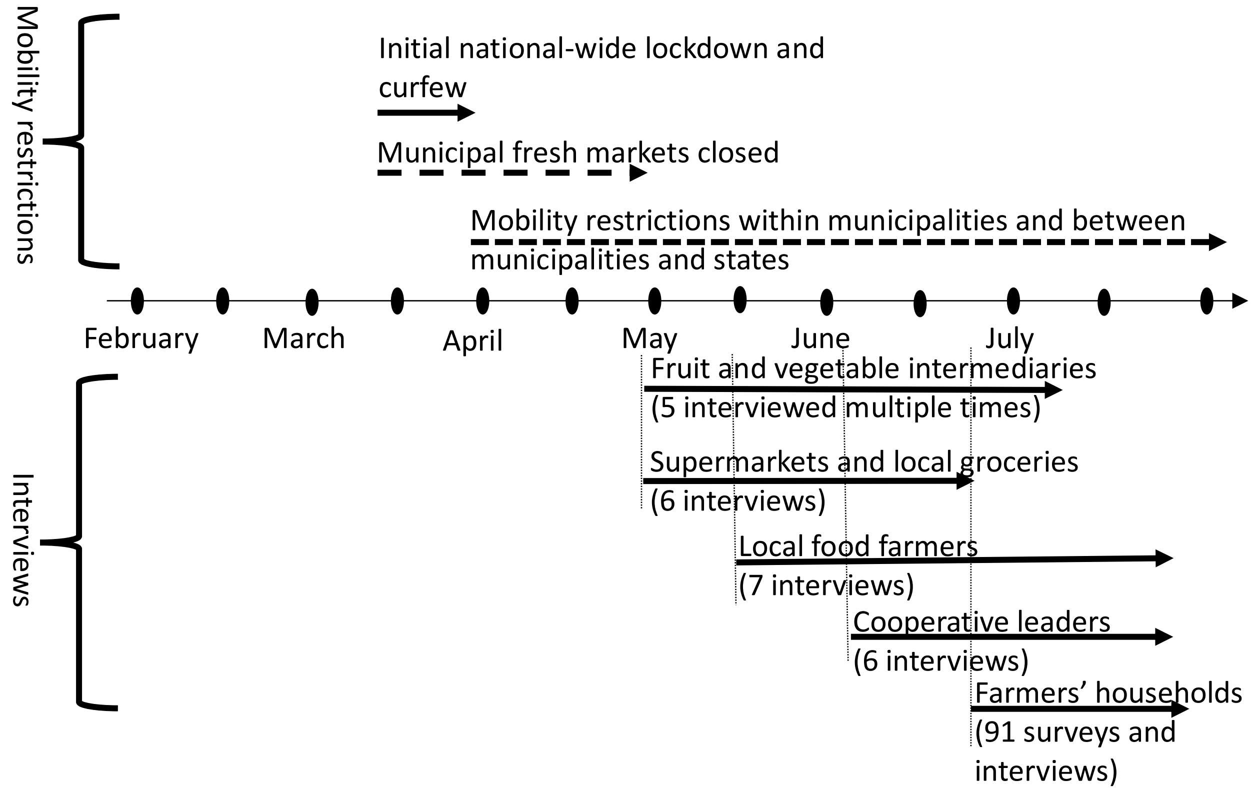


Figure. 3.2 Timeline of mobility restrictions and interviews from February to September 2020.

We interviewed key informants such as leaders of the two cooperatives to identify the most popular fruits and vegetables in the region. We photographed fresh food and food vendors from the food marketplace in San Marcos in 2019. For 2020, we took photos of informal fresh food vendors (intermediaries, vendors in the international road and pick-ups vendors), grocery stores, and supermarkets along the C4 transnational road in the municipalities of Mercedes, La Labor and the village of Rosario. The first author of this paper logged field observations between 2019 and 2020 and recorded day by day events in a logbook.

We documented the origin of all staple food, vegetables and fruits mentioned during the households' survey and cross-referenced this information with the photographic data on fresh food items sales by local food market before and during the lockdown. Finally, we followed the linkages from the coffee households' preferences to the origin of fresh food by asking food system actors. This allowed us to map and better understand which food items originated from outside the local food system as well as describing the local food system for both periods.

3.2.3. Data analysis

We performed two types of analysis: (1) a descriptive analysis of the households' socioeconomic characteristics, poverty, and food insecurity levels; and (2) an analysis of resilience strategies of the coffee household farmers, and farmers' cooperatives to assure food security, and actors within the local food system strategies aimed at keeping the local food system flowing to sure food availability in the study area. For (1) we used the household survey data from 2019 for socioeconomic characteristics, poverty, and food insecurity measures, and from the 2020 survey data we used the food insecurity measure. For the analysis of food insecurity, we used the data from the eight questions FIES applied: a) You were worried you would not have enough food to eat? b) You were unable to eat healthy and nutritious food? c) You ate only a few kinds of foods? d) you had to skip a meal? e) You ate less than you thought you should? f) Your household ran out of food? g) You were hungry but did not eat? h) You went without eating for a whole day?. Quantitative categorical types of data were analyzed using percentages, frequency distributions, and cross-tabulation. While quantitative continuous data were analyzed using means, and standard deviations. ANOVA and t-Test were used to see whether there were significant differences among different groups like cooperatives A and B and three grouped by coffee income dependency. The Kruskal-Wallis and Wilcoxon non-parametric tests were utilized to investigate potential differences in FIES among cooperatives and income groups over the years and within them, respectively. For non-normally distributed variables, the Mann-Whitney test and Dunn Bonferroni test were used by pairwise comparison among cooperatives and coffee income dependency groups.

The FIES analysis methodology utilizes Item Response Theory (IRT) to examine responses to survey or test questions. Within IRT, the Rasch model, employed for analyzing FIES data, aims to enhance measurement accuracy and reliability by systematically assessing response data. This IRT measurement model, known as the Rasch model, not only offers a theoretical foundation but also provides a set of statistical tools (Nord, 2014). We ran a probabilistic model linking unobservable traits with respondents' experiences is the Rasch Model, following by a procedure jointly developed by the FAO and Cafiero, Viviani and Nord (2018) for a prevalence of food insecurity. This was applied to each cooperative for both periods (i.e., 2019 and 2020). Finally, we classified the food (in)security of households by year, following the four FAO groupings and thresholds, i.e., (i) food secure, (ii) marginally food insecure, (iii) moderately food insecure, and (iv) severe food insecure (Ballard et al., 2013). We then analyzed differences in the FIES scores between years across cooperatives and income groups using boxplots. In these latter analyses, significance in the differences was assessed using a Kruskal-Wallis non-parametric test, with pairwise comparisons assessed using Wilcoxon's rank-sum test.

For the resilience analysis we used the survey data from 2020 and the food-system actor interviews and observations.

The descriptive analysis focused on describing households' demographic and socioeconomic characteristics for farmers cooperatives, and for three households' coffee income dependency groups. Our research focused exclusively on coffee farmers, meaning that all households had a level of dependence on incomes from coffee. We determined these groups according to the income distribution of households' coffee, other crops, animals, forestry, off-farm labor (e.g., construction, commerce, and commercial farms) and external incomes (e.g., remittances, aid assistance). A group with coffee incomes below 50% of total households is here termed "diversified", those with coffee incomes between 50% and 75% "coffee specialized", and households with coffee incomes above 75% "coffee-dependent".

All qualitative interviews were transcribed and analyzed using Atlas.ti software and coded them thematically such as impacts of lockdowns to formal and informal food vendors, households' responses and strategies to keep food security, changes of food suppliers, cooperatives strategies to maintain food security members, barriers of coffee cooperatives to linked food production and local food demands.

3.3. Results

Our study showed that (i) that local food-system changed under mobility restrictions, (ii) that the status of coffee farming households and their food insecurity differed before and during the pandemic and illustrated (iii) describes the resilience capacity of coffee households' and (iv) cooperatives' and their strategies to address pandemic-induced food insecurity. These results are explained in more detail in the following subsections.

3.3.1. Changes of the local food system under mobility restrictions

In this section, we will delineate the transformations within the local food system both before and during the COVID-19 triggered lockdown, presenting our analysis in two sections.

3.3.1.1. The local food system prior to the pandemic

Prior to the pandemic, the local food system in Ocotepeque state in Western Honduras consisted of farmers growing vegetables, fruit, and staple foods (beans and maize); intermediaries; public markets; supermarkets, and grocery shops. Intermediaries can be split in two groups, including vegetable and fruit sellers with a fixed business location, using wheelbarrows or tents along the international road called CA4. These vendors buy fruit and vegetables from international transporters and local farmers, and some source directly from Guatemala or El Salvador. They sold products to residents in the surrounding villages and lorry drivers and tourists who use the international road. The intermediaries in the second group have a vehicle (pickup truck) and bring fruit and vegetables to open markets, villages, local restaurants, supermarkets, and groceries. Like the first group of intermediaries, they procure products from local farmers and international transporters.

The main municipal marketplace in the region is in San Marcos, 12 km away from La Labor (Fig. 2). There are four local supermarkets based in the main towns of La Labor and San Marcos. There are also smaller grocery shops in these towns and nearby villages. A grocery shop in the region refers to a small shop that most often sells processed food with a long shelf life and staple food, and some sell a smaller quantity of fresh vegetables, such as tomatoes and onions.

Maize and beans were physically accessible from three sources regards to vendors and coffee farmers interviewed: local farmers, including coffee growers; open markets, and supermarkets. 37% of the coffee farmers located in La Labor and Mercedes buy beans after the coffee season in December and January, keeping them for consumption during the next three to six months. Other coffee farmers (46%) plant beans and maize between March and April and harvest them between June and August. If the coffee harvest is good, beans and maize for consumption usually last three to six months according to coffee farmers and cooperative leaders interviewed. All other coffee farmers buy these staples from the open marketplace, supermarkets, and grocery shops. The money for these expenses comes from either coffee sales or from off-farm labor such as fixed jobs as staff of the cooperatives, owner of small businesses and/or from temporary labor on construction sites or temporary labor on commercial farms such as large landowners selling monocultures to specialized supermarkets on capitals of main cities of Honduras.

Interviews with staple food sellers in the study area suggest that the government regulates beans and maize prices through two national institutions that buy, stock, and sell grain. During scarcity periods, these institutions release their grain stocks to avoid extreme market prices and high prices variability. This also reduces the capacity of intermediaries to establish higher market prices. The two governmental institutions are: The Honduran Institute of Agriculture Marketing (Instituto Hondureño de Mercado Agrícola; IHMA) and the National Basic Supplies Bank (Suplidora Nacional de Productos Básicos; Banasupro). According to the interviewees, IHMA has two functions: a) buying beans and maize in regions where the crops are grown and stock the produce in collection centers; and b) selling beans and maize to intermediaries or Banasupro. Banasupro operates in the retail market through its own shops and alliances with supermarkets and grocery shops in each municipality. Through this scheme, the government tries to establish market prices and guarantee the availability of beans and maize for the local population.

According to the food system actors interviewed and households survey, 60% of the fruit sold comes from outside the Ocotepeque municipality, including Guatemala, Mexico, Salvador, and the United States (see Figure 4). International fruit transporters move cargo from Guatemala or El Salvador to supermarkets and open markets in Honduras. Before reaching their destination, transporters sell a portion of their freight to the intermediaries located along the international road, who then sell the fruit to local customers. In addition, some intermediaries located in La Labor independently transport fruit (grapes, apples, mangoes, and pears) directly from Guatemala to Honduras. The most planted vegetables in the study area, like broccoli, cabbage, carrots, onions, peppers, potatoes, and tomatoes, come from specialized vegetable farmers around the Guisayote Forest Reserve in Ocotepeque department and Guatemala (see Figure 4) according to local food system stakeholders. However, almost all farms have contract arrangements with large supermarkets in the main cities of Honduras, Tegucigalpa, and San Pedro Sula, where they deliver the highest quality ("class extras" and "class I" according to FAO's Codex Alimentarius) products. The secondary quality (“class II”) harvest is supplied to town marketplaces, such as San Marcos, Ocotepeque, and Santa Rosa, Copán. The remaining harvest is sold to intermediaries who sell it to further villages and small towns.

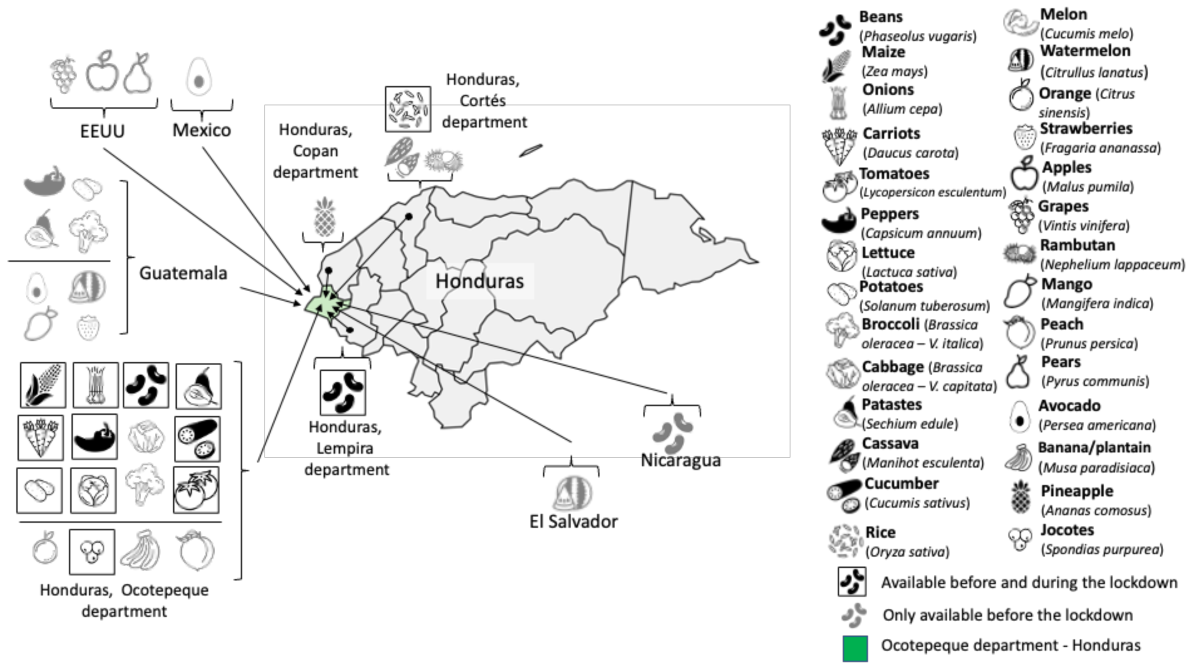


Figure 3.3 Places where fresh food such as vegetables, fruits and staple food comes before and during the lockdowns in the study area.

Households in villages located far from urban areas access fruit and vegetables through open marketplaces in nearby towns. Thus, these households must frequently travel from their villages to open marketplaces in urban areas to access food.

3.3.1.2. The local food system during the lockdown

As an observer into the study area, at the beginning of the nation-wide lockdown (March 15–31, 2020), supermarkets, public markets, and grocery stores were closed following government-imposed regulations. In the subsequent lockdown (from April 1 to September 2020), there was more flexibility in urban and peri-urban areas, such as Tegucigalpa and San Pedro Sula, where the food chain and strategic sectors, such as health and transportation, were allowed to reopen. However, the situation in rural areas was different. In the study area, the main market was closed for more than 45 days; hence, local vegetable producers (one of the sources of fresh vegetables) could not transport vegetables to the markets each week and were compelled to discard produce. Mobility restrictions between municipalities and department presented further barriers to moving fresh products from growing regions to markets. As a result of international border closures, the availability of imported vegetables and fruits were severely reduced, according to local sellers (see Figure 3.4).

Consequently, most vegetable farmers reduced their agricultural activities between March and May 2020 to avoid another loss of harvest as shown in the interviews with local food farmers and intermediaries. During this time, intermediaries with vehicles (pickup trucks) purchased vegetables from vegetable producers (who still had some vegetables) around the Guisayote Forest Reserve area and transported them to the municipality of La Labor and villages for sale in the study area. Week by week, the local vegetable supply became scarcer, and prices began to increase. By June 2020, 77% of coffee households surveyed reported that could no longer afford vegetables due to higher prices according to informal discussions with coffee households. With a fall in demand because of higher prices, intermediaries stated that they had to reduce the fresh food supply to these small cities and villages.

According to interviews with supermarket owners and intermediaries, when households ran out of stock at the end of April, the population began to demand more beans. Bean prices in the study area increased from 13 Lempiras/500 grams (US$ 0.50) in April 2020 to 25 Lempiras/500 grams (US$ 1.00) at the end of June 2020. The intermediaries, usually selling vegetables, began offering small amounts of beans and maize in their tents and vehicles between May and June, as the high prices of beans and maize guaranteed superior profits. The intermediaries obtained the beans and maize from local stocks, their own production or other intermediaries who transported them undeclared from Nicaragua and Guatemala. In the first week of July, the local harvest of beans began, and prices returned to 13 Lempiras/500 grams by the last week of July 2020. One of the supermarkets' owners, who is a major supplier for grocery shops around neighboring villages (including where Coop A is located), reported high demand for snacks like potato- or tortilla chips and sugary drinks like regular soda or fruit drinks, due to their lower prices (affordable) in comparison to fresh food available during the lockdowns.

In the interviews and surveys, none of the participants noted that governmental agencies Banasupro or IHMA supported either the availability of beans and maize or controlled prices. In the interviews and surveys, none of the participants noted that governmental agencies Banasupro or IHMA supported either the availability of beans and maize or controlled prices. Following the initial lockdown, Banasupro reopened shops in

Tegucigalpa and San Pedro Sula, including temporary stores at many points in these cities; however, in the rest of Honduras, especially in the Ocotepeque department, Banasupro shops were open only in the capital of this department at a fixed point (more than 30–70 km away from these households), limiting rural households' access to Banasupro services.

3.3.2. Coffee-farming households and their food insecurity before and during the lockdown

The pre-pandemic 2019 survey revealed the demographic, socioeconomic, and income distribution of coffee households (Table 3.1).

The survey results show that the households from Coop A have a higher probability of being under the national poverty line than those from Coop B according to the PPI index collected in 2019, which could be explained by different income-diversification strategies, where coffee households with diversified income accounted for 59% in cooperative A and 26% in cooperative B (see Table 3.1). Among these groups, the primary source of income was off-farm labor, constituting 45% and 41% for cooperatives A and B, respectively. Additionally, income from coffee contributed 36% and 37% for cooperatives A and B, respectively. According to cooperatives' representatives and staff, they are all also coffee-household members who had been granted off-farm labor such as technical assistants or administrative staff, with stable incomes.

Table 3.1. Demographic, socioeconomic, and income distribution variables of coffee households by cooperative - 2019

	Coops			
Variables	**A (n=40)**	**A Standard deviation**	**B (n=51)**	**B Standard deviation**
PPI - Probability of being below of the national poverty line - (%) †	38%*	0,19	29%*	0,17
Number of households members - (Mean) ‡	4,3	1,53	3,9	1,63
Age of household head - (Mean) ‡	46	12,70	46	13,00
Size of farm (Ha) - (Mean) †	2,2*	3,78	2,6*	2,02
HDDS - Households dietary diversified score - (Mean) †	9,4	1,78	9,3	1,44
Farm elevation (MASL) - (Mean) †	1288*	132,79	1330*	95,91

Household head male - (%)	90%		88%	
Access to clean water (public system) - (%)	100%		88%	
The education of the head of household - (%)				
No studies	8%		4%	
Elementary	75%		67%	
Middle	15%		24%	
Higher	3%		6%	
Income distribution - (%)				
HHs incomes with > 75% of coffee (Coffee dependent)	35%	6,30	33%	2,42
HHs incomes with < 75% > 50% (Coffee specialized)	39%	7,04	8%	7,07
HHs incomes with < 50% (Diversified)	26%	14,28	59%	13,93

Note: * indicate a significant difference between two groups. Symbol ‡ indicates normally distributed variables. Symbol † indicates non-normally distributed variables. t – Test was used to test for statistical differences for normally distribute variables. Mann-Whitney post hoc test was used for non-normally distributes variables.

The coffee households with more dependence on coffee income (Specialized and Dependent group) are more likely to be poor than the coffee households of the diversified income group (see table 3.2).

Nearly all interviewed households, (97% of the coffee households) have Fairtrade and/or the Organic certification. The remaining coffee households had been in a pre-certification process with the certifier or had not been clear about the current status of their farm certification during the survey conducted in 2019.

Table 3.1 Demographic, and socioeconomic variables by income distribution groups (2019)

Variables	**Income distribution**		
	Diversified (n=40)	**Specialized (n=20)**	**Dependent (n=31)**
PPI - Probability of being below the national poverty line - (%) †	26%[a]	43%[a]	36%[a]
Number of households members - (Mean) †	3,9	4,9[a]	3,7[a]
Age of household head - (Mean) ‡	43	45	50*

Size of farm (Ha) - (Mean) †	3,0	1,8	2,0
HDDS - Households dietary diversified score - (Mean) †	9,5	9,8[a]	8,8[a]
Farm elevation (MASL) - (Mean) ‡	1324	1298	1307
Household head male - (%)	90%	90%	90%

Note: Symbol ‡ indicates normally distributed variables. Symbol † indicates non-normally distributed variables. ANOVA test was used to test for statistical differences for normally distribute variables *** p>0,01; **p<0,05; *p<0,1 indicates a significant difference, then we used a Turkey test for pairwise comparison. Kruskal-Wallis tests were used to test for statistical differences, letter (a) indicate a significant difference between groups, followed by pairwise comparisons based on the Dunn-Bonferroni test post hoc test was used for non-normally distributes variables.

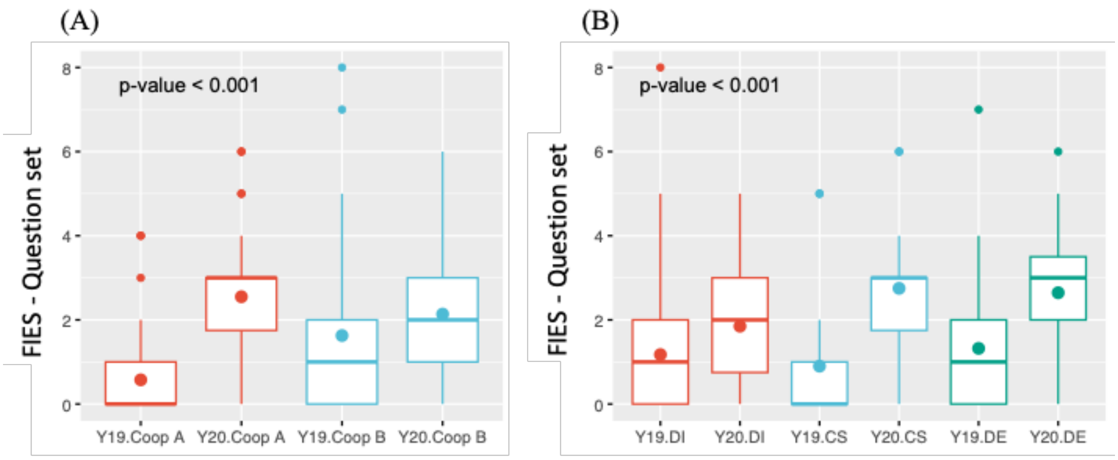
Notably, there were considerable local differences in access to food, and especially vegetables, experienced by coffee farmers organized in the two coffee cooperatives. Based on the data from the households' survey in 2020, coffee farmers from Coop A had limited access to vegetables and fruit due to mobility restrictions, as most fresh food consumed by households in Coop A consume comes from outside of the municipality. In contrast, households surveyed from Coop B accessed fruits and vegetables through a local grocery shop (in Mercedes) and intermediaries between April and June. This food availability was facilitated by a local grocery shop that began buying fresh food (primarily vegetables) from local farmers and surrounding villages in the Mercedes municipality. Additionally, new intermediaries began to sell some fruits and vegetables in the small town where Coop B is located. These intermediaries and food producers were from neighboring villages that had sold fresh produce in the San Marcos market prior to the lockdown. This supply of fresh food guaranteed food availability for the households in Coop B (Table 3.3). For both cooperatives, coffee households did not report a shortage of beans, as these had already been stored before the COVID-19 crisis. For example, 37% of the households interviewed started to buy beans from intermediaries and/or harvested them from their farms between February and April to store them for the upcoming months (as usually practiced).

Table 3.2 Changes in households' access to vegetable, fruit, and staple food suppliers before and during mobility restrictions

Food suppliers	Fruit and vegetables		Staple food (beans and maize)	
	Before mobility restrictions (n = 91)	During mobility restrictions (n= 91)	Before mobility restrictions (n = 91)	During mobility restrictions (n = 91)
Local grocery shop (pulpería)	16.5%	33.0%	15.4%	20.9%
Grocery shop	0.0%	0.0%	0.0%	0.0%
Supermarket main town	3.3%	2.2%	16.5%	17.6%
Local seller	4.4%	6.6%	5.5%	2.2%
Local farmer	4.4%	8.8%	17.6%	7.7%
Intermediary	36.3%	41.8%	9.9%	11.0%
Food self-production	34.1%	18.7%	46.2%	29.7%
Marketplace in San Marcos	55%	7.7%	19.8%	5.5%
Supermarket in San Marcos	2%	1.1%	0.0%	0.0%
Staple food storage	0%	0.0%	0.0%	37.4%
Other / no answer	1.1%	0.0%	5.5%	3,3%

Table 3.3 reveals an increase in food purchases from local grocery shops, while access to the traditional fresh food suppliers in the marketplace fell sharply. On-farm production of staple foods and vegetables decreased by one-third, due to shortages of inputs, such as seeds, fertilizers, and technical assistance, according to the farmers surveyed.

Food insecurity increased among coffee producing households during the lockdown. According to first question of the survey of FIES, around 50% of the households did not report food insecurity in 2019, whereas only 15% of the households did not report food insecurity in 2020. The Rasch model, used to analyze the other FIES questions, revealed that the prevalence of moderate and severe cases of food insecurity in households increased from 6% in 2019 to 19% during the lockdown. It means that households reduced the quality of nutritious food and quantity. The situation is confirmed by households surveyed, one respondent expressed, "*We could not find all kinds of food that we used to buy due to shortages of fruits and vegetables*" (The head of a coffee household, personal interview, 2020). Another said, "*Our situation is bad because we don't have enough money to procure food*" (The head of a coffee household, personal interview, 2020). Furthermore, a participant remarked, "*We are buying fewer vegetables because they are very expensive.*" (The head of coffee household, personal interview, 2020). These voices illustrate the impact of the lockdown on the food security of coffee households, reinforcing the quantitative data.



Pairwise comparisons (Wilcoxon's test)

Between years	Coop A (2019)	Coop A (2020)	< 0.001 (***)
	Coop B (2019)	Coop B (2020)	< 0.1 (n.s.)
Within years	Coop A (2019)	Coop B (2019)	< 0.001 (***)
	Coop A (2020)	Coop B (2020)	≤ 1 (n.s.)

Pairwise comparisons (Wilcoxon's test)

Between years	Diversified (2019)	Diversified (2020)	< 0.2 (n.s.)
	Specialized (2019	Specialized (2020)	< 0.01 (**)
	Dependent (2019	Dependent (2020)	< 0.01 (**)
Within years	Diversified (2019)	Specialized (2019)	≤ 1 (n.s.)
	Diversified (2019)	Dependent (2019)	≤ 1 (n.s.)
	Specialized (2019	Dependent (2019)	≤ 1 (n.s.)
	Diversified (2020)	Specialized (2020)	≤ 1 (n.s.)
	Diversified (2020)	Dependent (2020)	≤ 1 (n.s.)
	Specialized (2020	Dependent (2020)	≤ 1 (n.s.)

Figure 3.5 Variation in the FIES score of coffee households according to their response to the 8 FIES questions before and during the lockdowns; (A) distribution by cooperative 2019 (pre- lockdown) and 2020 (during lockdown); (B) distribution by income group 2019 (pre-lockdown) and 2020 (during lockdown).

Note: Figure 5a (on the left) shows the changes in food security for households linked to Coops A and B, and Figure 5b (on the right), the food security for household income groups. Moreover, in Figure 5b FIES by year 0 represent households with complete food security, and the scale from 1 to 8 represents households with increasing levels of food insecurity. In both panels, thick black, horizontal line represent the median, the large dot represents the mean, boxes mark the 25 and 75 % of the data and black whiskers extend to 5 and 95 % of the data. The p-value on each boxplot panel corresponds to a Kruskal-Wallis test, whereas the table underneath the boxplot shows pairwise comparisons performed through a Wilcoxon rank-sum test. In panel (A) and (B) Y19 and Y20 refer to year 2019 and 2020, respectively; in panel (B) DI: diversified; SC: coffee specialized; DE: dependent.

Figure 3.5 reveals the changes in households food security before and during lockdowns in the study area. Figure 3.5a shows that Coop A moved from being food secure in 2019 (mean value “0”), to eating only a few kinds of foods (mean value “3”) during the lockdowns, while for Coop B households, the mean changed from ‘worried about not having enough food’ (mean of “1”) to ‘unable to procure healthy and nutritious food’ (mean of “2”). The mean of the specialized group indicated that they are food secure (0), and the mean of the dependent and diversified groups represented a ‘worried about not having enough food’ (1 of 8). During the lockdowns, food insecurity is more severe for specialized and dependent groups (3 of 8) than for the diversified group (2 of 8). In general, where households’ food insecurity is higher (Coop A) and for specialized and dependent groups, two varaibles are recurrent in both cases, a) high rates of poverty, and b) high dependence on coffee incomes (see also table table 3.1 and 3.2).

3.3.3. Resilience capacity

3.3.3.1. Coffee households' strategies to address pandemic-derived food insecurity

Coffee-farming households' strategies to address food insecurity can be divided into two categories (absorptive and adaptive). The first involves coping strategies used during lockdown to respond to food insecurity, and the second comprises strategies that households implemented over the medium-term to mitigate lockdown-effects on food security in the upcoming months.

The most common coping strategy used by households to address food insecurity was tapping into savings from coffee sales, with 57% adopting this approach. Additionally, 18% of households resorted to seeking credit from coffee cooperatives. Some coffee farmers expressed their concern about the situation: "*Coffee incomes could not cover coffee debts and now we requested a credit to procure food, I am worried*" (Coffee farmer, personal interview, 2022). Households in Coop B accessed much higher credit levels than those of Coop A because this cooperative had greater cash flow (available budget to offer credit) than Coop A, according to the representatives of each cooperative. Subsequently, the households of Coop A reported to having eaten food and sought assistance from relatives and friends to cope with food insecurity. Selling goods, animals, or land was not a strategy for any of these households. Table 3.4 summarizes the household strategies used to cope with food shortages during household lockdown.

Table 3.4 Strategies to confront food insecurity at the household level during mobility restrictions

		Coop A	**Coop B**
Strategies to confront food insecurity at households' level		**(n=40)**	**(n=51)**
Sold	Sold some goods	0%	0%
	Sold/ate some livestock	0%	0%
	Sold some land	0%	4%
Access to credits	Loan from a financial institution	0%	6%
	Loan from an informal lender	8%	2%
	Loan from the coop	8%	25%
Less food	Reduced the number of meals per day	5%	2%
	Ate less food	23%	12%
Sought help from friends or relatives		25%	8%
Worked longer than usual to reduce costs of coffee production		5%	4%

	Coop A	Coop B
Strategies to confront food insecurity at households' level	**(n=40)**	**(n=51)**
Some family members who previously did not work had to work	0%	0%
Used savings	48%	65%
Signed up for a government aid program	3%	4%
A family member moved to a new place	0%	0%
Nothing	30%	24%

Asked between June and July of 2020 what households would do to counter the effects of the lockdown in the coming months (i.e., moving toward adaptive strategies), 30% of households in Coop A indicated that they could not do anything to mitigate food insecurity in the coming months, and 24% of Coop B households responded the same. For 40% of all households shared that they were desperate, fearing that their current strategies would not work to reduce their food insecurity in the coming months, but they perceived no other option other than to wait. The coffee households said: "*We have no idea what to do to eat in the next months, but we know that God will save us*" (The head of a household, personal interview, 2020). "*I could do nothing, just wait to see what will happen.*" (The head of a household, personal interview, 2020).

In contrast, the other 60% of households highlighted two strategies. First, producing food on their farms by growing crops like beans, maize, and other vegetables, with 18% and 41% of households from Coop A and B listing this strategy, respectively. The second strategy was better management of household resources by taking measures such as a budget planning to determine where household expenses could be reduced. This strategy was reported by 10% and 21% from households Coop A and B, respectively.

3.3.3.2. Cooperatives' strategies to address members' food security

The interviews with cooperatives' leaders and members revealed that the cooperatives supported coffee households with food provisions. Cooperative A gave one bag of food provisions to each household member and provided loans to acquire food and other items between May and June. The bag contained beans, flour, maize, oil, pasta, salt, and sugar, to make tortillas, i.e., enough food for 15 days for a family with four members according to the interviews. The cooperative struck a deal with Fairtrade to use funds from its meeting budget for direct cash transfers to the member households; thus, a sum proportional to the amount of coffee sold by each household to the cooperative was transferred to members' accounts. Additionally, cassava cuttings and plantain seeds were distributed to members to promote independent food production.

Cooperative B delivered three bags of food provisions to each household between May and June (one bag each 15 days). One of them was sponsored by the cooperative and the other two were donated by a coffee importer and a coffee roaster that were traditional customers of the cooperative. The donation from these customers was in cash, so the cooperative arranged logistics to make bags with essential foods available for members. The bags of food provisions contained rice, beans, maize, oil, pasta, salt, sugar, and flour to make tortillas. In addition to this, the cooperative gave 4,000 lempiras (US$ 160) to their members at the beginning of the lockdown to address rising food costs.

One potential avenue to improve households' food security involves the active participation of cooperatives in marketing food crops. When questioned about the feasibility of such an initiative, cooperative representatives responded that the current cooperative some barriers, the current cooperative statutes only permit engagement in marketing for coffee and not for food crops, skills to market fresh food and a defined marked. The representatives of Coop A explicitly stated, "*We cannot market fresh food due to restrictions in the statutes. Also, we need steady food production and a defined market, lacking the necessary skills to do so… the bottleneck is the market, we had experiences with food garden projects before, but they failed without a market connection*" (President of Coop A, personal interview, 2020). Similarly, the representatives of Coop B acknowledged the constraint, stating, "*We need to explore options with all members through a full assembly, but the existing statutes do not allow us to market crops other than coffee, our business is the coffee*" (President of Coop B, personal interview, 2020). Then, questioned about options without changing statutes, the representatives responded that they could offer technical assistant to management beans and maize, access to credits to procure inputs such as fertilizer for other crops and seeds. "*We could offer technical assistant for other crops and access to credits for inputs such as pests and diseases management and fertilizers*" (President of Coop A, personal interview, 2020) "*Now, we are offering beans and maize seeds and credits*" (President of Coop B, personal interview, 2020).

However, the interviews with the local coffee system actors indicated evidence of a potential demand side in case cooperatives and farmers would engage in local vegetable production. The local supermarket and local groceries located in La Labor said that they were ready and able to procure and offer vegetables from local production if these vegetables met the local demand. A supermarket owner explained:

"*Customers want vegetables, they're growing them in our region, but we do not have anyone to supply them to us. We would like to offer small boxes of fresh food according to demand; for instance, a box with avocado, carrots, onions, patastes (Sechium edule), peppers, and tomatoes for 200 lempiras (US$ 8) for a family. I am sure that it would sell easily and quickly*" (Supermarket owner, personal interview, 2020). This is confirmed by two grocery shop owners (personal interviews, 2020) who stated that:

"*People demand ayote (Cucurbita argyrosperma), broccoli, carrots, onions, patastes, peppers, onions, and tomatoes but the suppliers are not consistent in bringing vegetables. We need around 50 kg of vegetables per week*". (Grocery shop owner, personal interview, 2020).

This evidence demonstrates that local markets need specific kinds and quantities of vegetables each week. Therefore, a local demand for fresh food exists. Bottlenecks are the low local food production and a lack of links between food production and the local markets. For example, one intermediary stated that "*main vegetables could grow here but the producers do not have transport to bring vegetables from farms to the market*" (Intermediary, personal interview, 2020). In addition to that, a grocery show owner emphasizes the need for further support of local farmers to grow vegetables: "*Local producers need technical assistance and credit. Without those, it is not possible to produce with consistency, quantity, and quality of fresh food*" (Grocery shop owner, personal interview, 2020). However, currently the cooperatives do not support their farmers in income diversification and linking them to alternative markets despite the existing market demand.

3.4. Discussion

3.4.1. Impacts on coffee households and the local food system

The vulnerability of local food system already existed before the COVID-19 crisis. Our evidence suggests that coffee households in the study area suffered food insecurity before the pandemic, although beans, maize and some vegetables were grown around them. This could be explained by the lower purchasing power of the more vulnerable coffee households due to their poverty level in the study area. This phenomenon has been termed the food-system paradox by Béné & Devereux, (2023), where a region or country shows a growing malnutrition or food insecurity status. However, this same region could produces food for domestic demand, with the issue being that the produced food moves to neighboring states, following the laws of supply and demand, seeking who can afford to pay for it.

During the lockdowns, those households that were more dependent on coffee income experienced greater food insecurity than the households with diversified incomes such as off-farm labor (e.g., personnel staff of coffee cooperatives who are also coffee farmers and coop members). This is partially explained by their poverty status and their high dependency on coffee, making them more vulnerable to external shocks such as climate hazards and variability of international coffee prices. Similar evidence from Guatemala reveals that households with coffee income dependence have less access to food and less agricultural income than households with coffee and food intercrops (Lopez-Ridaura et al., 2019; van Asselt & Useche, 2022). Bacon , (2021), reported that diversified and better incomes for farmers' households has a positive correlation with their food security in Nicaragua. In addition, coffee farmers with intercropping such as beans and maize, livestock and home-gardens had less months of food insecurity from south of Mexico, despite of high volatile of coffee prices and low availability of food in the local food system (Fernandez & Méndez, 2019). Thus, there is mounting evidence that income diversified households enjoy greater food security than households with a high dependence on coffee as their main income.

Food availability was disrupted at the beginning of quarantine because some fresh food, such as fruits and vegetables come from beyond state and country borders. Also, beans stored by households began to become scarce due to mobility restrictions. This finding is similar to Lopez-Ridaura et al. (2021), who reported that high dependencies on food imports in Central America, such as vegetables and fruit, impacted the food system via supply disruptions during the COVID-19 lockdown. Our finding is in contrast to Harris et al. (2020) and Workie et al. (2020) who reported that food availability disruptions in developing countries occurred due to reductions in fresh food production by vegetable farmers. These latter were unable to deliver their produce to the market, also reporting a reduction in food production due to market interruptions in developing countries.

Informal actors, such as local intermediaries with vehicles (pick-ups) and some local small food producers had an important role in linking local vegetable production and local consumers (transport and distribution) in villages. Without the fresh food shortages would have started already in the beginning of the lockdown. The creation of new food supply channels between local food producers and consumers was also evidenced in South and Central America (Tittonell et al., 2021) and India (Harris et al., 2020). This flexibility of formal and informal actors of food systems was crucial to maintaining sales and reducing food insecurity at the height of the COVID-19 crisis (Reardon & Swinnen, 2020). This study offers new evidence to add to the discussion on resilience strategies in developing countries in specific and informal contexts.

3.4.2. Household responses

Coffee farming households demonstrated limited resilience to cope with negative impacts of mobility restrictions on food security due to high dependency of coffee incomes and poverty status. Indeed, they lacked resilience capacity to keep food security before the COVID-19 crisis. Some coffee farmers were able to maintain access to food through savings, reduced expenses, and assistance from friends and relatives (absorptive capacities), and other measures such as access to credit (adaptive capacities). Evidence from India reveals a similar pattern among farming households, including reductions in household expenses and increased borrowing during periods of mobility restrictions (Harris et al., 2020). Lopez-Ridaura et al. (2021) reported the same pattern for farm households in Central America and Mexico during the first wave of COVID-19. In Perú, Vargas et al., (2021) reported that coffee household farmers used savings and accessed loans to cover household expenses such as food and changed their food consumption behavior (i.e., ate more staple food crops) than animal products. Coffee households’ strategies, such as reducing expenses and taking on financial debt are unsustainable when facing increasingly frequent extreme events (IPCC, 2012). Small-scale coffee farmers in some countries in Latin America are poor and vulnerable, and continuous accumulation of debt without improved incomes could make them poorer and more vulnerable to new extreme events in the long term.

We found little evidence related to adaptive strategies, though more may have evolved after the field research ended. Despite the absorptive strategy of loans between farmers and cooperatives to access and store staple food for the months following the dates of the lockdown, we note that was already a common practice before the pandemic due to the seasonal nature of agriculture and sale markets. Regarding strategies related to transformative capacity, it was too early to capture and discuss any evidence due to the short period of fieldwork during the first months of the pandemic.

3.4.3. Role of cooperatives

The third aspect of the results addressed the role of coffee cooperatives in supporting households' management of food insecurity. Farmers cooperatives' resilience-building strategies, such as food assistance and financial support, can mitigate the impact of extreme events on households' food access in the short-term. The collective actions implemented during mobility restrictions had an important role across the food system. Existing networks between local and national institutions from civil society, such as community based farmers organizations; government; NGOs, and related organizations, are essential for improving food system sustainability of during crises (Tittonell et al., 2021).

The mandate (legal statutes) of the cooperatives in this study is exclusively focused on coffee production, while their members have much more diverse farming systems. Farmer cooperatives often have different orientations; for instance, community orientation (e.g., to enhance food security), or market orientation (e.g., marketing services for coffee), or both (Bijman & Wijers, 2019). Inclusive business could be a means for meeting to farmers' basic needs beyond profit from a cash crop only (Hahn, 2012), thereby reducing poverty though development of inclusive food systems (food value chains) (Vos & Cattaneo, 2021). As Bacon et al. (2014) reported, coffee cooperatives in Nicaragua could be useful in coping with food insecurity through the development of local food system approaches that increase access to beans and maize. A case study conducted in Nicaragua, as reported by Putnam, Cohen, & Jaffe, (2016), highlights that the promotion of an agroecological approach by farmer cooperatives through a project serves as a crucial strategy to enhance food security in coffee communities. This approach plays a key role in fostering food sovereignty and building resilience against economic and weather-related extreme events. In such cases, national institutions and NGOs could promote cooperative members' active inclusion to support local food production and food security within the main goals of the cooperatives and business models. Coffee cooperatives' roles could be extended to partially or comprehensively offer market access services and technical training for growing fresh foods such as vegetables, beans, and maize, facilitating the link between farmers' households and local markets.

The evidence of this research contributes to the debate regarding the importance of local food production to achieve and maintain food security in developing countries (Erokhin & Gao, 2020), which also authors using a food sovereignty perspective have emphasized (Gliessman & Ferguson, 2021; Gliessman, et al., 2019). In this study case, we found a potential opportunity for the coffee sector to promote food security and access to healthy and diversified diets for more vulnerable coffee households through a strategy that integrates coffee cooperatives and their members within the local food system according to their priorities. The link between a higher crop diversity in coffee farming systems and a better dietary diversity was also confirmed by Bacon et al (2023). Notably, coffee farming system diversification appears as a crucial strategy that gives farmers the ability to cope and adapt to shocks such as from the COVID-19 pandemic. This would also follow the transformative potential of the COVID-19 crisis to rebuild the resilience capacity of local food systems, reintroducing diversification and linkages between food production, distribution, and consumers (Gliessman, 2020).

3.5. Conclusions

This work offers valuable insights into local food systems and coffee value chain actors' resilience (e.g., farmers and farmers' cooperatives) under the COVID-19 lockdowns. The certified coffee households were already food insecure before the COVID-19 crisis. Our study also showed that the most vulnerable households, the ones that experience higher levels of food insecurity, are those that depend more on coffee as main source of income. Despite fresh food production in the study area, many coffee farmers did not have access to fresh food from the local food system. This is partially attributed to the fact that the main target market for local food production is the supermarkets in the departmental capitals. Additionally, the purchasing power of these coffee households is impacted by the levels of poverty, further deteriorated during the COVID-19 crisis. Food insecurity further increased among the certified coffee households as markets closed, staple crops and vegetable produce became expensive, and fruits were hardly unavailable.

Our findings contribute to the debate on cash crops versus the integration of food production under the umbrella of local food systems to achieve and maintain food security in developing countries. It also helps identify opportunities for transforming food systems, strengthening food security, and improving access to healthy and diversified diets, especially identifying where cooperatives can contribute to these outcomes. This includes several aspects. First, adaptive strategies to face extreme events such as a lockdown need to ensure that the local food production is linked with local food markets and consumption patterns to ensure the continuous availability of food during extreme events. This should be part of adaptive strategies. Second, coffee cooperatives supported by committed buyers and coffee certification should prioritize and adopt transformative strategies aimed at enhancing the food security of coffee households. This endeavor may necessitate amendments to existing statutes, underlining the need for an inclusive approach in aligning cooperative structures with the evolving challenges in the food security landscape of their members. Thirdly, it is essential to emphasize the significance of crop diversity within coffee farms, a promotion facilitated by cooperatives. This involves actively involving local food market actors, including both formal and informal vendors, contributing to strengthening the resilience of local food systems, especially in the face of extreme events. The coffee sector, especially cooperatives and their partners, should explore innovative strategies that address household needs for food security and strengthen farmers' resilience practices on the farm, such as intercropping with beans, maize, vegetables, and fruits. These approaches should complement certifications, emphasizing the necessity for a comprehensive and collaborative approach in designing and implementing new initiatives within the coffee sector.

Lastly, we underscore that more research is needed to extend both the geographic (in terms of areas covered in and outside Honduras) and temporal (in terms of long-term implications) of the COVID-19 pandemic and other shocks. Future studies should further study the long-term implications of COVID-19 and other recurrent crises over larger geographic areas, as this would help build a robust evidence base to inform adaptation and resilience policy and action.

4. ADVANCING CLIMATE RESILIENCE AND FOOD SECURITY IN SMALLHOLDER COFFEE SYSTEMS: THE ROLE OF CERTIFICATION AND COFFEE INDUSTRY ENGAGEMENT IN HONDURAS

Abstract

Coffee production is a vital livelihood for thousands of households and for local economies in rural areas of Central America. However, climate variation such as droughts and irregular rainfalls has negatively affected food production, household incomes and food security. In response, coffee certification programs and industry stakeholders have promoted agroecological farming practices to address climate variation and enhance the well-being of coffee households. Despite these efforts, there is limited evidence that voluntary standards and certifications effectively improve food security, and many coffee households continue to experience food insecurity. This study aims to identify climate resilience actions promoted by the coffee sector, including certification bodies, traders, and coffee roasters, that could enhance food security among coffee households. The study employed two primary methods: (i) a systematic literature review, and (ii) qualitative interviews with key stakeholders in the coffee sector, including traders, roasters, certification bodies, and industry experts.

Findings reveal that adaptation strategies adopted by coffee farmers throughout Latin America can contribute to food security. Traders and roasters play a critical role in shaping supply chain sustainability; however, their current initiatives do not directly address food security, and there is no market-driven demand to prioritize this issue. While certification schemes offer a valuable framework for promoting sustainability, they do not explicitly address food security, and their effectiveness depends on complementary efforts from coffee buyers and local institutions. Without additional efforts, food insecurity will continue to be a persistent challenge in coffee regions, limiting the long-term resilience of both coffee systems and farming communities, while threatening the sustainability of the entire coffee industry.

4.1. Introduction

Coffee production has a key role as a livelihood for thousands of households and for local economies in rural areas of Central America (FEWSNET, 2014). Climate variation, such as droughts and irregular rains, have had negative effects on food production, incomes and food security in the region (Alpízar et al., 2020; Harvey et al., 2018). As a consequence, food availability and access decrease, particularly impacting the more vulnerable households in the area (FEWSNET, 2023; Harvey et al., 2018).

In response, many coffee farmers have adopted agroecological practices such as shade management for better water retention, often as part of sustainability certification programs (Koutouleas et al., 2022; Pico-Mendoza, et al., 2020). More recently, these practices have been reframed under the umbrella of Climate-Smart Agriculture (CSA) practices (Bunn et al., 2019; Djufry & Wulandari, 2021; Reay, 2019), a framework grounded in three pillars: (i) enhancing food security and income, (ii) adapting to climate change, and (iii) mitigating greenhouse gas emissions (FAO, 2021; Lipper et al., 2014). Evidence suggests that CSA has the potential to strengthen farmer resilience in terms of productivity, food security, and climate risk management (Aggarwal et al., 2018; Prestele & Verburg, 2020; Sain et al., 2017).

The promotion of CSA and other sustainable farming approaches in the coffee sector has been driven by a range of actors, including NGOs, research institutions, national agencies, and through initiatives of buyers and roasters (Grabs, 2018), the latter two often linked to certification schemes and premium market access. Yet, despite widespread adoption of CSA practices, food insecurity persist among coffee households, particularly in Honduras (Rodriguez-Camayo et al., 2025).

Food insecurity among coffee households is not a new phenomenon for the coffee sector. As early as 2007, research by Keurig Green Mountain Coffee Roasters (GMCR), a large specialty coffee roaster in the U.S., and the International Center for Tropical Agriculture (CIAT) presented evidence about a recurring period of seasonal hunger among coffee households—commonly referred to as the "thin months"—, lasting over three months annually (Caswell et al., 2014). In response, certification programs and coffee roasters promoted agroecological interventions such as food storage and on-farm food production, reducing the hunger period to two months by 2012 among farmers in Nicaragua (C. M. Bacon et al., 2014; Caswell et al., 2014; Scholte & De Groot, 2010).

Simultaneously, mid-sized and small specialty coffee roasters such as Intelligentsia (Chicago, U.S.) and Union Hand-Roasted (London, U.K.), developed inclusive business models that emphasized high coffee quality alongside direct engagement with producers, including tailored capacity-building and personal visits to discuss coffee prices, commercial challenges and livelihood issues (Lundy et al., 2012). However, between 2009 and 2016, many of these roasters, including GMCR, Intelligentsia, Stumptown, Blue Bottle, Peets Coffee and others were acquired by multinational corporations such as Jacobs Douwe Egberts (JDE, part of JAB Holding Company) and Nestlé, resulting in the consolidation of corporate power within the global coffee value chain (Grabs, 2018). This shift has contributed to a dilution of earlier sustainability commitments. Moreover, current evidence shows limited impact of voluntary standards and certification schemes on improving livelihoods (Glasbergen, 2018) or food security (Schleifer & Sun, 2020).

Despite the promises of CSA, recent research indicates that households adopting these practices promoted by the coffee sector in Central America continue to experience food insecurity (Rodriguez-Camayo et al., 2025). In Honduras, producers often rely on coping strategies such as reducing expenses (e.g., purchasing less fresh food), using savings and incurring debt to manage shortfalls during extreme events (Alpízar et al., 2020; Rodriguez-Camayo, et al., 2024). These mechanisms, however, are unsustainable in the face of increasingly frequent and severe climate events (IPCC, 2012).

Efforts to integrate food security into sustainability standards, such as the Food Security Standards (Gamba et al., 2020), have yet to gain traction in the coffee sector, particularly in Central America. This limited uptake may stem from the absence of mandatory traceability requirements for food security in importing countries, in contrast to emerging due diligence regulations for instance on deforestation. Additionally, weak incentives and accountability mechanisms among traders and roasters contribute to the lack of concrete actions on this issue.

Given these challenges, this study aims to identify climate resilience actions promoted by the coffee sector, including certification systems, traders, and coffee roasters, that could improve food security in coffee households. To achieve this, the three specific objectives were to (i) determine whether there are agricultural practices that can enhance the climate resilience of coffee systems and improve food security under climatic stress, (ii) explore whether traders and coffee roasters are interested in improving the food security of coffee households, and (iii) identify actions that certification systems, traders and roasters can take to enhance food security for coffee households.

4.2. Methods

The study employed two primary methods, i.e., a) a systematic literature review, and b) qualitative interviews with key stakeholders in the coffee sector, including traders, roasters, certification schemes, and sustainability coffee experts. For the first objective a systematic literature review was conducted to identify agricultural practices and adaptation options aimed at enhancing the resilience of coffee systems to climate variability while improving food security, especially within Latin America and the Caribbean (LAC). For the second objective, the current interests and concrete actions within the coffee sector, specifically from certification schemes, traders, and roasters that extend beyond increasing coffee production, were explored. For the third objective, the way how certifiers can promote climate resilient practices that improve food security among coffee households within the framework of existing certification standards was examined. For the second and third objectives, qualitative interviews with representatives from coffee trading companies, coffee roasters, certification schemes, and experts were conducted to gain insights into broader sectoral perspectives and ongoing initiatives.

For the systematic literature review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses or PRISMA guidelines were followed (Yepes-Nuñez et al., 2021). The review was conducted across four databases (see Figure 4.1): two scientific databases, i.e., Web of Science and Scopus, and two technical databases from the Colombian National Center for Coffee Research (CENICAFE) and the Tropical Agricultural Research and Higher Education Center (CATIE). These sources were used to identify existing studies on resilience practices in agricultural coffee systems in LAC. Additional sources were sought from industry platforms and representatives as recommended by Grabs (2018), including Coffee&Climate, Global Coffee Platform, Sustainable Coffee Challenge, and Hanns R. Neumann Stiftung (HRNS), as well as certification bodies such as Fairtrade, Rainforest Alliance, and 4C. Then, a primary document analysis of companies' websites, policy statements, codes of conduct, certification standards, sustainability annual reports and published interviews to identify their commitments and positions on food security, climate change as well as their actions addressing these issues in practice was conducted.

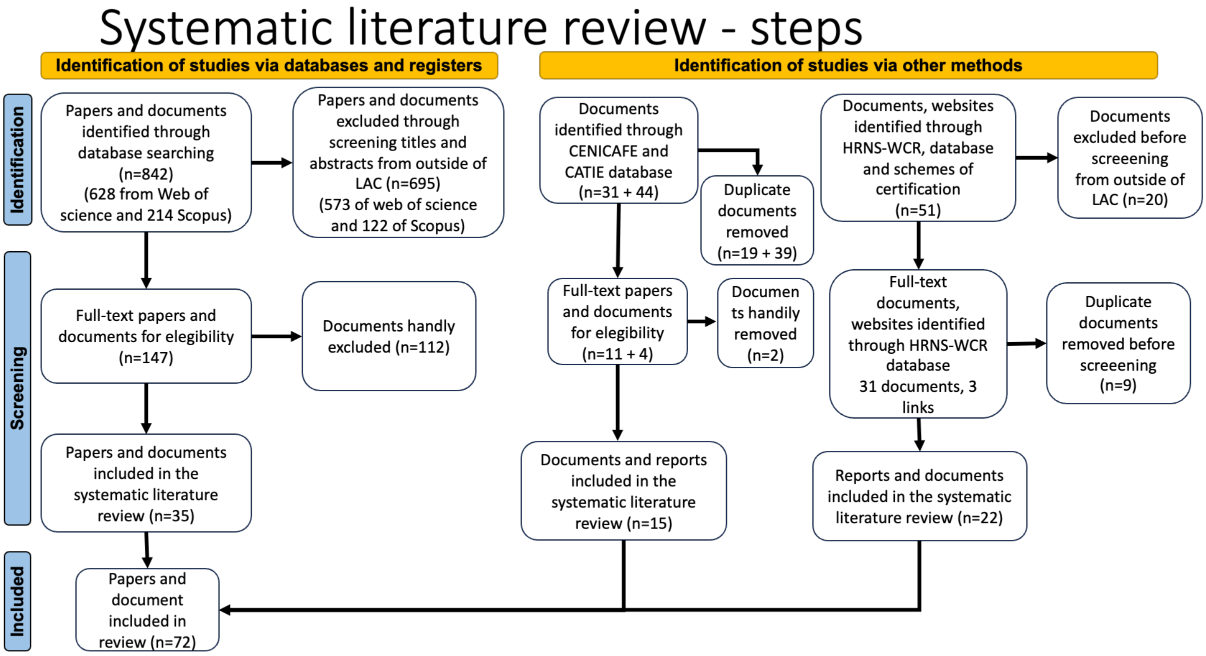


Figure 4.1 Systematic literature review steps following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.

Note: Acronyms used: Hanns R. Neumann Stiftung - HRNS; World Coffee Research – WCR; Tropical Agricultural Research and Higher Education Center – CATIE; Colombian National Center for Coffee Research (CENICAFE); Latin America and the Caribbean – LAC.

For the interviews with stakeholders, participants from green coffee traders, coffee roasters, certification schemes representatives and experts (see table 4.1) were selected based on the following criteria:

<u>Green Coffee Traders:</u>

a) Purchase coffee from at least two Arabica-producing countries in LAC, such as Honduras, Guatemala, Colombia, Peru, Mexico, Brazil, and Nicaragua.
b) Engage in projects related to adaptation, mitigation, and the well-being of coffee growers, (e.g., improving coffee income, enhancing food availability/food production, and supporting income diversification).
c) Supply coffee to at least one of the major global coffee roasters.

The five largest coffee traders, which together control roughly half of the global market, include Neumann Kaffee Gruppe (NKG), Louis Dreyfus Company (LDC), ECOM, ED&F MAN (Volcafe), and OLAM (Coffee Barometer, 2020). These companies source green coffee from coffee-producing countries in LAC and collaborate with farmers and their organizations on field-based projects. However, some of them were reluctant to discuss coffee households' food insecurity. We interviewed representatives from two of these traders, i.e., a representative from OLAM (Honduras) in 2020, and three representatives from HRNS as part of NKG (Honduras, 2020; Guatemala, 2024; Germany, 2023).

Coffee Roasters:

a) Engage in projects focused on adaptation, mitigation, or the well-being of coffee growers.
b) Purchase coffee from at least two Arabica-producing countries in Central America/LAC.
c) Be willing to participate in an interview regarding climate change and food security.

Major coffee roasters include JAB Holding Company (JDE, JDE-Peet's, Dr Pepper, GMCR), Nestlé (Nespresso, Blue Bottle, Chameleon Cold Brew, Nescafé, etc.), Lavazza, Tchibo, JM Smucker, and Starbucks (International Trade Centre, 2021). However, many of these companies were also reluctant to discuss coffee households' food insecurity. Despite this, we secured interviews with one representative from JDE-Peet's in Honduras, one representative from the Specialty Coffee Association of America (SCA) in the U.S., one from Union-Hand Roasted in the U.K., one previous co-owner of 24Grad Kaffeerösterei, a specialty coffee roaster in Germany, and one from the Global Coffee Platform in Germany/Honduras.

Certification Schemes

The certification schemes included in this study are third-party verified and promote practices aimed at improving climate adaptation and coffee farmers' well-being. These schemes address environmental, social, and economic themes within their frameworks. The primary certification schemes relevant to Arabica coffee from Latin American countries include Fairtrade, Rainforest Alliance/UTZ, and Organic. Although 4C certification is most prevalent among Robusta producers (notably in Vietnam, Indonesia, Brazil, and Mexico), it is also becoming increasingly popular for Arabica coffee in Colombia. Recently, 4C has incorporated Food Security Standards into its certification criteria in collaboration with the

German NGO Welthungerhilfe. Interviews were conducted with two representatives from Fairtrade (El Salvador and Germany), two from Rainforest Alliance (Guatemala), one from Welthungerhilfe (Germany), and two from 4C (Germany).

Expert Interviews

Finally, experts were interviewed based on their experience with climate adaptation and food security strategies for coffee communities in LAC. These experts were independent of affiliations with coffee traders and roasters. The selected interviewees included a representative from CENICAFE, a sustainability expert focused on LAC coffee, and a representative from the Alliance Biodiversity/ CIAT with extensive experience in coffee communities.

Table 4.1 Interviews from the coffee industry and experts

Actors	Interviewed	Countries
Coffee roasters' representatives	5	U.S., Germany and U.K.
Coffee traders' representatives	4	Honduras, Guatemala, Germany
Certified schemes and representatives	6	Germany, LAC, Global
Experts and others	3	Colombia, LAC
Total	18	

4.3. Results

4.3.1. Options to adapt coffee systems to climate variation while enhancing food security

The literature review identified three main approaches frequently promoted by coffee industry stakeholders across LAC to enhance climate adaptation while supporting food security: (i) multipurpose agriculture practices with focus on adaptation or CSA practices, (ii) agroecology, and (iii) regenerative agriculture (Figure 4.2). These approaches often overlap in practice and reflect evolving priorities within the coffee sector.

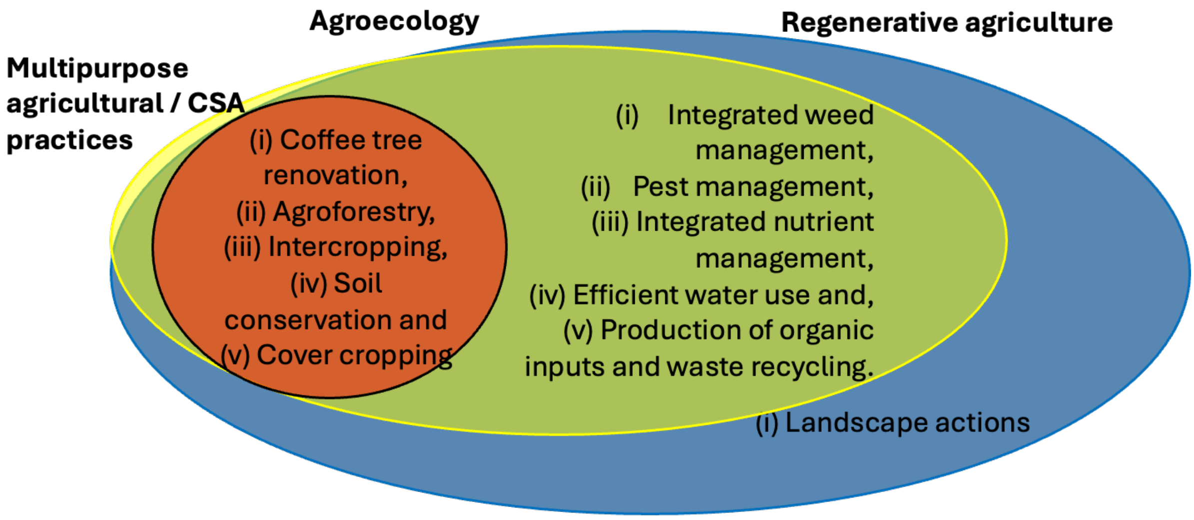


Figure 4.2 Consolidated agricultural practices across approaches promoted by the coffee industry in Latin America and the Caribbean.

(i) Multipurpose agriculture / climate-smart agriculture

The literature review revealed that CSA practices include both long-standing traditional techniques and those formalized under the CSA framework. In Mesoamerica, for example, coffee has been successfully integrated into the traditional *milpa* polyculture system in the local communities (Casanova-Pérez, 2018), which is resilient and food production system that includes beans, maize and other local food crops (Anderzén et al., 2020; Drexler, 2022).

Key CSA practices identified in the literature include:

- Soil and water management, such as the use of cover crops like *Brachiaria brizantha* and *Crotalaria spectabilis* to enhance moisture retention (Anzueto, 2020).
- Agroforestry, especially permanent shade using species like nogal, pine, and eucalyptus, which helps regulate soil temperature and prevent erosion (Alvarez-Alvarez et al., 2021; Cerda et al., 2020).
- Intercropping systems, integrating temporary shade crops such as maize, beans, plantain, cassava, and vegetables (CENICAFE, 2004; Lopez-Ridaura et al., 2019; Moreno-Berrocal & Mestre-Mestre, 1995).
- Pollinator support (e.g., honey production) and livestock integration, which contribute to food availability and income diversification (Chain-Guadarrama et al., 2021; Guzmán-Luna et al., 2022).

The reviewed publications provide substantial evidence that these integrated systems have the potential to enhance food availability and diversified household income, improving resilience among coffee-growing families across Mesoamerica and South America (Granada-Diaz et al., 2008; Guzmán-Luna et al., 2022; Haggar et al., 2021; Moreno Berrocal, 2005). Many shade and intercropping practices are tightly linked to soil management and cover crops strategies. Notably, the widespread promotion of cover crops such as *B. brizantha* and *C. spectabilis* are consistently cited as the most promoted response to heat and water stress in Central America coffee systems (Anzueto, 2020; CIAT, 2018; Hanns R. Neumann Stiftung, 2025).

Another adaptation strategy frequently highlighted in the literature is coffee tree renovation, a process that involves replacing aging coffee trees with diseases-tolerant and climate-resilient varieties. This practice is particularly important in regions affected by rising temperatures and humidity, which have intensified the spread of diseases such as coffee leaf rust (*Hemileia vastatrix*) (Dalberg Advisors, 2017; Federacion Nacional de Cafeteros de Colombia, 2018).

These renovation programs have received extensive support from public and private actors, including coffee exporters, roasters, development agencies (e.g., USAID, GIZ), and financial institutions such as Root Capital, International Finance Corporation – IFC, Inter American Development Bank (BID), and national institutions from coffee growing countries (Dalberg Advisors, 2017). More than US$ 1,2 billions has been invested for 40 coffee tree renovation programs between 2008 and 2014, 24 of which were in Latin America (Dalberg Advisors, 2017).

Despite the scale of investment in coffee renovation, the literature indicates that opportunities to enhance food security during the renovation period remain underutilized. For example, the use of temporary shade crops such as legumes like tefrosia (*Tephrosia candida*) or guandul (*Cajanus cajan*) is promoted to protect young coffee trees (Anzueto, 2020), but intercropping with food crops like maize, beans or plantain during this transition phase is still limited across the region (Granada-Diaz et al., 2008; Jaramillo Cardona & Salazar Echeverry, 2021; Moreno-Berrocal & Mestre-Mestre, 1995).

Evidence from Colombia suggests a more integrated approach, where national institutions, including the National Federation for Coffee Growers (FNC), incorporate food security and nutrition into renovation programs. For instance, new maize and bean varieties developed in collaboration with international partners have been biofortified with iron and zinc to address nutritional deficiencies in coffee growing communities (Jaramillo Cardona, 2023).

Table 4.2 Multipurpose agricultural / CSA practices identified in the consulted literature that enhance coffee productivity, improve food availability, or generate additional household income

Agricultural practices	Country	Households' well-being			References
		Cash crop production and yields	Food Availability / self-production	Additional income	
Coffee trees renovation / rehabilitation	México, El Salvador, Honduras, Nicaragua, Guatemala, Colombia, Perú, Brazil	X	X	X	(Anzueto, 2020; Dalberg Advisors, 2017; Granada-Diaz et al., 2008; Rendón Saenz, 2016)
	Colombia	-	X	X	(Jaramillo & Salazar, 2021)
Agroforestry	Colombia	-	X	X	(Goncalves et al., 2021)
	Colombia	-	-	X	(Farfan-Valencia, 2014)
	Costa Rica	-	X	X	(Alvarez-Alvarez et al., 2021)(Cerda et al., 2020)
	Colombia	X	-	-	(Acosta-Alba, Boissy, Chia, & Andrieu, 2020; De Leijster et al., 2021)
	Honduras and Guatemala	-	X	X	(Anzueto, 2020)
Intercropping	Belize, México, Guatemala and Honduras	-	X	X	(Drexler, 2022)
	Honduras, Guatemala, México and Colombia	X	X	X	(Lopez-Ridaura et al., 2019; Moreno-Berrocal, 2011)
	Colombia	X	X	-	(Acosta-Alba et al., 2020; Jaramillo & Salazar, 2021)
	Costa Rica	X	X	-	(Chain-Guadarrama et al., 2021)
	Colombia	X	X	X	(Granada-Diaz et al., 2008; Jaramillo Cardona, 2023; Moreno-Berrocal & Mestre-Mestre, 1995)
	Guatemala, Costa Rica, Honduras, Nicaragua & El Salvador	X	X	X	(Haggar et al., 2021)
	Perú, México, Nicaragua, Brazil	X	X	X	(Guzmán-Luna et al., 2022)
	Brazil	X	-	-	(Teixeira et al., 2021)
	Guatemala	X	-	-	(Charbonnier et al., 2017)
	Costa Rica, Honduras, Guatemala	X	-	-	(Harvey et al., 2017)

Soil conservation practices and cover cropping	Colombia	X	-	-	(Hincapié-Gómez & Salazar-Gutiérrez, 2007; Lince Salazar et al., 2018)

(ii) Agroecology

The reviewed literature identified agroecology as a second key approach for adapting coffee systems to climate variability while enhancing food security. Unlike CSA, agroecology adopts a holistic framework that extends beyond on-farm practices to include agroecosystem services, local food systems, cultural heritage, and food sovereignty (Dagunga et al., 2023; Gliessman, 2016; Gliessman et al., 2019). This integrative perspective enhances both ecological sustainability and social resilience, particularly among smallholder coffee farming communities (Dittmer et al., 2023; Gliessman et al., 2019)

Agroecological practices commonly described in the literature include a diverse range of ecological and socio-cultural strategies, including agroforestry and intercropping system described before:

- Soil and pest management, including composting biomass from harvested beans and maize, organic inputs, and pollinator habitat support (Babin, 2015; Sachet et al., 2021; Wezel et al., 2020).
- Cultural preservation, such as farming rituals and traditional food systems (Dagunga et al., 2023; Guzmán-Luna et al., 2022).

These practices are cross-referenced in Tables 4.2 and 4.3 and demonstrate the multiple functional roles of agroecology in strengthening agroecosystem resilience.

Case studies from Mexico and Nicaragua further illustrate the food security benefits of agroecological approach. For example, Escamilla P. et al. (2005) and Guzmán-Luna et al. (2022) document how cooperatives-supported intercropping systems enabled coffee-producing households to diversify diets and incomes by cultivating fruits, vegetables, beans, and maize. In these contexts, cooperatives not only facilitated on-farm diversification but also strengthened local food markets, thereby reinforcing food availability at the community level.

Additional findings emphasize that income diversification whether through food retail, cooperative labor, or on farm crop diversification is positively associated with households food security (Rodriguez-Camayo et al., 2025). Composting of crop residues and organic nutrient cycling are also commonly promoted within agroecological systems as strategies for improving soil health, closing input loops, and reducing dependence on synthetic fertilizers (Babin, 2015).

While the literature highlights a diverse range of agroecological practices at the farm level, documentation of their broader application and use such as integration into local food systems, cultural dimensions, or community-based governance remains limited within coffee systems in LAC.

Table 4.3 Agroecology practices identified in the consulted literature that enhance coffee productivity, improve food availability, or generate additional household income. (*) This practice is part of a regenerative agriculture approach.

Agricultural practices	Country	Households' well-being			References
		Cash crop production and yields	Food availability / self-production	Additional income	
Integrated weed management	Costa Rica, Colombia	X	-	-	(Hincapié-Gómez & Salazar-Gutiérrez, 2007; Moreno Berrocal, 2005; Virginio Fiho et al., 2021)
Integrated pest management	Colombia	X	-	-	(Constantino et al., 2015; Gil Palacio et al., 2015)
Integrated nutrient management	Colombia	X	-	-	(Diaz Poveda & Sadeghian, 2020; Sadeghian, 2022; Sadeghian & Duque Orrego, 2021)
Efficient water use	Colombia	X	-	-	(Oliveros Tascón et al., 2022; Oliveros Tascón et al., 2018; Valencia Rodriguez et al., 2015)
Production of organic inputs and waste recycling	Colombia	X	-	-	(Dávila & Ramírez, 1996; Rendón et al., 2015; Rodríguez-Valencia, 2023)
Landscape actions*	Colombia	X	-	-	(Harvey et al., 2021; Lentijo, Gomez, & Botero, 2013; Lince Salazar et al., 2018)

(iii) Regenerative agriculture

The literature reviewed identified regenerative agriculture as the most recently emerging approach among the three analyzed. It is gaining momentum in coffee-producing regions of LAC, particularly through initiatives promoted by private-sector actors such as Nespresso, JDE-Peets, and Rainforest Alliance. As described in the reviewed sources, regenerative agriculture integrates principles from agroecology and sustainable intensification (Giller et al., 2021), with a focus on enhancing climate resilience, restoring soil health, and conserving biodiversity (Pulleman et al., 2024). Key practices include improved soil and water management, organic input production, increased on-farm biodiversity, agroforestry, and renovation or rehabilitation of coffee trees (Pulleman et al., 2024; Schreefel et al., 2020).

Although evidence on the application of regenerative agriculture in coffee systems is still emerging, some studies point to co-benefits that extend beyond environmental restoration. For example, Guzmán-Luna et al. (2022) report that the use of organic nutrient recycling, combining coffee pulp, food waste, and livestock manure, not only contributed to improved soil fertility but also facilitated small-scale livestock production like poultry chicken, eggs and dairy products.

However, the literature provides limited documentation of regenerative agricultures' broader application or systematic integration into food security strategies within LAC coffee systems.

4.3.2. Interest and concrete actions within the coffee sector toward improving food security among coffee households

4.3.2.1. Responsibility to act on food insecurity

The literature and stakeholder interviews revealed that addressing food insecurity among coffee households remains a voluntary responsibility for coffee traders and roasters. These actors typically operate through corporate sustainability departments, which implement a code of conduct designed to demonstrate compliance with environmental, social and economic minimum standards in their sourcing regions (Global Coffee Platform, n.d.; JDE Peets, 2023; Olam, 2018; TCHIBO, 2023). Actions are usually informed by risk assessment at both national and subnational levels, in line with buyer operations (Fairtrade International, 2025; Rainforest Alliance, 2023).

These codes are commonly framed to meet European legislative expectations such as the German Supply Chain Due Diligence Act and the EU Deforestation Regulation (4C Services GmbH, 2024b). While they demonstrate interest in sustainable production models, including agroecology and regenerative agriculture, they do not explicitly reference the right to food. Although the final EU Directive[3] refers to the aforementioned Article 11 of the UN Social Covenant, it remains unclear how companies can fully uphold the right to food across their

[3] https://data.consilium.europa.eu/doc/document/ST-6145-2024-INIT/en/pdf

supply chains. Despite this legal ambiguity, most interviewed stakeholders emphasized the shared responsibility between public and private actors in addressing food insecurity within coffee growing communities:

"I believe there is a shared responsibility within the coffee sector. On one side, there are the guilds (exporters and importers), the private sector, and of course the public sector, which plays a fundamental role because it's not just about poverty but also public goods, like roads, energy, access to clean water, etc." (Coffee and rural development expert, personal interview, 2024)

"Knowing the best approach to improving food security is complicated... The problems are so big that different types of solutions are needed at different levels, from cooperatives to the municipal level, etc." (Specialty coffee buyer, interview, 2024)

"I think big problems need big solutions, and these can only be achieved through alliances between various actors, such as municipalities, governments, producer organizations, households, NGOs, buyers, and others." (Certified scheme representative in LAC, interview, 2024)

In many developing countries, however, national governments face financial and institutional constraints, often prioritizing urban or national development over rural communities, limiting support for infrastructure, technical assistance in food production, or the development of the local food markets:

"Technical assistance systems in Latin America practically don't exist at the level of small producers—they've been dismantled. Genetic improvement in plants and animals isn't geared towards family farming systems. These require heavy technological inputs, which small farmers can't afford." (Coffee expert, interview, 2024)

For the coffee industry, addressing food insecurity is a challenge. For some specialty coffee roasters, their typical response to food insecurity involves improving incomes by paying slightly higher coffee prices. However, interpretations of what constitutes "better payment" vary:

"I prefer to pay more than the market price, rewarding coffee quality, and with that, I ensure consistent quality and quantity year by year from a cooperative." (Specialty coffee buyer, interview, 2024)

"For us, the food security is associated with income, we believe that if coffee farm income is stable, families can purchase food. But from a nutritional perspective, we may need a better understanding." (Certifier representative, interview, 2024)

Other stakeholders expressed that low-price sourcing strategies still dominate, hindering progress on food-related outcomes:

"We are looking for similar coffee profiles where pricing is more favorable. Honduras for example, it is a great option because we can find good coffee profiles at better prices compared to other Latin-American countries. However, when coffee quality improves due to coffee projects, we often cannot purchase it because the prices increase." (Coffee buyer, interview, 2024)

"Some roasters only focus on buying coffee as cheaply as possible and refuse to pay certification premiums offered by cooperative." (Exporter, interview, 2020)

"In some countries where the living income is being implemented, the market only buys one container at that price, and the rest is bought without certification, just so they can say they are supporting living income." (Certifier representative, interview, 2024)

Recently, pilot programs in Honduras and Kenya have integrated the right to food into Food Security Standards (FSS), as part of "due diligence" in two certification schemes. These initiatives involve producers, cooperatives, buyers, certifiers, and a German aid organization:

"We have seen good improvements in Kenya after four years. Coffee farmers now have access to water, no longer experience lean periods, and enjoy more transparent payment schemes." (FSS representative, interview, 2024)

"In Central America, the certified producers showed no hunger periods during a rapid assessment, and they received the FSS label." (FSS representative, interview, 2024)

Despite these pilots, food security remains largely absent from most corporate codes of conduct. When asked why this issue has not been more widely adopted, many interviewees pointed to a lack of interest from both consumers and industry players while others chose not to comment, reflecting the topic's sensitivity and complexity.

4.3.2.2. The interest of traders and coffee roasters in addressing food insecurity among coffee households

While food insecurity continues to affect coffee-growing communities in Central America, industry engagement with this issue appears limited and declining. Interviewees noted that food insecurity was a visible concern in the early 2000s, often addressed by NGOs and international development efforts supported by coffee companies. Today, however, industry priorities have shifted toward climate adaptation and mitigation, deforestation, and coffee productivity.

"*The industry does not understand the food insecurity of coffee households and has no interest in understanding or addressing it. Their focus is in improving yields, developing climate resilient varieties, and agricultural practices." (Coffee expert, personal interview, 2024)*

"For the coffee industry, food insecurity is not really a priority. They talk about it in their narrative, such as Nespresso clusters, but their priority is the supply and quality of coffee. In the context of regenerative agriculture, food security is not the priority." (Coffee expert, interview 2024)

Industry actions are also shaped by global policies addressing broader social and environmental concerns such as deforestation, child labor, and gender inclusion, often response to regulatory pressure and reputational risk:

"Right now, the only real industry concern is deforestation. No one is thinking about food security, just deforestation." (Certified representative, personal interview, 2024)

"To be honest, there are so many issues we must keep an eye on like gender, climate change, child labor, etc. Basically, it all boils down to how much a coffee producer should earn from their harvest. There are great ideas, but resources are very limited, and you must allocate them where that will have the greatest impact." (Specialty coffee buyer, interview, 2024)

"Exporters and big retailers in Germany don't know what food insecurity looks like on the ground. They think the food insecurity is the picture about people need humanitarian aid, but when it comes to child labor, there is awareness because it is seen as a business risk." (Coffee and rural development expert, interview, 2024)

Furthermore, industry stakeholders often assume that food insecurity exists primarily outside of certified supply chains, though they lack evidence to support this claim:

"Food insecurity is found among marginal coffee producers, who are not certified, not accessing specialized markets or only selling their coffee to middlemen." (Certified scheme representative in LAC, interview, 2024)

Also the certifiers representatives have clear information about the food insecurity of coffee farmers, here two examples,

"Our coffee farmers do not experience food insecurity, although we do have detailed information, we believe that this is an issue faced by coffee farmers who are not certified and are not part of a coffee cooperative. This is more common among subsistence farmers, and our coffee producer are not subsistence producers." (Certified representative, personal interview, 2024)

"We do not have studies or data. However, this varies from country to country. In some countries where there is a focus on monoculture, there will certainly be greater food insecurity problems. But in countries and coffee farmers organizations that have understood the importance of diversification for climate resilience, and as a source of income and of dietary diversity, they are in a better condition. Those are the context in which our coffee organization operate." (Certified representative, interview, 2024).

Large-scale industry representative and specialty coffee roasters report having no direct knowledge or monitoring systems related to food insecurity, focusing instead on broader economic indicators:

"We don't know anything about food insecurity of coffee households at local level, we know about poverty issues but at a country level through the Fairtrade Risk Map tool." (Specialty Coffee buyer, interview, 2024)

"We don`t have any specific work on food security because the key issue for us is the equitable distribution of value." (Coffee industry representative, interview, 2024)

"People in the coffee sector don't know what food insecurity or malnutrition is. That's not visible when the food insecurity starts, so no action is taken". (Coffee buyer, interview, 2024).

4.3.3. The role of certification systems, traders and roasters in enhancing food security

Certifications schemes such as Fairtrade, Rainforest, and 4C share common goals but differ in their implementation approaches. They primarily provide services to the coffee value chain, especially coffee roasters, coffee producers and their organizations by offering frameworks to assess environmental, social, and economic indicators at origin, as well as to meet due diligence obligations. Their role includes diagnosing existing conditions and recommending actions for compliance. However, certification schemes alone do not necessarily lead to behavioral change or encourage the adoption of improved agricultural practices unless coffee roasters or traders actively support projects promoting practices aligned with certification approaches, such as agroecology, regenerative agriculture, or climate-resilient farming practices.

For example, Fairtrade within the coffee industry supports farmers' resilience to climate events through projects and initiatives in Central America by working with cooperatives in three areas: (1) identifying environmental risk, (2) developing adaptation management plans, and (3) promoting agroecological practices on coffee farms.

"*You could refer to these resilience practices as Climate-Smart Agriculture (CSA), organic practices, or regenerative agriculture. In the end, all of these practices must follow an agroecological approach and be adapted to different local contexts.*" (Certified representative, personal interview, 2024).

Through the Fairtrade premium, cooperatives receive additional resources which can be allocated to support actions that align with certification goals. Recently, Fairtrade has also promoted living income and living wage standards to ensure that basic needs such as housing, food, education are met (Fairtrade International, 2023). These standards address a wide range of human rights and sustainability concerns, including child labor, forced labor, gender equality, and environmental protection. However, they do not explicitly include food security or address the risk of coffee household food insecurity.

Part of the premium price paid by the coffee buyers for certification can be used by cooperatives to implement actions that help meet certification standards.

"*We don't have specific food security standards in our policy, but Fairtrade does outline expectations for farmers' cooperatives to improve democratic decision-making, such as how cooperatives should provide services to their members and the procedures for electing leaders...*" (Certified representative, personal interview, 2024)

4C also offers a specific set of criteria to address challenges in the coffee supply chain, such as equity, women's empowerment, carbon footprint reduction, and food security

(4C Services GmbH, 2024a). Although the coffee sector has access to food security standards, there is limited demand for their implementation from coffee buyers. All the interviewees stated that they were not aware of any existing food security standards reflecting their poor interest to address it.

Recently, Rainforest Alliance signed agreements with two major coffee roasters Nespresso and JDE-peets (Peets, 2024; Pulleman et al., 2024; Rainforest Alliance, 2022), to include regenerative agriculture with their coffee supply chains (see Figure 4.3). Rainforest Alliance's certification incorporates regenerative agriculture through a framework built on four interconnected pillars: i) forest and biodiversity – conserving forests, reducing deforestation, and increasing biodiversity; ii) climate – enhancing resilience and using nature-based solutions like agroforestry to mitigate carbon emissions, provide shade, and prevent soil erosion; iii) rural livelihoods – supporting sustainable livelihoods, improving household incomes through better yields, and expanding access to specialty markets; and iv) human rights – addressing child labor, forced labor, gender equality, and indigenous workers' rights.

Interviewees noted that a key motivation behind regenerative agriculture is the high cost of synthetic fertilizers, exacerbated by global disruptions such as COVID-19 and the war in Ukraine. Soil management, agroforestry, and biofertilizers are now promoted to reduce external input dependence.

"*I have been working on the projects for 15 years, and the practices labeled as "regenerative agriculture" today are the same practices we promoted before.*" (Coffee buyer, interview, 2024)

"*We come from Good Agriculture Practices – GAP, then moved to Climate Smart Agriculture – CSA, environmentally friendly agricultural practices and now, Regenerative Agriculture, but these all involve similar agricultural practices, such as shade management, soil management, biofertilization, pruning, etc.*" (Specialty coffee buyer, interview, 2024)

As outlined in earlier sections (see Tables 4.1, 4.2, and Figure 4.2), these practices widely applied in LAC can contribute to food availability, income diversification, and can lower production costs, while also supporting climate adaptation and mitigation (see Figure. 4.3).

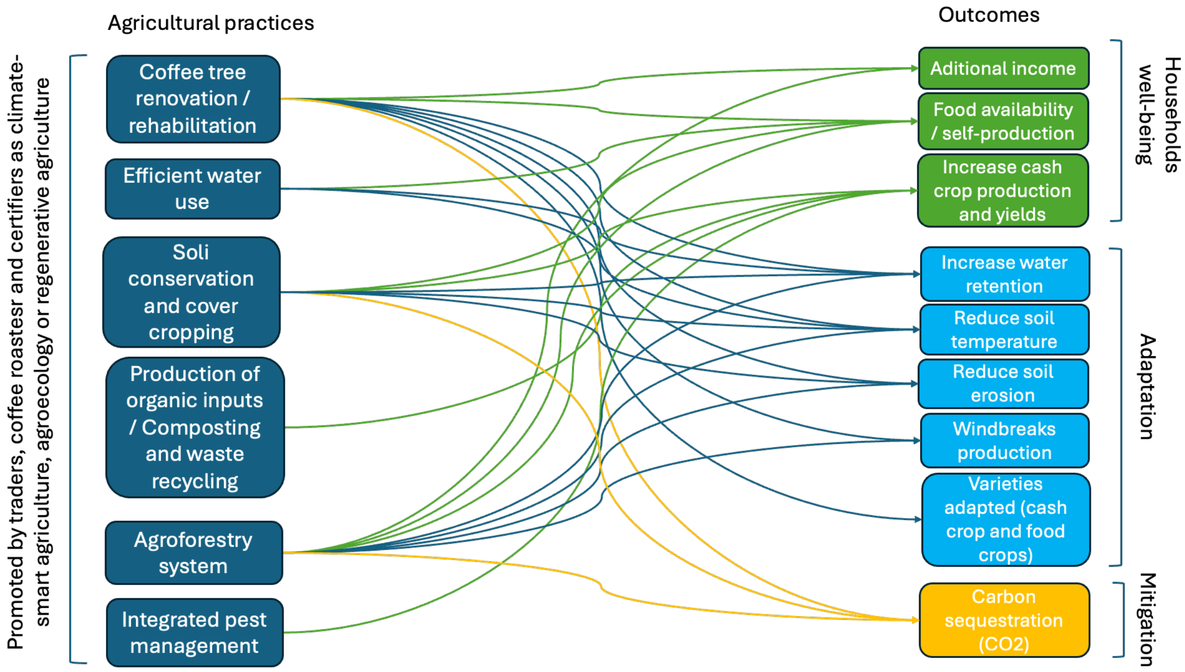


Figure 4.3 Main approaches with practices applied by the coffee industry on coffee farms in LAC, along with their outcomes reported in the literature review.

Yet, when we asked to the interviewees why such practices, which could enhance food availability, are not specifically promoted for food security, interviewees pointed to the lack of sustainability of food-related projects after external funding ends. Additionally, they noted an absence of clear evidence explaining producers' limited interest or engagement.

"We promoted home gardens for food production at coffee farms through projects, but they have not worked, coffee farmers don't like them." (Coffee buyer, interview, 2024)

"In the past, we promoted honeybee production and food home gardens with a certifier in Guatemala and Honduras. We started with 80 coffee farms, but after three years, only 3 or 4 farms still maintained their food home gardens, it is not sustainable, farmers were not interested." (Specialty coffee buyer, interview, 2024).

Nevertheless, there are ongoing efforts to integrate food-producing trees into coffee systems.

"We are promoting new adaptation strategy and food security with fruit trees, we called 5x1 strategy, every five lines of coffee trees, we promote a line of fruit tree according to the local environmental conditions, such as banana or lemon for lowlands or avocado for highlands." (Coffee industry representative, interview, 2024).

The interviewees suggested that the food crops promoted on coffee farms are often well-suited to local environmental conditions. However, it remains unclear whether these crops align with the specific dietary needs and food demands of coffee households and their communities. This disconnect reflects broader gaps within the coffee industry, which still lacks a comprehensive understanding of food insecurity, effective strategies to address it, and the motivation to make it a priority.

Many interviewees highlighted the importance of implementing due diligence to address food security in value chains linked to Europe. However, opinions varied regarding its potential benefits and challenges for coffee-growing households. Some interviewees argued that the industry is unlikely to address food security voluntarily and would only act if legally mandated:

"The industry doesn't understand the food insecurity faced by coffee households and has no interest in understanding or acting. There's no demand to address household food insecurity beyond empty speeches, pretty photos, and hiding behind certification labels, which don't actually solve the problem. That's why due diligence for food security is essential." (Coffee and rural development expert, personal interview, 2024)

"One challenge is that European consumers are not yet prepared to bear the higher costs of sustainability. Ultimately, consumers will have to cover the costs, but buyers are also reluctant to reduce their profit margins." (FSS representative, interview, 2024)

Some interviewees expressed concern that applying due diligence for food security could create inequalities, leaving the most vulnerable producers excluded from better-paying markets:

"Due diligence for deforestation has already created imbalances among producer organizations. Buyers are aggressive, refusing to purchase coffee from suppliers without georeferenced farm data. Those lacking this data are excluded from the market." (Certified representative, interview, 2024)

"Adding more criteria for food security, especially within certifications, is challenging. Every new set of criteria brings investment needs that producers cannot afford.

Forcing this won't work—solutions must be voluntary for producers, not mandatory." (Cooperative representative in LAC, interview, 2024)

The coffee industry has been implementing agricultural practices, such as agroforestry, soil conservation, and organic input production, which could contribute to improving food security and diversifying household incomes. However, interviewees emphasized that a stronger commitment is needed from farmers, cooperatives, and coffee buyers to address this issue effectively. Many stakeholders suggested that the inclusion of a clear mandate for food security within due diligence frameworks could catalyze more coordinated and impactful actions across the industry.

4.4. Discussion

4.4.1. Climate adaptation strategies and their impact on food security

The climate adaptation strategies promoted by coffee industry actors in LAC, including coffee buyers, ONGs and certification representatives, can be broadly categorized into three overlapping approaches: a) multipurpose agriculture practices focused on adaptation or climate smart-agriculture practices, b) agroecology, and c) regenerative agriculture, which has gained prominence more recently.

While distinct in branding and emphasis, these approaches share several core agricultural practices: coffee tree renovation, agroforestry systems, intercropping, soil conservation, cover cropping, and efficient water management. These practices support both climate adaptation and, potentially, improved food security outcomes. The finding of the research contribute to existing debates on the intersections of resilience, food security, coffee production, and climate adaptation (e.g., Aggarwal et al., 2018; Prestele & Verburg, 2020; Sain et al., 2017).

Despite the reported high promotion of these practices by the coffee sector, food insecurity remains prevalent among coffee producers (Rodríguez-Barillas et al., 2024; Rodriguez-Camayo et al., 2025). However, some regions in LAC have demonstrated that tailoring these agricultural strategies to local nutritional needs can lead to meaningful improvements.

While recent research highlights a high adoption rate of climate adaptation practices among coffee producers, food insecurity remains widespread (Rodríguez-Barillas et al., 2024; Rodriguez-Camayo et al., 2025). However, some cases from LAC demonstrate that climate change adaptation practices can contribute positively to household food security, particularly when tailored to local needs within local stakeholders. For instance, integrating coffee renovation programs with the cultivation of staple crops enriched with micronutrients such as iron and zinc has proven effective in addressing nutritional deficiencies (Jaramillo Cardona, 2023; Jaramillo Cardona & Salazar Echeverry, 2021). Case studies from Mexico and Nicaragua further illustrate the food security benefits of agroecological approach. Escamilla P. et al. (2005) and Guzmán-Luna et al. (2022) document how cooperative-supported intercropping systems enabled coffee-producing households to diversify both diets and incomes through the cultivation of fruits, vegetables, beans, and maize. Findings of this research contribute to guiding policymakers, particularly by highlighting the importance of incorporating local needs such as food insecurity into the design of resilience practices that focus on both on-farm and off-farm outcomes, where cooperatives not only facilitated on-farm diversification but also strengthened local food markets, thereby reinforcing food availability at the community level.

These examples suggest that climate adaptation practices can strengthen food systems and contribute to diversified and nutritious diets in coffee-growing communities (Gliessman, 2020; Rodriguez-Camayo et al., 2024). However, realizing this potential requires intentional design that explicitly considers both dietary and economic needs.

4.4.2. The role of traders and coffee roasters in supporting food security

Despite the persistent issue of food insecurity among coffee-producing households, industry stakeholders, including buyers and certifiers, lack concrete data on its prevalence and impact. Many industry stakeholders assume that food insecurity primarily affects marginal or non-certified producers, leading to a lack of targeted interventions. This perception, rooted in limited evidence, fosters inaction and prevents meaningful engagement with the issue.

Furthermore, food insecurity is frequently misunderstood within the sector. It is often conflated with acute humanitarian crises, whereas in reality, it often manifests as chronic conditions such as seasonal hunger and limited dietary diversity. This narrow framing could contribute to its invisibility in sustainability agendas and weakens incentives for actions.

This study's findings reveal that the implementation of food security standards in the coffee value chain is largely dependent on the willingness of buyers to prioritize the issue. Existing research has mostly focused on producers and certification bodies (Schleifer & Sun, 2020), but broader industry dynamics, especially the role of voluntary commitments, remain underexplored.

Corporate responsibility efforts are often shaped by legal frameworks like the German Supply Chain Due Diligence Act. Yet, these frameworks do not explicitly mandate food security measures. As a result, industry-led initiatives tend to emphasize topics like deforestation, labor rights, and climate change, while overlooking the basic nutritional needs of farming households. Despite growing evidence on food insecurity among coffee producers (e.g., Bacon, 2015; Caswell et al., 2014; Morris et al., 2013; Rodriguez-Camayo et al., 2024), household vulnerability persist (Alpízar et al., 2020; Harvey et al., 2018; Rodriguez-Camayo et al., 2025).

While traders and roasters play a critical role in shaping supply chain sustainability, their current efforts do not directly address food security, and there is no market-driven demand to prioritize this issue.

4.4.3. The potential and limitations of certification systems and coffee buyers

Certification programs such as Fairtrade, Rainforest Alliance, and 4C promote sustainable farming practices that could indirectly support food security. However, food security remains peripheral in most certification standards. Only 4C includes specific criteria, yet implementation is limited due to low demand. Interviewees revealed that many coffee buyers were unaware that food security standards even exist.

While certification systems create valuable frameworks for promoting sustainability, they rarely lead to substantial behavior change without complementary investment or direct support from traders and roasters. In the absence of market incentives or regulatory pressure, certification alone is unlikely to significantly improve household food security.

Some industry stakeholders acknowledge the need for collaborative action, including stronger partnerships between the private sector, governments, NGOs, and producer organizations (see Glasbergen, 2018; Meemken, 2020; Schleifer & Sun, 2020). However, government agencies in coffee-producing regions often lack the resources to implement food security initiatives at scale. This leaves producers without access to infrastructure, technical assistance, or local markets that could enhance their household food security.

Over the past decade, the coffee industry has been allocating resources to sustainability initiatives and multi-stakeholder programs in coffee growing regions, such as Coffee&Climate, Global Coffee Platform and Sustainable Coffee Challenge (Grabs, 2018; Wright et al., 2024). These multi-actor initiatives present an opportunity to enhance food security for coffee households and reduce poverty. For example, coffee tree renovation programs—frequently funded through public-private partnerships—could be reimagined to include food security components, such as income diversification and household nutrition, alongside existing adaptation goals.

Nonetheless, without stronger coordination, clearer accountability, and a defined industry mandate to address food security, these initiatives are unlikely to deliver systemic improvements. As it stands, food insecurity remains a secondary concern within most sustainability agendas in the coffee industry.

4.5. Conclusion

This study explores the role of certification systems, traders and coffee roasters in improving the food security of coffee households while adapting the coffee system to climate variation.

The findings highlight key agricultural practices that enhance both climate resilience and food security, the interest of coffee industry actors in addressing these issues, and underscore the potential role of certification systems and coffee buyers could play in tackling food insecurity.

Climate adaptation strategies in the coffee sector, including multipurpose agriculture, agroecology, and regenerative agriculture, offer promising solutions for improving both coffee production resilience and household food security. Common agricultural practices such as coffee tree renovation, agroforestry systems, intercropping, soil conservation, and efficient water management contribute to both goals. However, while some regions in Latin America and the Caribbean have successfully linked agricultural adaptation to food security, widespread food insecurity persists among coffee-producing households. This indicates that climate adaptation strategies must be designed more intentionally to address both food insecurity and economic challenges faced by coffee farmers.

Despite growing awareness of food insecurity in coffee communities, traders and roasters have not systematically prioritized food security initiatives. A key barrier is the assumption that food insecurity primarily affects marginal or non-certified producers, leading to a lack of targeted interventions. Additionally, corporate social responsibility efforts tend to focus on climate change, deforestation, and labor rights, while food security remains a secondary concern. Given that coffee traders and roasters are not legally required to address food insecurity in their supply chains, voluntary commitments have had unclear results. The findings suggest that the implementation of food security actions within the coffee value chain depends largely on the priorities of coffee buyers, reinforcing the need for broader industry engagement on this issue.

Certification programs such as Fairtrade, Rainforest Alliance, and 4C promote sustainability but do not directly address food security. While 4C includes food security as an additional standard, there is minimal demand for its implementation from coffee buyers. The impact of certification on food security remains limited without additional support from traders, roasters, and local institutions. Multi-stakeholder initiatives present opportunities to integrate food security into coffee sustainability efforts. However, without stronger coordination, investment, and accountability from industry actors, food security will remain an overlooked aspect of coffee sector sustainability.

To effectively improve food security while adapting coffee systems to climate change, the coffee sector must take a more proactive and integrated approach. Certification systems, traders, and roasters should:

- Incorporate food security as a clear measurable component of sustainability initiatives.
- Promote research and data collection to better understand the extent of food insecurity among coffee households.
- Integrate food security criteria into the selection of agricultural adaptation practices, ensuring the inclusion of food crops that meet the nutritional needs and market demand of local communities.
- Implement participatory adaptation strategies that address the needs of coffee households, including income diversification, food security, and climate adaptation within coffee systems.

- Strengthen partnerships among private-sector actors, governments, NGOs, and producer organizations to implement long-term food security strategies tailored to local contexts.

Without efforts, food insecurity will continue to be a persistent challenge in coffee producing regions, limiting the long-term resilience of both coffee systems and farming communities, while threatening the sustainability of the coffee industry.

5. CONCLUSIONS AND OUTLOOK

5.1. Main findings of the thesis

The main findings of the studies conducted within the context of this thesis are summarized, clustered into three groups and used to draw overarching conclusions. These findings directly address the challenges of climate vulnerabilities and food insecurity, emphasizing the practical implications of adaptive strategies and resilience building measures for coffee households in Central America, particularly in Honduras.

5.1.1. Coffee households' characteristics and coping mechanisms

Coffee households in Honduras face significant challenges related to climate variability and non-climate events. As coffee remains the primary source of income for many households that heavily depend on coffee production, they are more susceptible to income fluctuations and food insecurity. Understanding the characteristics of these households and the coping mechanisms they employ is essential to identifying strategies that enhance resilience and reduce vulnerability to climate and non-climate shocks.

- The findings suggest that diversified households, whose income relies more on off-farm labor and less on coffee, tend to have a higher probability of being food secure. Conversely, coffee-specialized and coffee-dependent households are more frequently associated with food insecurity and higher poverty levels.
- Although half of the coffee households suffer food insecurity in the study region, the most vulnerable households for climate hazards and external shocks are those that depend highly on coffee as main source of income.
- The majority of coffee households either lacked strategies in the face of food insecurity under climate hazards or had to resort to financial measures, such as reducing expenses or accessing credits. Their current strategies are unsustainable considering the projected long-term climate changes in Central America and the high variability of coffee market prices.
- Current climate resilience agriculture practices promoted by the coffee stakeholders, which primarily focus on improving coffee productivity, appear limited in addressing the broader adaptive needs of households. This indicates a critical gap between the strategies

promoted by coffee stakeholders and the actual requirements of coffee farmers to secure their livelihoods and food security.

5.1.2. Coffee stakeholder perceptions and actions

Stakeholder engagement within the coffee value chain is critical to bridging the gap between climate resilience and food security. While certification schemes and industry platforms and initiatives promote sustainable practices, they often fail to adequately address food security challenges. Strengthening stakeholder collaboration and commitment can enhance the effectiveness of adaptive strategies and promote comprehensive support for coffee households.

- Climate adaptation strategies in the coffee sector throughout Latin America, including multipurpose agricultural practices, agroecology practices, and regenerative agriculture practices, offer promising solutions for improving both coffee production resilience and household food security. Common agricultural practices such as coffee tree renovation, agroforestry systems, intercropping, soil conservation, and efficient water management contribute to both goals.
- Despite growing awareness of food insecurity in coffee communities, traders and roasters have not systematically prioritized food security initiatives. A key barrier is the assumption that food insecurity primarily affects marginal or non-certified coffee producers, leading to a lack of targeted interventions. The findings suggest that the implementation of food security actions within the coffee value chain depends largely on the priorities of coffee buyers, reinforcing the need for broader industry engagement on this issue.
- Certification programs such as Fairtrade, Rainforest Alliance, and 4C promote sustainability but do not directly address food security. While 4C includes food security as an additional standard, there is minimal demand for its implementation from coffee buyers. The impact of certification on food security remains limited without additional support from traders, roasters, and local institutions. Multi-stakeholder platforms and initiatives present opportunities to integrate food security into coffee sustainability efforts. However, without stronger coordination, investment, and accountability from industry actors, food security will remain an overlooked aspect of coffee sector sustainability.

5.1.3. Local food system dynamics

Local food production plays a vital role in enhancing food security, particularly during crises when external supply chains may be disrupted. Strengthening the connection between local production and local markets is crucial to ensure continuous food availability. This approach not only mitigates the impacts of climate shocks but also builds resilience in rural communities dependent on coffee production and other agricultural activities.

- Although some farms in the study region grow vegetables and staple food exclusively for supermarkets located in the capitals of states, local consumption depends on fresh food coming from outside of the state and country.
- The local food market has a high demand for fresh fruits, vegetables and staple food even before the pandemic, but limited local food production supply the local market.
- Informal intermediaries played an important role during lockdowns, transporting fresh food from neighboring states and outside the country to rural areas, especially coffee growing communities.

This study contributes to the debate on cash crops versus the integration of food production under the umbrella of local food systems to achieve and maintain food security in developing countries. It also helps identify opportunities for transforming food systems, strengthening food security, and improving access to healthy and diversified diets, especially identifying where cooperatives can contribute to these outcomes. This includes several aspects.

- First, adaptive strategies to face climate and non-climate events, particularly during extreme conditions, need to ensure that the local food production is linked with local food markets and consumption patterns to ensure the continuous availability of food during extreme events. This should be part of adaptive strategies. For example, traders, roasters, and certifiers can continue to promote agricultural practices through their projects and programs with suppliers, with the addition of a targeted approach that encourages integrating food crops into shade and soil management practices. These efforts should consider: a) identified climate risks, b) food preferences in local markets, and c) local nutritional needs, drawing on malnutrition data from governments and NGOs, for example.

- Second, coffee cooperatives supported by committed buyers and coffee certification should prioritize and adopt transformative strategies aimed at enhancing the food security of coffee households. This endeavor may necessitate amendments to existing statutes, underlining the need for an inclusive approach in aligning cooperative structures with the evolving challenges in the food security landscape of their members. Thus, coffee cooperatives could also market the fresh, nutritious foods produced by their members in local markets, thus linking local food production with local markets.
- Third, it is essential to emphasize the significance of crop diversity within coffee farms, a promotion facilitated by cooperatives. This involves actively involving local food market actors, including both formal and informal vendors, contributing to strengthening the resilience of local food systems, especially in the face of extreme events. For example, coffee households can participate, alongside their organizations, in designing and adapting resilient coffee practices that also meet household needs for increased income and improved access to fresh, nutritious foods, including during times of scarcity. This approach builds on traditional agricultural systems, like the milpa in Mesoamerica, and more recent agroecological approaches.

5.2. Outlook

The findings of this thesis highlight the complexity of achieving both climate resilience and food security among coffee-growing households in western Honduras. While the adoption of CSA practices shows potential for improving productivity and climate adaptation, their limited application in addressing household food security remains a key challenge. Moving forward, future research for development should expand beyond productivity of specific cash crops to include farmers' households and local communities, particularly the factors influencing farmers' decision making and the socio-cultural contexts of climate resilience agricultural practices adoption. As demonstrated in Chapter 2, households reliant on coffee as their primary income source are more vulnerable to food insecurity. Therefore, promoting diversified farming models becomes imperative to reduce vulnerability and enhance household resilience.

One significant research gap is the long-term socio-economic impact of integrating climate resilience agricultural practices like regenerative agriculture or agroecological approaches into coffee systems. Future studies should examine how diversified agricultural models can sustainably balance coffee production with food availability and income diversification, especially in regions prone to extreme climate and non-climate events. Further research should examine how improved socio-economic conditions for coffee households can strengthen sustainable commercial relationships between farmers, coffee cooperatives, traders and coffee roasters. Additional studies should also explore how integrating different food production systems into coffee communities such as using manure from livestock (e.g., poultry, cows) to produce biological fertilizers, can benefit both coffee and food crops, while simultaneously enhancing food availability through products like dairy and eggs. Comparative analyses between coffee regions in Central America (Nicaragua, Honduras, México) and Colombia and Perú in South America or Kenya and Ethiopia in Africa could provide insights into the generalizability and scalability of these practices, according to their local contexts.

Capacity-building programs should be prioritized to increase farmers' understanding and adoption of adaptive practices. Stakeholders, including cooperatives and extension services, must work collaboratively to deliver training that addresses both technical skills and practical knowledge of diversified farming and develop new agri-business models. Such initiatives will help ensure that farmers are better equipped to face the challenges posed by climate variability and socio-economic pressures.

5.3. Policy implications

To enhance the resilience and food security of coffee households, policy interventions should be grounded in the realities faced by smallholder farmers. One of the most significant steps forward would be to embed food security considerations within sustainability initiatives of the coffee sector. This could include the development of new standards explicitly linking sustainable coffee production with households' food availability and/or nutritional outcomes.

Incentivizing agroecological and regenerative agricultural practices should be a priority here. Governments and development organizations could establish public-private partnerships to support multipurpose agriculture that not only boosts coffee productivity but also integrates staple crops and livestock systems. Inclusive agri-business development, financial incentives and technical assistance could motivate cooperatives to adopt and promote diversified production systems towards strengthening local food systems. For instance, agroecological initiatives in Colombia have successfully combined coffee production, especially during coffee tree renovation, with staple food cultivation (plantain, tomatoes, maize and beans with high contain of iron), leading to both increased income and enhanced food security, and particularly aiming to address nutritional deficiencies for vulnerable population. Drawing from such examples can guide similar interventions in Honduras.

Furthermore, strengthening local food systems is crucial to enhancing community resilience. Policies should encourage the formation of community-based food hubs and local agri-business models that connect local producers with school-feeding programs (via public procurement) or local markets, thereby stabilizing food supplies for more vulnerable population during time of crises. However, implementing these strategies requires overcoming challenges such as limited technical knowledge, financial constraints, and market access. Addressing these obstacles through targeted capacity-building and fostering inclusive agri-business models is essential for sustainable outcomes.

Stakeholder collaboration remains essential to addressing the multidimensional challenges of food insecurity and climate change. Coffee buyers and roasters should be encouraged to adopt a broader perspective on sustainability by actively engaging with local communities and supporting initiatives that address food insecurity alongside environmental issues of coffee systems.

Finally, monitoring and evaluation frameworks must be strengthened to assess the impact of CSA practices on both productivity and food security outcomes. Data-driven approaches can help policymakers and practitioners understand which strategies are most effective under varying socio-economic and environmental conditions.

5.4. Strengths and limitation of the thesis

The strengths of this thesis include the consideration of the following points that could enhance food security in the context of coffee communities in western Honduras.

5.4.1. Strengths:

- **Interdisciplinary Approach:** By examining three dimensions—coffee households, local food systems, and coffee stakeholders—this research provides a holistic perspective on the food security challenges faced by coffee households. It also highlights the current limitations of climate resilience strategies promoted within the coffee sector.
- **Timely Contextual Analysis:** The evaluation of coffee household food security before COVID-19 and during the initial lockdowns of 2020 offers exceptional insights into how households and local food systems respond to external shocks. This analysis contributes valuable lessons for crisis preparedness and adaptive strategies.
- **Stakeholder Perspectives:** By incorporating the viewpoints of diverse stakeholders—including coffee farmers, technicians, cooperatives, traders, roasters, and industry experts—this research provides a comprehensive understanding of the coffee sector's sustainability challenges and opportunities.
- **Contextual Depth:** Focusing on western Honduras, the study provides practical relevance to local adaptation strategies while also contextualizing findings within broader LAC experiences. Additionally, the systematic literature review on climate resilience and agricultural practices across LAC contributes to the depth of understanding of coffee system resilience and food security.

5.4.2. Limitations:

- **Gender-Specific Insights:** Due to the lockdown restrictions, data collection by gender was constrained, limiting the ability to capture gender-specific perspectives on food security. This gap hinders a deeper understanding of how men and women differently perceive and experience food security challenges.
- **Industry Engagement Limitations:** The limited participation of European coffee industry stakeholders in interviews restricted the study's ability to comprehensively understand the sector's commitment to the sustainable livelihoods of coffee households. A more extensive engagement would have enriched insights into industry-driven sustainability initiatives.

- **CSA Adoption Analysis:** This study did not evaluate the actual adoption of CSA practices among coffee households. Consequently, the research cannot fully assess the practical implementation and on-the-ground effectiveness of recommended CSA strategies.

5.5. Closing remarks

This thesis has demonstrated the inherent interconnectedness between coffee production, climate adaptation, and food security. By identifying key challenges and proposing forward-looking strategies, this research aims to contribute to academic discourse and outline practical solutions for enhancing the resilience of coffee-growing communities in Honduras and beyond.

Addressing food insecurity in coffee-growing regions requires collective action from stakeholders across the coffee value chain, local communities and governments. Policymakers, certification organizations, coffee buyers, and local cooperatives must work together to transform coffee systems into models of sustainable agriculture that are resilient, inclusive, and food secure.

The path forward is challenging yet rich with opportunities for innovation and collaboration. By prioritizing food security within coffee sustainability efforts and fostering inclusive, community-centred approaches, the sector can build a resilient and prosperous future for the next generation of coffee-growing communities while ensuring long-term business sustainability for the coffee industry.

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