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32nd International Conference of Agricultural Economists
2-7 August 2024 I New Delhi I India

Sustainability standards in agri-food value chains: impacts and trade-offs for smallholder farmers

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Abstract

The global agri-food system faces major challenges of meeting growing food demand in an equitable way, while mitigating environmental impacts such as deforestation, soil degradation and climate change. Voluntary sustainability standards (VSS) have surged in recent decades as a potential instrument to foster more sustainable global value chains and sourcing practices. While the number of VSS impact evaluations is growing, most studies focus on a single outcome dimension. In this paper, we propose a conceptual framework to assess the effects of VSS interventions on sustainable food system outcomes in three dimensions, considering potential trade-offs between them. To illustrate key trade-offs identified in our conceptual framework, we present empirical data from three case studies in Ghana, Rwanda, and Peru. Our empirical results shed light on associations between certification and various outcomes, including agricultural yields and income, biodiversity at farm and landscape scales, female empowerment, and food security. We highlight the importance of balancing trade-offs in multiple sustainability dimensions and assessing VSS performance within the broader policy and landscape context. Our study contributes to ongoing discussions on the effectiveness of VSS in promoting sustainability while highlighting potential trade-offs that must be addressed to achieve more sustainable food systems.

JEL Codes: Q56, Q13, D13, Q18

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Keywords: certification, sustainable food systems, food security, dietary diversity, gender equity, biodiversity conservation, impact evaluation, coffee, cocoa

JEL codes: Q01, Q13, Q57, J22

Introduction

The global demand for tropical cash crops, such as coffee, cocoa, palm oil and soybeans, continues to rise, driven by consumer preferences and international trade (Kastner et al. 2021). However, the rapid expansion of agricultural plantations has significant environmental and social costs, including deforestation and biodiversity loss (Curtis et al. 2018). While cash crop farmers often fare better economically than subsistence farmers (Achterbosch et al. 2014), they still face substantial challenges, including market exclusion, poor livelihoods, inadequate working conditions, and vulnerability to highly volatile prices (Meemken et al. 2021; Garrett et al. 2021; Starobin 2021). These issues are further compounded by climate change, which threatens to render many current growing areas unsuitable for production (Grüter et al. 2022; Ariza-Salamanca et al. 2023), thereby exerting immense pressure on the environment and rural livelihoods, disproportionately affecting women (Andrijevic et al. 2020).

In light of these challenges, transitioning towards more sustainable food systems is imperative (Ambikapathi et al. 2022). Sustainable food systems are central to achieving the UN Sustainable Development Goals, including universal access to healthy diets, while safeguarding the environment and building inclusive communities (FAO 2018b). In the context of tropical cash crop agriculture, sustainable food systems would entail access to stable markets and fair prices for cash crop producers, ensuring economic prosperity and food security, while at the same time promoting environmentally friendly farming practices to protect and recover local ecosystems. Another key dimension of sustainable food systems is the provision of equitable working conditions and opportunities. This includes promoting gender-inclusive practices that empower women and provide them with equal access to resources (Njuki et al. 2022).

Voluntary sustainability standards (VSS) have emerged as a potential tool to address multiple sustainability goals in global sourcing of tropical cash crops (Traldi 2021). Originally developed with varying foci, VSS have gradually converged in their objectives to encompass comprehensive sustainability goals (Lambin and Thorlakson 2018; Meemken et al. 2021). Traldi (2021) provides an overview of thirteen major international agricultural VSS and their key characteristics, principles, and criteria covering environmental, social and economic dimensions. Garrett et al. (2021) review eight VSS that pursue conservation and livelihood objectives simultaneously. Most VSS encourage, e.g., the adoption of sustainable farming practices, which can improve soil health, increase biodiversity, and reduce environmental impact. Many VSS also facilitate access to inputs and fair prices, aiming to enhance agricultural productivity and economic stability of farming households. Furthermore, VSS commit to supporting gender equity by enacting human and labor rights and offering gender-sensitive training (Garrett et al. 2021; Traldi 2021).

A large body of literature evaluates whether VSS contribute to economic, environmental, and social outcomes. However, most studies focus on only one dimension at a time. This single-dimension focus can obscure potential trade-offs between different types of outcomes (Garrett et al. 2021; Rubio-Jovel 2023; Rubio-Jovel et al. 2024; Barbier and Burgess 2019). In this paper, we address whether VSS can effectively support sustainable food system outcomes for smallholder farmers in international cash crop sectors, by considering multiple dimensions of sustainability. We propose a conceptual framework that brings together three dimensions of sustainable food systems - healthy ecosystems, economic prosperity, and equity - and identifies key trade-offs between them. We present data from Ghana, Rwanda, and Peru to provide empirical evidence on whether VSS can balance these diverse and often competing objectives inherent in sustainability efforts. Based on the conceptual framework and empirical findings, we derive recommendations for future certification efforts and future research evaluating such efforts.

Literature review: Can VSS support sustainable food system outcomes?

Sustainable food systems provide food security and nutrition for all without compromising the economic, environmental and social capacity to do so in the future (FAO 2018b). This requires balancing often competing objectives. Barbier and Burgess (2019) note the existence of trade-offs and synergies among sustainable development goals and the importance of considering them more explicitly. In the remainder of this section, we review the current evidence on whether VSS can contribute to sustainable food system outcomes in international cash crop sectors, focusing on the three sustainability dimensions: economic prosperity, healthy ecosystems, and equity.

Can certification increase economic prosperity?

Most economic studies focus on the impact of VSS on economic outcomes, including yields, prices, net crop income and total household income. Overall, the economic effects of VSS for farm households seem moderately positive (Meemken et al. 2021; Oya et al. 2018), although individual case studies show varying combinations of significant and non-significant relationships. Several studies show positive yield effects due to more intensive input use and agricultural training provided to certified farmers (Iddrisu et al. 2020). However, other studies show no yield effects (Boonaert and Maertens 2023; Gather and Wollni 2022), or even negative yield effects, especially for organic certification (Meemken 2020; Beuchelt and Zeller 2011). Similarly, the effects of VSS on producer prices vary depending on the certification scheme. Yet, even if there is a significant increase in prices, it is often not substantial enough to compensate for higher production costs (Boonaert and Maertens 2023; Garrett et al. 2021). Ultimately, the combination of production cost, price and yield effects determines the extent to which VSS affect net crop incomes. While some studies find no significant effects of VSS on net crop incomes

(Boonaert and Maertens 2023), many studies do find positive effects, with some VSS showing more consistent results than others (Akoyi and Maertens 2018; Dompreh et al. 2021a; Meemken 2020; Mitiku et al. 2018; Sellare et al. 2020b). Additionally, the evidence points to a positive, albeit small and highly context-specific, link between certification and total household income (Schleifer and Sun 2020; Meemken 2020; Garrett et al. 2021).

Different VSS impose different requirements and offer different services to certified farmers, accordingly, the mechanisms through which they influence economic outcomes vary (Boonaert and Maertens 2023; Meemken et al. 2021). As long as the overall effects on income are positive, we can conclude that VSS are contributing positively to the economic outcome dimension. However, the mechanisms that lead to income improvements at the farm level may have divergent effects on the environmental outcome dimension. Thus, economic outcomes should not be considered in isolation.

Can certification maintain and restore healthy ecosystems?

Many studies evaluating the environmental performance of VSS focus on the adoption of sustainable agricultural practices, like organic fertilizer, mulching, shade trees, or integrated pest management. These practices are expected to improve environmental outcomes at the farm level. Several studies find positive associations between certification and adoption (Haggar et al. 2017; Ibanez and Blackman 2016; Gather and Wollni 2022) However, there is variation across different practices, crops and standards, and some studies report small or no effects (Meemken 2021). In analyzing the impact of certification on climate resilience among cocoa farmers in Ghana, Thompson et al. (2022) emphasize that certification is successful in promoting basic management practices, like fertilization, but has no significant influence on more complex resilience strategies, like agroforestry diversification.

To draw meaningful conclusions on VSS's contribution to healthy ecosystems, it is necessary to assess the actual effects on key biodiversity and ecosystem outcomes (Tscharntke et al. 2015). Such evidence on whether certification indeed improves ecological on-farm conditions is much more limited and inconclusive (Meemken et al. 2021). Furthermore, many ecological studies are based on very small sample sizes (Hardt et al. 2015), since comprehensive ecological on-farm assessments are time-consuming. Some larger studies compare plot-level shade tree crown cover, shade tree diversity, invertebrate diversity and carbon stocks between certified and non-certified coffee farms. These studies find mixed effects, ranging from positive and non-significant to negative, depending on the VSS and environmental indicator considered (Vanderhaegen et al. 2018; Haggar et al. 2017; Thompson et al. 2022).

Given their focus on on-farm conditions, these studies do not capture potential environmental spillovers and landscape effects of certification (Meemken et al. 2021; Tscharntke et al. 2015). Ecosystem health and biodiversity, however, depend on processes at larger landscape scales (Tscharntke et al.

2015). Many VSS include regulations and requirements regarding zero-deforestation and reforestation (Garrett et al. 2021), making forest protection, landscape connectivity, and habitat maintenance relevant environmental outcome measures at larger scales. Only a few studies evaluate these aspects of VSS using remote sensing data (Traldi 2021). While there seems to be a tendency for certified coffee systems to show positive (albeit small) landscape effects (Takahashi and Todo 2017; Hardt et al. 2015; Asante et al. 2022; Rueda et al. 2015), overall findings are mixed and depend on the type of VSS, crop and geographic location (Carlson et al. 2018; Lee et al. 2020; Morgans et al. 2018; Garrett et al. 2021).

Very few studies examine economic and environmental dimensions simultaneously (Garrett et al. 2021). The few that collect both environmental plot-level data and economic household data from the same farmers find mixed results. For instance, Vanderhaegen et al. (2018) analyze certification among Ugandan coffee farmers and find trade-offs between economic and environmental dimensions that vary by the type of VSS. Fairtrade/Organic certification has positive effects on shade tree crown cover, shade tree diversity and invertebrate diversity, but negative effects on coffee yield, labor productivity and income. In contrast, UTZ/Rainforest Alliance/4C certification has positive effects on the economic outcomes, but negative effects on most environmental outcomes, except for shade tree diversity. Haggar et al. (2017) find positive effects of VSS on many, but not all, environmental outcomes and on some economic outcomes. Generally, they observe trade-offs between tree diversity and economic outcomes, however, these trade-offs are somewhat mitigated for certified famers who receive higher prices.

Can certification improve gender equality in outcomes?

While the evidence shows a positive, albeit small, link between certification and income, little is known about the intra-household distribution of costs and benefits (Traldi 2021). Earlier studies on cash crop agriculture have found that specialization and commercialization can exacerbate intra-household inequalities, since men often take control of crop revenues at the expense of women (Katz 1995; Njuki et al. 2011; Fischer and Qaim 2012). VSS can address these issues through gender measures, such as strengthening women's inclusion in producer organizations and conducting trainings on gender mainstreaming (Meemken and Qaim 2018). Recent literature reviews on the effects of VSS on various sustainability dimensions, however, conclude that the evidence on gender effects is scarce and that the few existing studies mostly find non-significant or even negative effects on gender empowerment (Traldi 2021; Rubio-Jovel 2023).

Evaluating the labor implications of VSS is important, since poor households, and especially women, are often time-constrained (Daum et al. 2023; Lyon et al. 2017). Labor-intensive practices associated with certification can negatively influence women's workload, depending on the prevailing social norms regarding the division of labor (Arora and Rada 2020; Lyon et al. 2017; Bolwig 2012). The existing evidence is scarce and mostly qualitative, but indicates that women are often affected by higher time burden, since they are responsible for many of the labor-intensive tasks associated with certification (Lyon et al. 2010; Lyon et al. 2017; Bolwig 2012). On the other hand, previous research has shown that greater involvement of women in the production activities of certified crops can lead to higher participation in decision-making and control over crop revenues (Meemken and Qaim 2018).

A focus on gender equity and empowerment is especially important when evaluating VSS impacts on nutrition outcomes, since female-controlled income has been found to contribute more significantly to food security and nutrition than male-controlled income (Doss 2013; Malapit and Quisumbing 2015). Although several studies have shown a positive link between VSS, income and food security/dietary quality (Schleifer and Sun 2020; Becchetti and Costantino 2008; Meemken et al. 2017), there are also examples that reveal no effects or even negative effects on food security and dietary quality, despite yield and income increases associated with certification (Dompreh et al. 2021b; Iddrisu et al. 2020; Meemken et al. 2017). It is therefore crucial to consider equity-related outcomes and assess whether income increases benefit all household members equally. While the literature on the links between certification, female empowerment, and nutrition is very scarce, a notable exception is the study by Chiputwa and Qaim (2016), which finds that female empowerment is an important pathway through which VSS affect household dietary quality.

Conceptual framework: Assessing VSS impacts on sustainable food system outcomes

Based on the literature review, we develop a conceptual framework to guide assessments of the effects of VSS on sustainable food system outcomes and potential trade-offs between dimensions. VSS can influence food system outcomes through different types of interventions (Boonaert and Maertens 2023). In line with the three dimensions of sustainable food systems outlined above, we distinguish between environmental, economic and equity-related interventions (see Figure 1).

Environmental interventions include regulations and requirements regarding zero-deforestation and reforestation on the farmer’s land and in its surroundings (Garrett et al. 2021). They also relate to the promotion of sustainable agricultural practices, such as integrated pest management, mulching, and agroforestry, as well as to the provision of access to environmental inputs, such as native shade tree seedlings (Schulte 2020). VSS should then – through these interventions – lead to more sustainable farm management, healthier soils, and increased biodiversity on and around certified farms, contributing to ecosystem health (Tscharntke et al. 2015).

Economic interventions include training on good agricultural practices, access to agrochemical inputs and improved crop varieties, as well as price premiums for certified produce. VSS should then – through these interventions – lead to increases in prices, input use, yields and income (Boonaert and Maertens 2023). If the certified activity represents a substantial share of overall household income and if it does not absorb labor resources from other more remunerative income-generating activities, higher income from the certified crop should contribute to the economic prosperity of the household.

Equity-related interventions include strengthening collective action, e.g., through producer organizations and cooperatives, and providing gender-related awareness training. VSS should then – through these interventions – increase women's time agency, their participation in decision-making and their control over income, which should contribute to female empowerment and equal access to resources for all household members, including food and nutrition security (Morgan and Zaremba 2023).

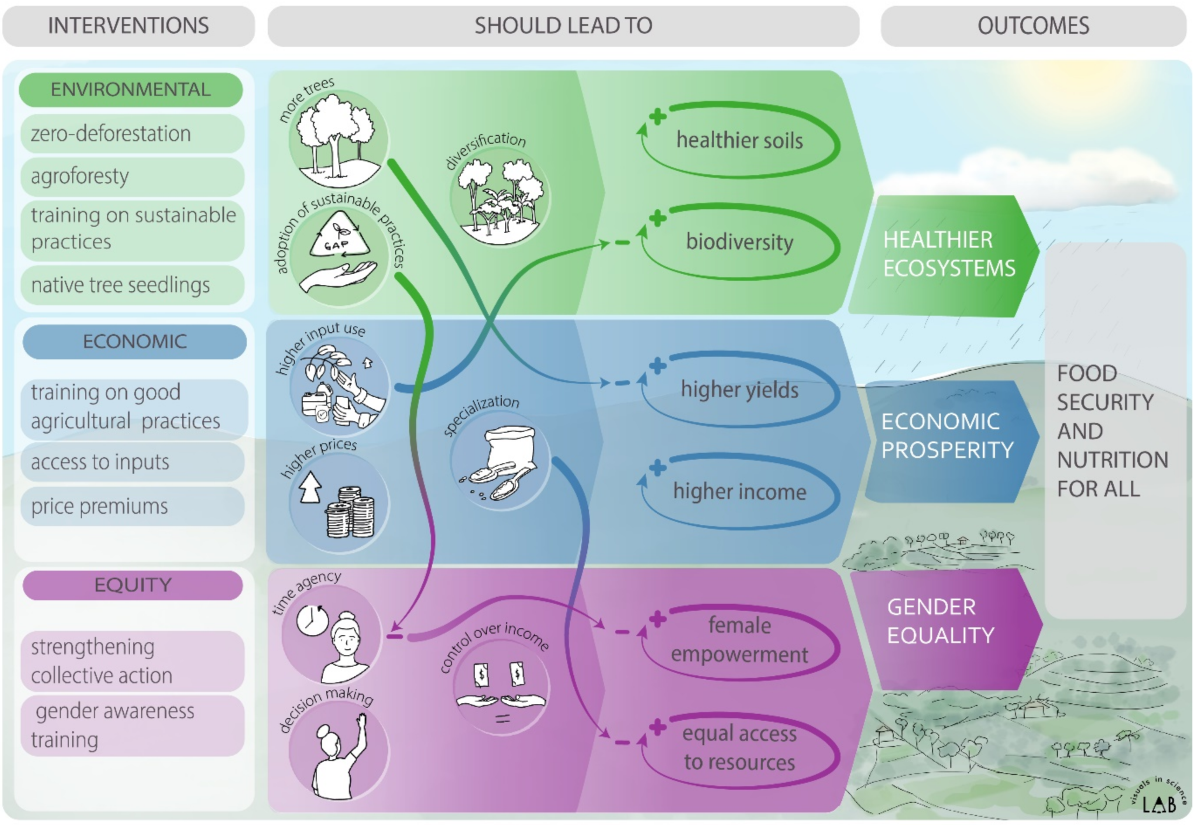

Figure 1: Conceptual framework
Graphical design by Visuals in Science LAB (www.visualsinscience.com)

While these interventions are designed to contribute to a specific sustainable food system outcome, they may have negative side effects on other outcomes. In this context, it is important to recognize that it is often not possible to maximize all outcomes simultaneously. Barbier and Burgess (2019) stress the importance of explicitly considering trade-offs and synergies between different sustainability goals. In the following, we highlight some of the trade-offs frequently identified in the literature:

Environment-economy trade-offs: VSS promote sustainable farming practices, including agroforestry, in cash crop plantations to improve ecosystem health. At the same time, these practices may reduce yields, e.g., shade trees and cash crop trees might compete for nutrients (Asitoakor et al. 2022; Blaser et al. 2018). On the other hand, many VSS promote the adoption of agrochemical inputs to increase agricultural yields (Sellare et al. 2020a), but with potentially adverse effects on biodiversity. It is therefore critical for research to consider both economic and environmental outcomes to assess *whether VSS can simultaneously achieve economic and environmental improvements at the farm level*.

Environment-equity trade-offs: More environmentally-friendly practices promoted by VSS are often more labor-intensive, and can lead to additional time burden for women (Lyon et al. 2017). But if women are more actively involved, they may also be more empowered in terms of participation in decision-making and control over income (Meemken and Qaim 2018). Research on the performance of VSS should therefore consider both environmental and equity outcomes to capture *if labor-intensive sustainable practices promoted by VSS exacerbate intra-household inequalities*.

Economy-equity trade-offs: VSS aim to increase the profitability of the certified crop, which alongside higher incomes may also be associated with specialization and a reallocation of household resources towards the certified crop (Vellema et al. 2015). If men take control over these resources, this can further exacerbate intra-household inequalities and lead to lower food security and nutrition outcomes, despite higher incomes (Doss 2013; Malapit and Quisumbing 2015). VSS evaluations should therefore equally pay attention to economic and equity outcomes to assess *whether VSS induced specialization on cash crop agriculture may jeopardize food security and nutrition for all*.

The links between VSS interventions and sustainable food system outcomes can be direct, but they often depend on a range of mediating factors. Many of these factors are shaped by the landscape and policy context, the market environment, and climate and weather conditions. These factors are not strictly exogenous, as some elements, such as the landscape and policy context, can be influenced by VSS certification bodies. For example, VSS certification bodies could target areas that are particularly suitable for the certified crop or that have favorable ecological conditions, making it easier for farmers to comply (Meemken et al. 2021). The landscape context, including the diversity of agricultural systems and the presence of primary forests, will influence the prevailing animal diversity and hence the potential ecological outcomes that VSS can achieve at the farm level. In addition, VSS can shape the landscape through environmental interventions such as fostering agroforestry and implementing zero-deforestation regulations. Therefore, it is important to consider the context in which VSS are implemented, both in terms of factors influencing VSS performance and in terms of outcomes shaped by VSS.

Empirical evidence from three case studies

In the following sections, we explore the trade-offs identified in our conceptual framework using data from three case studies, namely Ghana, Rwanda, and Peru. All three case studies were designed to assess the impact of VSS on sustainable food system outcomes, but with varying key aspects in mind. We therefore refrain from a joint analysis of the data, but rather present particular insights that can be gained from the respective studies. For example, the studies in Ghana and Rwanda both collected economic and ecological data from the same sub-set of households, whereas the study from Peru provides in-depth insights into the equity dimension. More detailed analyses and case study descriptions are provided elsewhere (Wätzold et al. 2024; Paz et al. 2024; Bohn et al. 2024; Santalucia, Wollni 2024). The focus here is on describing and comparing a selection of indicators, guided by our conceptual framework.

To test associations between certification and food system outcomes, we use inverse probability weighted regression adjustment (IPWRA) that allows us to take a range of confounding factors into account (Manda et al. 2018). This is important since certified and non-certified households are likely to differ systematically with respect to certain characteristics that may at the same time influence their performance in economic, environmental and equity-related outcomes (Gather and Wollni 2022). It is important to note that the IPWRA method relies on observable covariates to reduce selection bias, and thus estimates may still be vulnerable to systematic bias in unobserved characteristics (Hörner and Wollni 2021). The relationships presented in the following sections should therefore be interpreted as associations rather than causal effects. The same applies to the results on animal diversity that are obtained using generalized linear mixed models (GLMM). GLMM are considered more appropriate for estimating animal diversity outcomes, which are likely correlated across nearby plots, because they can account for the hierarchical structure of the data (Rana and Sills 2024; Krumbiegel et al. 2018). More detailed descriptions of the GLMM estimator and the IPWRA method are provided in Appendix A.

The next section presents the empirical data and case study contexts. We then present case study evidence on the trade-offs identified in the conceptual framework.

Description of data and case study context

In Ghana, our data covers 814 cocoa-cultivating households in five main cocoa-producing regions. The survey design followed a multi-stage random sampling procedure, first selecting 46 villages within the five regions, and then randomly selecting around 18 cocoa households per village. Our survey was conducted from November 2022 to January 2023. Since the survey was not stratified by certification status, the share of certified (n=338) and non-certified (n=476) households in the sample is representative of the research area. In addition to socio-economic household data, we collected ecological plot-level data on vegetation structure and animal diversity for a subset of 119 households in our sample (54 certified and 65 non-certified). In Ghana, certification is implemented and operationalized by government-licensed buying companies (LBC) that are typically linked to an international trader or chocolate company and are responsible for sourcing cocoa in Ghana. To reach out to farmers, LBC hire purchasing clerks who collect cocoa from farmers and manage the certification process at the farm level. To get certified, farmers need to fill out a registration form provided by the purchasing clerk, and subsequently their farms are geo-mapped and inspected by LBC staff. Generally, there are several purchasing clerks in each village working for different LBC. Purchasing clerks working for a certified LBC also collect cocoa from non-certified farmers. Thus, farmers can choose which purchasing clerk(s) to deliver their cocoa to and whether to undergo the process of certification. The relevant sustainability standards in our research area include Rainforest Alliance, Cocoa Life, Cocoa Horizon, Cargill Cocoa Promise, and Fairtrade.

In Rwanda, our data covers certified and non-certified coffee farm households in five major coffee-producing districts. The survey was conducted between November 2022 and January 2023. The Western districts, in particular, are characterized by high levels of poverty and malnutrition. For example, Nyamasheke, Karongi, and Rutsiro have poverty rates of 69.3%, 52.7%, and 49.5%, respectively (NISR 2018). Data was collected based on a multi-stage stratified random sample. In the first step, we randomly selected 24 certified and 15 non-certified coffee washing stations (CWS). In the second step, we selected a random sample of about 20 households from each CWS, resulting in a total sample of 515 certified and 327 non-certified farm households for the socio-economic survey. Similar to the Ghana case study, we additionally collected ecological plot-level data for a subset of 100 households in our sample (62 certified and 38 non-certified). In Rwanda, certification is implemented at the CWS level, meaning that the certified CWS must operationalize certification criteria with their farmers. This situation is unique because the government of Rwanda implemented a zoning policy in 2016 to reduce competition between CWS and improve services to farmers (Gerard et al. 2022). The zoning policy assigns coffee farmers to a particular CWS based on geographical location and obliges farmers to sell their coffee cherries only to the designated CWS. Accordingly, farmers' certification status is determined exogenously at the CWS level, and individual households do not have the option to opt into or out of certification. The zoning policy was lifted in mid-2023 (van Kollenburg and van Weert 2024), implying that farmers will again be able to choose which CWS to deliver their coffee to in the future. The relevant sustainability standards in our research area include Rainforest Alliance, Café Practices, Fairtrade, and, to a lesser extent, Organic and 4C.

In Peru, cocoa production has expanded rapidly over the last two decades due to coca eradication programs jointly implemented by the Peruvian government and the United States Agency for International Development (Nash et al. 2016). This initiative, through public-private partnership, supported the specialization of smallholder farmers in cocoa production by strengthening cooperatives, providing inputs and training, and facilitating access to market channels. As a result, sustainability standards like Fairtrade and Organic have proliferated, with around 56% of the land under cocoa cultivation now certified organic or in transition to organic certification (Willer et al. 2022). Our survey was conducted in three cocoa-producing regions targeted by the cocoa expansion program, which together represent about 60 percent of total cocoa production in Peru. We first selected ten cooperatives in our research area and then applied stratified random sampling to select around thirty male members and thirty female members from each cooperative. The survey was implemented at the household level between April and July 2023, resulting in a total sample of 566 cocoa-producing households. To collect gender-disaggregated data and information on participation in decision-making and access to resources, we interviewed both spouses separately whenever applicable. All cooperatives in our sample have obtained Fairtrade and Organic certification. Since Fairtrade certification is implemented exclusively at the cooperative level, all farmers are automatically Fairtrade certified. Organic certification, however, requires registration and adaptation of production practices at the farm level, and hence, organic certification status varies in our household sample. Overall, 74% of the households in our sample have at least some of their land under organic certification.

Certification and farm management in Ghana, Rwanda and Peru

We first use descriptive statistics to compare certified and non-certified households in the three case studies with respect to the farming practices adopted (Table 1). In Ghana, certification is associated with an intensification of input use in cocoa production. On average, a larger proportion of certified farmers use conventional fertilizer, organic fertilizer and mulching compared to non-certified farmers. Certified farmers also engage significantly more in good agricultural practices like pruning and integrated pest management. Irrespective of certification status, nearly all cocoa farmers in Ghana have shade trees in their cocoa plantations. In Rwanda, certified farmers are less likely to apply conventional fertilizer, but are more likely to use sustainable practices like organic fertilizer, mulching, shade trees and integrated pest management on their coffee plots. In Peru, certified-organic farmers use less conventional fertilizer and apply less mulching compared to non-certified farmers. Overall, in the Peruvian sample conventional fertilizer use is low, and even among non-certified farmers ranges only around 14 percent. With respect to other practices like shade trees and organic fertilizer, there are no significant differences between certified-organic and non-certified farmers in Peru.

Table 1: Descriptive statistics of management practices

	Certified farmers mean	sd	Non-certified farmers mean	sd	Mean difference
Ghana	*N = 338*		*N = 476*		
Conventional fertilizer (0/1)	0.65	0.48	0.51	0.50	0.15***
Organic fertilizer (0/1)	0.07	0.26	0.02	0.15	0.05***
Mulching (0/1)	0.36	0.48	0.26	0.44	0.10***
Shade trees (0/1)	0.99	0.08	0.98	0.13	0.01
Pruning (0/1)	0.81	0.39	0.77	0.42	0.04
Weeding (0/1)	1.00	0.05	0.99	0.10	0.01
Integrated pest management (IPM) (number of IPM practices, 0-4)	2.15	0.88	2.04	0.86	0.11*
Rwanda	*N = 515*		*N = 327*		
Conventional fertilizer (0/1)	0.86	0.34	0.93	0.26	-0.07***
Organic fertilizer (0/1)	0.75	0.43	0.64	0.48	0.11 ***
Mulching (0/1)	0.96	0.20	0.91	0.28	0.04**
Shade trees (0/1)	0.98	0.39	0.74	0.50	0.24***
Pruning (0/1)	0.94	0.24	0.91	0.29	0.04
Weeding (0/1)	0.94	0.23	0.95	0.22	0.03
Integrated pest management (IPM) (number of IPM practices, 0-4)	3.39	0.69	3.11	0.88	0.28***
Peru	*N = 421*		*N = 145*		
Conventional fertilizer (0/1)	0.03	0.16	0.14	0.35	-0.12**
Organic fertilizer (0/1)	0.47	0.50	0.42	0.50	0.05
Mulching (0/1)	0.84	0.37	0.91	0.29	-0.07*
Shade trees (0/1)	0.77	0.42	0.77	0.43	0.00
Pruning (0/1)	0.94	0.23	0.94	0.23	0.00
Weeding (0/1)	0.99	0.08	0.98	0.12	0.01

Note: sd = standard deviations. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. IPM refer to the following four practices: monitor insects before treatment, maintain habitat for insects/predators, cut and burn infested material, sanitary harvest and pruning.

Despite variations in the promoted agricultural practices, in all three case studies, certification is associated with significantly higher yields – and in the case of Ghana and Rwanda also with higher net cash crop income per hectare (Table 2). These results suggest that VSS contribute to improvements in farm-level economic outcomes especially in the case of Ghana and Rwanda. Conversely, in the case of Peru, organic certification is ultimately not associated with better economic outcomes at farm level.

Table 2: Association between certification and economic outcomes

	Non-certified PO	$ADPO^C$	P-value	Obs
Ghana				
Yield (kg/ha)	355.79	64.83	0.02	814
Net cocoa income (GHC/ha)	2298.86	663.86	0.02	814
Rwanda				
Yield (kg/ha, fresh cherries)	6693.57	790.62	0.05	842
Net coffee income (RWF/ha)	2788649.69	847177.91	0.00	842
Peru				
Yield (kg/ha)	683.94	153.03	0.02	566
Net cocoa income (PEN/ha)	2723.87	263.50	0.24	566

Notes: IPWRA estimates; PO stands for 'predicted outcome'; $ADPO^C$ stands for 'average difference in predicted outcomes' for certified farmers under certification and hypothetical non-certification. 1 GHC ≈ 0.071 EUR, 1 RWF ≈ 0.00093 EUR, 1 PEN ≈ 0.244 at the time of the data collection (as of 1 Nov. 2022 for Rwanda and Ghana, 1 May 2023 for Peru).

Environment-economy trade-offs: Do VSS simultaneously achieve economic and ecological improvements at farm level?

Positive yield effects and crop income effects of certification have been documented in several studies (Meemken 2020; Sellare et al. 2020b). As illustrated in the conceptual framework (Figure 1), a critical question is whether the economic gains shown in Table 2 are achieved at the cost of healthy ecosystems. Tables 3 and 4 present ecological plot-level data from Ghana and Rwanda. In Ghana, differences in vegetation structure between certified and non-certified plots are small and non-significant (Table 3). Conversely, in Rwanda, the average differences in the number of shade trees per hectare and the number of shade tree species are significantly positive for certified farmers. These positive results for vegetation structure in Rwanda are, however, not reflected in higher animal diversity on certified plots (Table 4). In the case of Ghana, certified plots display a lower bioacoustics index and lower predation rates on the average, but the differences to non-certified plots are not statistically significant.

Table 3: Association between certification and plot-level data on vegetation structure

	Non-certified PO	$ADPO^C$	P-value	Obs
Ghana				
Shade trees per hectare	68.0	-2.71	0.65	119
Shade tree richness	14.5	0.23	0.84	119
Rwanda				
Shade trees per hectare	163.9	21.6	0.09	96
Shade tree richness	3.27	0.78	0.00	100

Notes: IPWRA estimates; PO stands for 'predicted outcome'; $ADPO^C$ stands for 'average difference in predicted outcomes' for certified farmers under certification and hypothetical non-certification.

Table 4: Association between certification and plot-level data on animal diversity

	Certification coefficient (GLMM)	Robust std. err.	P-value	Obs
Ghana				
Bioacoustics index	-0.08	0.06	0.18	119
Predation rate	-0.05	0.04	0.24	119
Rwanda				
Bioacoustics index	0.06	0.12	0.62	99
Predation rate	-2.86	2.47	0.25	99

Notes: Coefficient estimates from generalized linear mixed effects models (GLMM).

In summary, our data confirm positive associations of certification with production-related economic outcomes for Ghana and Rwanda (Table 2). In the Ghana case study, where certified households are characterized by higher levels of intensification, there is a tendency for environmental outcomes to be lower for certified than for non-certified households, although the differences are not significant. Overall, the trade-offs are not very strong, and in the case of Rwanda, there seems to be a balance between achieving higher yields and better environmental outcomes. However, even in the case of Rwanda, improved vegetation structure at the plot level does not translate into higher animal diversity at the plot level. This may be because animal diversity is not only determined by what happens on the plot, but is also influenced by landscape factors (Ocampo-Ariza et al. 2024).

Environment-equity trade-offs: Do labor-intensive sustainable practices promoted by VSS exacerbate intra-household inequalities?

Many of the agricultural practices promoted by VSS aim to improve soil conservation and increase the sustainability of agricultural production, but they are also very labor-intensive (Nkamleu and Kielland 2006). As highlighted in the conceptual framework (Figure 1), if certification is associated with the adoption of labor-intensive practices, the additional labor demand may not be shared equally among household members, but may fall disproportionately on women, increasing their time burden (Lyon et al. 2017). In Peru, we have gender-disaggregated data on labor use in cocoa production, which allows us to look at intra-household labor allocation. In the Peruvian case study, we find that organic certification increases the workload of women in cocoa production within certified households, but not that of men. Thus, the increased labor demand in cocoa production associated with organic certification is mostly met by women within the household.

Table 5: Association between organic certification and gender-specific labor demand in Peru

	Non-certified PO	$ADPO^{C}$	P-value	Obs
Peru				
Woman's cocoa labor days per ha	13.03	5.54	0.01	484
Man's cocoa labor days per ha	26.91	1.15	0.46	484
Woman's labor to men's labor ratio	0.51	0.30	0.00	476
Woman's labor as percentage of total labor	0.30	0.07	0.01	481

Notes: IPWRA estimates; PO stands for 'predicted outcome'; $ADPO^{C}$ stands for 'average difference in predicted outcomes' for certified farmers under certification and hypothetical non-certification. The Peruvian sample used in this analysis includes only dual-adult households (N = 484).

Does this imply increasing intra-household inequalities? Not necessarily. If women provide more labor to cash crop activities, they may also have greater decision-making power and control over cash crop income (Meemken and Qaim 2018). The overall welfare implications for women also depend on how their overall workload and time use are affected. Table 6 presents data from Peru and Rwanda comparing women's empowerment and time use between certified and non-certified households.

Drawing on the Women's Empowerment in Agriculture Index (Malapit and Quisumbing 2015; Alkire et al. 2013), we calculated an aggregate empowerment score measuring the extent to which women can participate in decision-making related to agricultural production, income, financial and physical assets and time use. In Peru, we find that there is no significant difference in women's empowerment between certified and non-certified households. While women gain decision-making power over cocoa and other crop production and the income derived from these activities (in line with their increased labor supply, as shown in Table 5), they appear to lose agency in other domains, particularly those related to credit and savings. The time use data suggest that as they supply more labor to cocoa production, they spend less time in off-farm activities and also less often receive individual income from off-farm activities. Thus, there is a shift in the activities in which women participate and exercise control, and the overall welfare effect will ultimately depend on the relative benefits of the certified cash crop activity compared to available off-farm activities.

Certification can also be associated with higher levels of women's empowerment, as the case of Rwanda shows. In Rwanda, women's empowerment scores are significantly higher in certified households than in non-certified households, indicating that they are more actively involved in decision-making and have more control over resources. The individual indicators show that significantly more women in certified households participate in decision-making regarding crop and livestock income than women in non-certified households. The total workload of women in certified households is slightly higher than that of women in non-certified households, and they tend to work slightly less in agricultural activities and slightly more in off-farm activities, but none of these differences in time use are significant.

Table 6: Descriptive statistics of women's empowerment and time use in Peru and Rwanda

	Peru					Rwanda				
	Certified farmers *N = 421*		Non-certified farmers *N = 145*		Mean difference	Certified farmers *N = 175*		Non-certified farmers *N = 119*		Mean difference
	mean	sd	mean	sd		mean	sd	mean	sd	
Aggregate empowerment score (0-11)	**5.90**	**1.69**	**5.72**	**1.91**	**0.18**	**7.19**	**1.94**	**6.68**	**1.88**	**0.51****
Items of empowerment score										
Makes decisions about cocoa/coffee production (0/1)	0.95	0.21	0.86	0.35	0.10**	0.81	0.39	0.75	0.43	0.06
Makes decisions about other crop production (0/1)	0.78	0.42	0.69	0.46	0.09*	0.92	0.27	0.92	0.28	0.00
Makes decisions about income from cocoa/coffee (0/1)	0.75	0.43	0.63	0.48	0.11**	0.91	0.29	0.90	0.30	0.01
Makes decisions about income from other crops (0/1)	0.63	0.48	0.53	0.50	0.10*	0.54	0.50	0.41	0.49	0.13**
Makes decisions about income from livestock (0/1)	0.27	0.45	0.21	0.41	0.06	0.70	0.46	0.54	0.50	0.16*
Makes decisions about income from employment (0/1)	0.10	0.29	0.14	0.35	-0.04	0.65	0.48	0.73	0.45	-0.08
Makes decisions about credit (0/1)	0.42	0.49	0.55	0.50	-0.14**	0.51	0.50	0.40	0.49	0.11
Makes decisions about savings (0/1)						0.90	0.30	0.89	0.32	0.02
Owns a savings account (0/1)	0.37	0.48	0.45	0.50	-0.08*					
Owns at least two small or one large asset (0/1)	0.98	0.13	1.00	0.00	-0.02	1.00	0.00	1.00	0.00	0.00
Workload is <10.5 hrs (0/1)	0.52	0.50	0.51	0.50	0.01	0.44	0.50	0.46	0.50	-0.02
Satisfied with leisure time (0/1)	0.14	0.35	0.15	0.36	-0.01	0.76	0.43	0.71	0.45	0.05
Time use										
Woman's overall workload	9.97	3.29	10.25	2.92	-0.28	11.74	7.47	11.10	7.22	0.64
Women's time spent in agriculture	2.92	3.08	2.76	3.16	0.16	3.30	2.66	3.53	2.98	-0.23
Women's time spent in off-farm activities	1.18	2.72	1.73	3.27	-0.55*	3.22	3.40	2.82	3.37	0.39
Woman has individual off-farm income (0/1)	0.16	0.36	0.25	0.43	-0.09*					

Notes: sd = standard deviations. * p < 0.1, ** p < 0.05, *** p < 0.01. The Rwandan sample used in this analysis includes only female respondents (N = 294).

In summary, these findings indicate that it is critical to consider the gender implications of certification, in line with the conceptual framework (Figure 1), to ensure that the adoption of labor-intensive practices does not perpetuate or exacerbate intra-household inequalities. The case study in Rwanda, where certification bodies have provided trainings to promote equal rights and opportunities, suggests that certification can act as a lever to promote women's empowerment.

Economy-equity trade-offs: Does VSS-induced specialization on cash-crop agriculture jeopardize dietary diversity and food security?

Certification can lead to a reallocation of household resources – land, labor, and capital investment – to the certified crop (Vellema et al. 2015). Increased income from certified crops can then be spent on food, improving household nutritional outcomes (Schleifer and Sun 2020). However, as outlined in our conceptual framework (Figure 1), greater specialization and higher income from cash crop production can also lead to the exclusion of women (Njuki et al. 2011). Male control over income can affect how income is spent, with potentially negative consequences for food security and nutrition (Fischer and Qaim 2012; Hoddinott and Haddad 1995; Quisumbing and Maluccio 2003). On the other hand, if certification promotes agricultural diversification, this may contribute to food security and dietary diversity through direct consumption pathways (Sibhatu et al. 2015).

Table 7: Association between certification and specialization

	Non-certified PO	$ADPO^C$	P-value	Obs
Ghana				
Total household income (GHC) (IHS-transformed)	9.01	0.05	0.88	814
Share cocoa income of total income	0.63	0.04	0.03	814
Share cocoa land of total land	0.85	-0.00	0.84	814
Agric. diversification	6.14	0.31	0.07	814
Rwanda				
Total household income (RWF) (IHS-transformed)	14.40	0.13	0.00	842
Share coffee income of total income	0.32	0.02	0.18	842
Share coffee land of total land	NA	NA	NA	NA
Agric. diversification	7.04	0.76	0.00	842
Peru				
Total household income (PEN) (IHS-transformed)	10.48	-0.06	0.35	566
Share cocoa income of total income	0.52	0.02	0.46	566
Share cocoa land of total land	0.82	-0.03	0.33	566
Agric. diversification	5.51	0.12	0.76	566

Notes: IPWRA estimates; PO stands for 'predicted outcome'; $ADPO^C$ stands for 'average difference in predicted outcomes' for certified farmers under certification and hypothetical non-certification. IHS refers to inverse hyperbolic sine transformation; approx. percentage changes of IHS-transformed values are calculated as described in Bellemare and Wichman (2020).

Our data do not provide strong evidence that certification leads to specialization and substantial income gains at the household level (Table 7). The observed increases in net cash crop income associated with certification in Ghana and Rwanda (Table 2), translate into higher total household income for certified households only in the case of Rwanda (Table 7). In the case of Ghana, the share of cocoa income in total income is positively and significantly associated with certification, but the magnitude of the effect is small. There is no evidence that certified households devote a greater proportion of their land to the certified crop (data not available for Rwanda). In Ghana and Rwanda, certification is indeed associated with agricultural diversification.

What are the implications for dietary diversity and food security? Our results show that only in Rwanda do we find significant associations between certification and various indicators of dietary diversity and food security, while in Peru and Ghana the associations are not significant (Table 8).

Table 8: Association between certification and dietary diversity and food security

	Non-certified PO	$ADPO^C$	P-value	Obs
Ghana				
Diet Quality Questionnaire - All 5 (0/1)	0.24	-0.05	0.14	814
Global Dietary Recommendations Score (0-18)	11.49	-0.06	0.62	814
Non-Communicable Diseases – Protect Score (0-9)	3.00	-0.03	0.78	814
Non-Communicable Diseases – Risk Score (0-9)	0.50	0.02	0.75	814
Food Insecurity Experience Scale (0-8)	2.81	-0.08	0.70	814
Rwanda				
Diet Quality Questionnaire - All 5 (0/1)	0.16	0.06	0.00	711
Global Dietary Recommendations Score (0-18)	12.40	0.29	0.05	711
Non-Communicable Diseases – Protect Score (0-9)	3.22	0.34	0.01	711
Non-Communicable Diseases – Risk Score (0-9)	0.17	-0.05	0.04	711
Food Insecurity Experience Scale (0-8)	4.07	-0.66	0.00	842
Peru				
Diet Quality Questionnaire - All 5 (0/1)	0.47	0.02	0.68	566
Global Dietary Recommendations Score (0-18)	12.17	0.07	0.74	566
Non-Communicable Diseases – Protect Score (0-9)	4.22	-0.22	0.92	566
Non-Communicable Diseases – Risk Score (0-9)	1.12	-0.16	0.38	566
Household Food Insecurity Access Scale (0-27)	6.00	-0.14	0.82	558

Notes: IPWRA estimates; PO stands for 'predicted outcome'; $ADPO^C$ stands for 'average difference in predicted outcomes' for certified farmers under certification and hypothetical non-certification. Detailed definitions of the indicators of dietary diversity and food security are provided in Appendix B.

In Rwanda, certification is associated with increased yields, greater shade tree diversity, more agricultural diversification and higher average women's empowerment scores, which in combination may contribute to the positive food security and dietary diversity outcomes observed in our data. In Peru, on the other hand, we find that women in certified-organic households gain control over cocoa income but lose access to individual off-farm income, credit, and savings. Overall, organic certification in Peru is not associated with higher average women's empowerment scores, which may be one reason for the lack of improvement in food security and dietary diversity outcomes. Of course, other factors would also be at play, such as the lack of significant increases in net cocoa income, total household income, or agricultural diversification in Peru.

Balancing trade-offs across multiple sustainability dimensions

The previous sections have shown that outcomes in different sustainability dimensions interact, creating trade-offs and synergies. In Ghana, VSS are associated with input intensification and higher yields but not with environmental improvements. Despite higher cocoa income, certified households in Ghana do not fare better in terms of overall household income, food security, and dietary diversity. Similarly, in Peru, organic certification is associated with higher yields but not with higher household incomes, food security, and dietary diversity. Additionally, in Peru, our data suggests that increased labor demand associated with organic certification creates trade-offs with women's time use and control over resources. Only in our case study in Rwanda do VSS seem to create synergies between economic, environmental and equity outcomes, and are ultimately associated with higher dietary diversity and food security among certified households.

Most studies on VSS performance focus on identifying increases in sustainability outcomes attributable to certification. However, it may not be possible or even necessary to achieve significant increases in all sustainability outcomes at the same time. Instead, it may be more relevant to reach and maintain minimum thresholds in all dimensions. To illustrate this point, we define thresholds for the environmental, economic and equity dimensions[1]. For the environmental dimension, VSS should support diverse and sustainable production systems that contribute to healthy ecosystems. We operationalize this dimension by considering whether households cultivate coffee or cocoa in agroforestry systems. The threshold for agroforestry systems is defined by the number of shade trees per hectare and the number of different shade tree species, with exact numbers being crop and country-specific (see Table 9). For the economic dimension, VSS should ensure decent incomes that lift cash-crop producers and their families out of poverty. We use the national poverty lines as thresholds to define whether households are categorized as poor or non-poor. Finally, for the equity dimension, VSS should ensure that all household members have equal access to sufficient and diverse food. We define thresholds based on the Food Insecurity Experience Scale (Ghana, Rwanda) and the

[1] Note that here we are only providing an illustrative example. The chosen thresholds are debatable and should ideally be the outcome of a participatory process involving different stakeholders and considering the local context.

Household Food Insecurity Access Scale (Peru) to categorize households as food secure or only mildly food insecure (see Table 9).

Table 9: Descriptive statistics of minimum thresholds for sustainable food system indicators

	Certified farmers		Non-certified farmers		Mean difference
	mean	sd	mean	sd	
Ghana	*N = 338*		*N = 476*		
Diverse agroforestry system (0/1)	0.32	0.47	0.27	0.44	0.05
Above national poverty line (0/1)	0.46	0.50	0.39	0.49	0.07**
Food secure or mildly food insecure (0/1)	0.64	0.48	0.59	0.49	0.05
Rwanda	*N = 515*		*N = 327*		
Diverse agroforestry system (0/1)	0.43	0.49	0.27	0.44	0.16***
Above national poverty line (0/1)	0.46	0.50	0.36	0.48	0.10***
Food secure or mildly food insecure (0/1)	0.53	0.50	0.40	0.49	0.13***
Peru	*N = 421*		*N = 145*		
Diverse agroforestry system (0/1)	0.34	0.47	0.29	0.46	0.05
Above national poverty line (0/1)	0.52	0.50	0.48	0.50	0.04
Food secure or mildly food insecure (0/1)	0.47	0.50	0.46	0.50	0.01

Notes: sd = standard deviations. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Definition of thresholds: Diverse agroforestry system thresholds (based on self-reported data from household survey): for Ghana and Peru (cocoa): at least 16 shade trees/ ha from at least three different species (Initiative for Sustainable Cocoa 2020); for Rwanda (coffee): at least 70 shade trees/ha from at least two different species (Belco 2024). The poverty threshold is defined based on the national poverty lines (2022): for Ghana 8.8 GHC/cap./day; for Rwanda 689 RWF/cap./day; for Peru 13.83 PEN/cap./day. Food security threshold for Ghana and Rwanda is based on FIES: households are food secure or only mildly food insecure if their FIES score is <4 (FAO 2018a); for Peru we use the Household Food Insecurity Access Prevalence (HFIAP) that is derived from HFIAS: food secure or mildly food insecure households do not cut back on quantity and do not experience any of three most severe conditions (running out of food, going to bed hungry, or going a whole day and night without eating) (Coates et al. 2007).

Table 9 presents descriptive statistics comparing certified and non-certified households with respect to the minimum thresholds. The results align closely with our earlier findings regarding absolute increases in sustainability outcomes. In Ghana, a significantly larger share of certified households are non-poor compared to non-certified households. This is in line with our previous findings that certification in Ghana is associated with increases in yields and net cocoa income. Note, that although total household income is not significantly higher for certified households in Ghana, certification seems to be effectively moving households above the poverty threshold. However, there are no significant differences between certified and non-certified households in terms of implementing agroforestry systems and achieving food security, even though improvements in both areas are needed according to the absolute numbers. In Peru, we find no significant differences between certified and non-certified households concerning any of the thresholds in the three dimensions. In Rwanda, certification achieves better outcomes in all three dimensions, consistent with our earlier findings. A larger share of certified households implement agroforestry, are non-poor, and achieve moderate food security compared to non-certified households. Despite the better outcomes for certified households, there is still room for improvement in all three dimensions.

For the case of Rwanda, we illustrate the proportion of households reaching the thresholds in the three dimensions and the extent of overlaps (Figure 2)[2]. These overlaps indicate that households meet thresholds in multiple dimensions. Comparing certified and non-certified households, Figure 2 suggests that VSS reduce trade-offs, particularly between the environmental dimension on the one hand and the economic and equity dimensions on the other hand. Additionally, the share of households reaching or exceeding all three thresholds is higher among certified households (12 percent) than non-certified households (4 percent). To fully appreciate the impact of VSS on minimum thresholds across multiple dimensions, it is necessary to adopt a dynamic, long-term perspective. This involves assessing the development of overlaps over time. Continuously growing and increasingly overlapping circles for certified farmers would indicate that VSS are successful in helping farmers adapt their production processes and achieve long-lasting improvements in multiple sustainability dimensions.

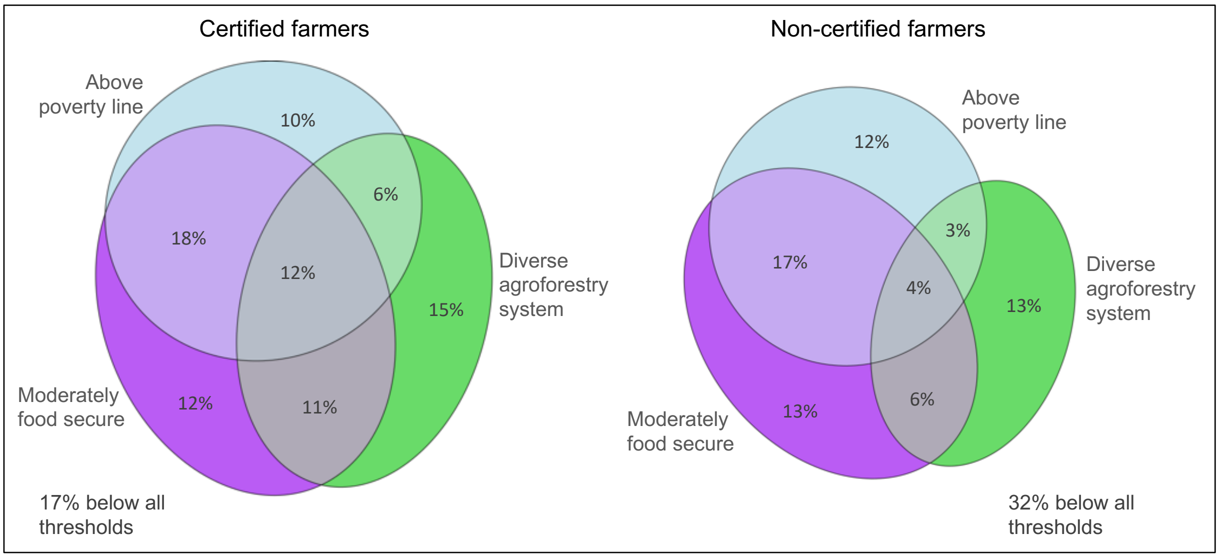

Figure 2: Achievement of thresholds in three sustainability dimensions – Rwanda

VSS within landscape and policy context

As emphasized in the conceptual framework (Figure 1), VSS do not operate in a vacuum; their performance is influenced by external factors, including policy, market and landscape contexts. For environmental outcome assessments, the surrounding landscape plays an important role (Tscharntke et al. 2015). Our data from Ghana and Rwanda suggest, for example, that the plot-level bioacoustic index, a measure of animal diversity, is influenced by the surrounding landscape context. In Ghana, it increases

[2] We focus here on Rwanda, since the differences between certified and non-certified households in Ghana and Peru are mostly not significant (Table 9).

with the plot's proximity to primary forest. In Rwanda, it is positively correlated with the enhanced vegetation index (EVI) score, a satellite-based measure of vegetation health and density, measured within a 500-meter radius around the farmer's coffee plot. Accordingly, national and regional policies with their effects on landscapes influence the environmental performance that VSS can achieve at the farm level.

But VSS, in turn, can also influence the landscape. Identifying such spillover effects on the ecosystem health of the surrounding landscape is challenging. In principle, the effects should be positive, since most VSS include regulations that prohibit the expansion of crops into forests and promote reforestation and shade tree planting on certified farms. However, attributing observed changes to certification is difficult because certified and non-certified farms often coexist within a given landscape, as in the case studies in Ghana and Peru.

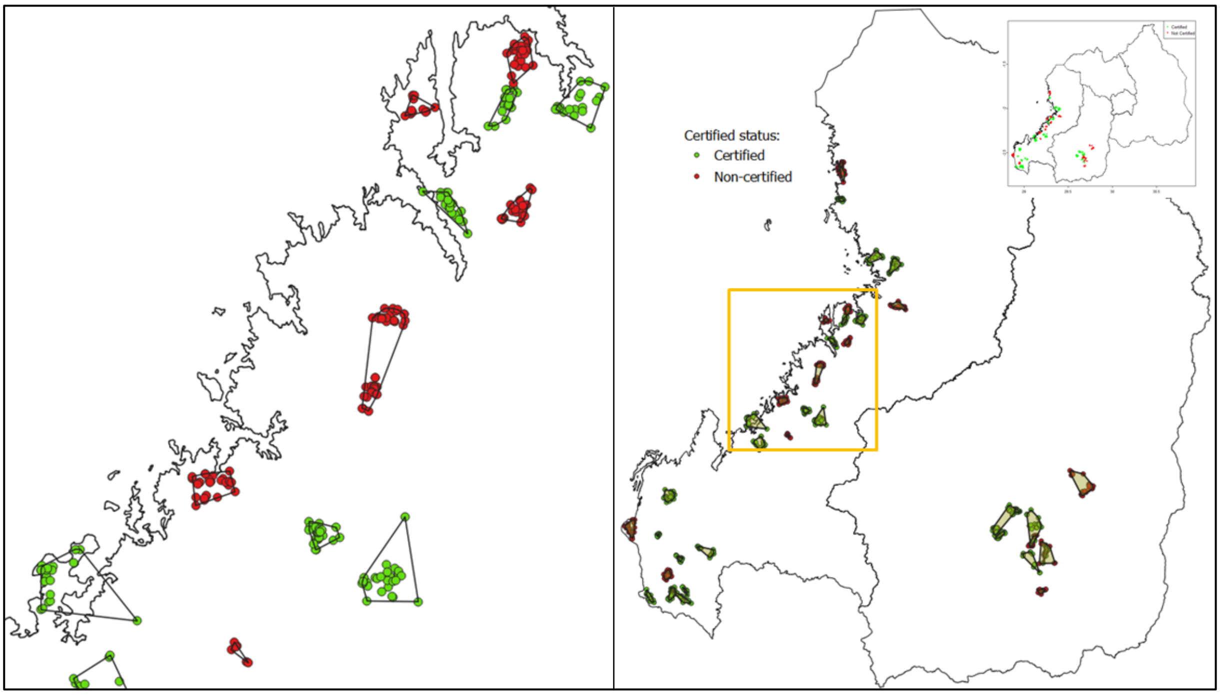

Figure 3: Certified and non-certified clusters due to zoning in Rwanda
Map created using QGIS

In the Rwandan case study, we have a unique setting due to a zoning policy, which creates clearly defined clusters of certified and non-certified coffee farms (Gerard et al. 2022) (see Figure 3). This allows us to compare "certified landscapes" and "non-certified landscapes" with respect to their ecosystem health. Table 10 shows that the differences in the enhanced vegetation index (EVI) between certified and non-certified clusters are small and not significant, both currently (averaged over 2020-2022) and prior to the start of the certification activities (averaged over 2001-2003). Considering the change in EVI over the last two decades, there is a tendency for certified landscapes to have experienced less degradation on average. However, these differences are currently only marginal and not statistically significant.

Table 10: Descriptive statistics of vegetation health and density in certified and non-certified clusters (Rwanda)

	Certified clusters *N = 24*		Non-certified clusters *N = 15*		Mean difference
	mean	sd	mean	sd	
Enhanced Vegetation Index (EVI) 2001-2003	0.42	0.07	0.43	0.05	-0.01
Enhanced Vegetation Index (EVI) 2020-2022	0.40	0.06	0.38	0.06	0.02
Change in Enhanced Vegetation Index from 2001-2003 to 2020-2022	-0.02	0.06	-0.05	0.05	0.03

Notes: sd = standard deviations. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Beyond potential spillover effects of VSS, there are many confounding factors shaped by policy and market environments. It is therefore essential to view VSS within the broader policy mix and not in isolation. In Rwanda, the government has been implementing reforestation policies (Rwanda Ministry of Environment 2019; Rwanda Ministry of Lands and Forestry 2018), which likely contribute to an environment where agroforestry can thrive and support measures are not limited to certified farmers. For example, the development of market channels for products from agroforestry, such as fruits and timber, makes investment in such systems more profitable and adds to the revenues derived from coffee plots. On the other hand, adverse policy and market environments can make it more difficult for VSS to achieve sustainability goals. In Ghana, for example, certified farms are often surrounded by (illegal) small-scale mining sites, which can have destructive effects on the environment and counteract VSS-related efforts for environmental improvements (Attuquayefio et al. 2017).

Conclusions

In this paper, we propose a conceptual framework to evaluate the impacts of voluntary sustainability standards (VSS) on sustainable food system outcomes, highlighting potential trade-offs among different sustainability dimensions. Our framework is built on three dimensions of sustainable food systems: ecosystem health, economic prosperity, and equity, and emphasizes the importance of balancing these three dimensions when assessing the performance of VSS. By considering the contexts in which VSS are implemented and the potential trade-offs between sustainability dimensions, the framework provides a comprehensive approach to evaluating the impacts of VSS.

Using original survey data from three case studies, we present evidence in line with the framework. Our results show that the outcomes in the different sustainability dimensions interact in various ways, creating trade-offs and synergies. In the Ghana case study, positive achievements of VSS in the economic dimension, are not mirrored in the environmental and equity dimensions. Research with a narrow focus on a single dimension would thus obscure the broader sustainability impact of VSS. In the Peruvian case study, labor demand associated with organic certification creates trade-offs with women's time use and control over resources. Research that neglects relevant sustainability outcomes, like equity, may fail to identify existing barriers to broader welfare achievements. Only a comprehensive assessment, as proposed by our framework, can reveal if VSS, as in the Rwanda case study, succeed in balancing achievements in all three sustainable food system dimensions and potentially exploiting synergies between them.

So, can VSS be a useful instrument to achieve more sustainable food system outcomes in global cash crop value chains? Clearly, VSS have evolved over time to incorporate a broad range of interventions that address multiple sustainability concerns (Lambin and Thorlakson 2018). These include interventions that target not only the economic and environmental outcomes of production, but provide capacity building, including gender mainstreaming and strengthening adaptive capacities (Traldi 2021). Some of these interventions produce more intangible outcomes that are inherently difficult to measure. It is crucial that certification bodies see themselves as service providers to export crop producers and strive for a balanced approach to achieving multiple sustainability outcomes (Marx et al. 2024). VSS are inherently value chain concepts and thus link different food system actors – a link that is urgently needed to address sustainability challenges in global food systems. Of course, VSS are not a silver bullet for making food systems more sustainable, but when they are aligned with other policy programs, they can be an important link in the chain.

One of the biggest concerns with certification is that farmers may not comply with the requirements and thereby harm the environment (Garrett et al. 2021). However, a narrow focus on environmental outcomes neglects the importance of broader food system outcomes and the synergies and trade-offs between them. Since environmental improvements do not depend on the actions of a single farmer, a spatially and socially inclusive approach to certification, as we see in Rwanda due to the zoning policy, may be more likely to achieve environmental goals. This requires a supportive policy environment and the ability of farmers to make a decent living from the certified crop, since otherwise they may engage in other activities that are potentially harmful to the environment. Certification bodies should explicitly consider the landscape and policy context to identify leverage points for achieving sustainable food system outcomes. This includes leveraging synergies with other food system actors, such as private sustainability initiatives, non-governmental organizations, and public policy programs (Marx et al. 2024).

What does it mean for future research on VSS impacts? Evaluation studies should consider a balanced mix of sustainability outcomes and explicitly analyze their trade-offs and synergies. For instance, a more inclusive approach to certification can imply less measurable welfare impact, because the poorest are harder to lift above the poverty line. Balancing trade-offs in environmental, economic and equity outcomes is a complex challenge and sometimes involves making difficult choices, since improvements in one dimension may come at the cost of another (Rubio-Jovel et al. 2024). In this context, for instance, keeping a decent income constant can be valuable, if simultaneously environmental and equity conditions are improved.

Future research should also adopt a longer-term perspective to analyze how VSS perform over time and whether they can strengthen farmers' adaptive capacity in the event of shocks and crises. This is particularly important in the context of climate change and increasing occurrence of weather extremes. Most VSS evaluation studies to date rely on cross-sectional data and attempt to identify a valid counterfactual to maximize their internal validity (Meemken et al. 2021). If VSS focus increasingly on inclusiveness, building adaptive capacity and strengthening resilience in the wake of climate change, a dynamic perspective is essential, and identifying a valid counterfactual will become even more difficult in real-world contexts. Here, it would be important for research to consider the role of VSS not in isolation, but in the broader policy and landscape context, and to explore potential synergies with other food system actors, such as private sustainability initiatives, which often coexist with VSS in the same areas (Marx et al. 2024).

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Appendix A: Estimation methods

Description of inverse probability weighted regression adjustment (IPWRA) method

To assess the relationship between certification and sustainable food system outcomes, we need to compare certified farmers to a suitable counterfactual. Given that certification is not randomly assigned, certified and non-certified farmers are likely to differ systematically in a range of observable and unobservable characteristics (Meemken et al. 2021). These factors may not only drive the certification decision, but also be correlated with the outcome variables. Consequently, estimates will be biased due to (self-)selection into certification.

In order to reduce selection bias, we follow recent examples in the literature (Gather and Wollni 2022; Hörner and Wollni 2021) and apply inverse probability weighted regression adjustment (Wooldridge 2010). The approach consists of two stages: in the first stage, the inverse of the estimated treatment probability weights are derived from the probability of being selected into certification. In the second stage, regression adjustment is used to model outcomes. Wooldridge (2010) refers to the property as 'doubly robust', since only one of the two models must be correctly specified to obtain consistent estimates.

In the first stage, the inverse probability weights (IPW) are calculated by weighting the observations based on the inverse probability of being certified. IPW aims to remove confounding factors by creating a "pseudo-population" in which treatment is independent of measured confounders. For this purpose, the probability of being certified (propensity score) is defined by ROSENBAUM and RUBIN (1983) as

$$P(X) = Pr(T_i = 1|X) = F\{h(X)\} = E(T_i|X)$$

where X is a multidimensional vector of covariates and F{.} is a cumulative distribution function. Based on the estimated propensity score $\hat{p}$, IPW are calculated as $\frac{1}{\hat{p}}$ for treated, and $\frac{1}{1-\hat{p}}$ for non-treated farmers. Each observation is thus weighted by the inverse probability of receiving the treatment level it received.

In the second stage, the RA method fits separate linear regression models for certified and non-certified farmers. Covariate-specific outcomes are then predicted for each subject under each certification status. Based on this, the method constructs the average differences between predicted outcomes (ADPO) for certified farmers under certification and hypothetical non-certification ($ADPO^C$) while considering differences in characteristics between certified and non-certified farmers. The IPWRA estimator is then constructed by combining the RA method with IPW and can be expressed as (Manda et al. 2018):

$$ADPO^C = n_C^{-1} \sum_{i=1}^{n} T_i[r_C^*(X, \delta_C^*) - r_N^*(X, \delta_N^*)]$$

where n_C is the number of certified farmers and $r_C^*(X)$ represents the weighted regression models for certified (C) and non-certified (N) farmers with covariates X and estimated parameters, δ_C^* and δ_N^*, which are obtained from the weighted regression procedure.

An underlying assumption of IPWRA is the overlap assumption. It requires that, conditional on covariates, each farmer has a positive probability of obtaining certification. The overlap assumption ensures that for each certified farmer, a non-certified farmer with similar characteristics exists. In case of a violation of the assumption, inferences would be made off-support of the data, and thus, conclusions would be model-dependent. To meet this condition, we set a tolerance level between $\hat{p} = 0.001$ and $\hat{p} = 0.999$ for the estimated probability of certification, as suggested by Hörner and Wollni (2021).

It is important to note that the IPWRA method relies on observable covariates to reduce selection bias and confounding. Thus, estimates are vulnerable to systematic bias in unobserved characteristics. As pointed out by Imbens and Wooldridge (2009), conditioning on a broad set of observable covariates, as we do in our estimations, may help to reduce selection bias resulting from unobservables. Still, IPWRA results in general should be interpreted as associations rather than causal effects.

Description of generalized linear mixed effects model

To assess the relationship between certification and animal diversity, we estimate generalized linear mixed effects models (GLMM). Compared to economic outcomes, animal diversity outcomes are less likely to be subject to endogeneity bias. Systematic differences between certified and non-certified households that influence the certification decision, are likely to influence economic outcomes, but rather unlikely to affect plot-level animal diversity outcomes. Animal diversity, in turn, is likely influenced by the surrounding landscape, and since animals are mobile, the same individuals may be recorded in nearby plots. Therefore, animal diversity outcomes are likely to be correlated within geographic clusters, more so than across clusters. GLMM can account for the hierarchical structure of the data by including these clusters as random effects (Krumbiegel et al. 2018; Rana and Sills 2024).

In the GLMM estimations, we include the community (in Ghana) and the coffee washing station's (CWS) procurement area (in Rwanda) as random effects. Since the outcome variables are normally distributed, we use a Gaussian conditional distribution. We further use a log-link function for easier interpretation and estimate robust standard errors to account for potential overdispersion. The GLMM take the following form:

$$AnimalDiv_{i,p,c,l} = \mu_0 + \mu_1 VSS_{i,p,c,l} + \mu_2 HH_{i,p,c,l} + \mu_3 P_{i,p,c,l} + \mu_4 L_l + C_c + \epsilon_{i,p,c,l}$$

where $AnimalDiv_{i,p,c,l}$ refers to the respective animal diversity outcome variable of plot *p* from household *i* in the community/CWS area *c*, in the landscape *l*; $VSS_{i,p,c,l}$ refers to household's certification status; $HH_{i,p,c,l}$ refers to a set of household-level and infrastructure control variables; $P_{i,p,c,l}$ refers to a set of plot level control variables; L_l are landscape control and regional dummy variables; C_c are community or CWS level random effects; and $\epsilon_{i,p,c,l}$ refers to the error term.

Appendix B: Variable definition

Definition of dietary diversity indicators

To analyze the nutritional impacts of certification we use the Dietary Quality Questionnaire (DQQ), a standardized, low-burden assessment tool for dietary adequacy which has been implemented in 55 countries in the Gallup World Poll in 2021-2022 (Herforth et al. 2019; Global Diet Quality Project 2022b). The DQQ comprises yes/no questions about foods consumed the previous day or night. Food items are adapted to the country-specific context and correspond to 29 food groups (Uyar et al. 2023). Indicators used in our study according to the Global Diet Quality Project (2022a) are detailed in the Table below.

Variable name	Variable definition	Food Groups	Scale
Diet Quality Questionnaire - All 5 (All5)	Binary variable which is considered adequate for respondents that consumed all 5 food groups typically recommended for daily consumption in food-based dietary guidelines	1) fruits; 2) vegetables; 3) pulses, nuts, or seeds; 4) animal-source foods; and 5) starchy staples.	0/1
Non-Communicable Diseases – Protect Score (NCD-P)	NCD-P is an indicator of dietary factors protective against noncommunicable diseases (NCDs). It includes nine food groups associated with meeting World Health Organization (WHO) recommendations on fruits, vegetables, whole grains, pulses, nuts and seeds, and fiber	1) whole grains; 2) legumes; 3) vitamin A–rich orange vegetables; 4) dark green leafy vegetables; 5) other vegetables; 6) vitamin A–rich fruits; 7) citrus; 8) other fruits; 9) nuts and seeds	0-9
Non-Communicable Diseases – Risk Score (NCD-R)	NCD-R is an indicator of dietary risk factors for NCDs, based on 8 food groups that are negatively associated with meeting WHO recommendations on free sugar, salt, total and saturated fat, and red and processed meat.	1) soft drinks (sodas); 2) baked/grain-based sweets; 3) other sweets; 4) processed meat (double weighted); 5) unprocessed red meat; 6) deep-fried food; 7) fast food and instant noodles; and 8) packaged ultra-processed salty snacks	0-9
Global Dietary Recommendations Score (GDR)	The GDR score (ranging from 0 to 18) has two components, NCD-P and NCD-R. The higher the GDR score, the more likely GDRs on healthy diets are to be met. The indicator is calculated by subtracting NCD-risk from NCD-protect and transforming to a positive range by adding 9.		0-18

Definition of food security indicators

Food Insecurity Experience Scale (FIES)

The Food Insecurity Experience Scale (FIES) is an experience-based measure of household or individual food security (FAO 2018). It consists of eight questions capturing a range of food insecurity severity, with yes/no responses (Data4Diets 2023). The questions focus on self-reported food-related behaviors and experiences associated with increasing difficulties in accessing food due to resource constraints.

During the last 12 months, was there a time when, because of lack of money or other resources:

1. You were worried you would not have enough food to eat?
2. You were unable to eat healthy and nutritious food?
3. You ate only a few kinds of foods?
4. You had to skip a meal?
5. You ate less than you thought you should?
6. Your household ran out of food?
7. You were hungry but did not eat?
8. You went without eating for a whole day?

Household Food Insecurity Access Scale (HFIAS)

The Household Food Insecurity Access Scale (HFIAS) is an experience-based, continuous measure of the degree of household food insecurity in the past four weeks (Coates et al. 2007). It is based on eighteen questions divided into two types of questions: nine occurrence questions and nine frequency-of-occurrence questions (Coates et al. 2007). The occurrence questions relate to three different domains of food insecurity (access): anxiety and uncertainty about the household food supply; insufficient quality; insufficient food intake and its physical consequences.

Occurrence Questions

1. In the past four weeks, did you worry that your household would not have enough food?
2. In the past four weeks, were you or any household member not able to eat the kinds of foods you preferred because of a lack of resources?
3. In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources?
4. In the past four weeks, did you or any household member have to eat some foods that you really did not want to eat because of a lack of resources to obtain other types of food?
5. In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?
6. In the past four weeks, did you or any household member have to eat fewer meals in a day because there was not enough food?
7. In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food?
8. In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food?
9. In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food?

For each occurrence question that was answered with ‘yes’, the following frequency-of-occurrence question was asked:

How often did this happen?
1 = Rarely (once or twice in the past four weeks)
2 = Sometimes (three to ten times in the past four weeks)
3 = Often (more than ten times in the past four weeks)

The HFIAS score is computed by summing the codes from all frequency-of-occurrence questions. It ranges from 0 to 27, where 0 implies that the household has not experienced any of the situations described in the occurrence questions, and 27 implies that the household has experienced all those situations often, i.e., more than ten times in the past four weeks. Thus, a higher HFIAS score indicates greater food insecurity (in terms of access) in the household (Coates et al. 2007).

Appendix C: Full estimation results

Ghana:

Table A1: Probit regression on the certification decision to derive inverse probability weights

HH years of education	0.09** (0.02)
HH head is female	-0.24 (0.22)
Age of the household head	0.00 (0.01)
No. of adults in HH	0.05 (0.05)
Risk aversion	-0.01 (0.02)
HH head is leader	0.40* (0.20)
HH has non-agric. income	0.06 (0.16)
Total cocoa area (ha)	0.02 (0.02)
Community has electricity	0.68* (0.27)
Distance to extension office (km)	0.02 (0.01)
Distance to tarred road (km)	-0.01 (0.02)
Western region	-0.52 (0.42)
Brong Ahafo region	0.24 (0.54)
Eastern region	-0.82 (0.56)
Central region	-0.58 (0.63)
Constant	-1.93* (0.82)
Observations	814

Robust standard errors in parentheses, * $p < 0.10$, * $p < 0.05$, *** $p < 0.01$

Table A2: Association between certification and economic outcomes

	(1)	(2)
	Yield (kg/ha)	Net cocoa income (GHC/ha)
ADPO^C	64.83* (27.78)	663.86* (281.26)
Non-certified PO	355.79** (23.92)	2298.86** (194.32)
OME0		
HH years of education	2.78 (3.00)	-7.13 (33.72)
HH head is female	9.08 (37.67)	-193.29 (477.41)
Age of the household head	-3.63** (1.07)	-22.67 (14.17)
No. of adults in HH	8.47 (6.36)	213.28* (83.33)
Risk aversion	9.91* (5.12)	47.28 (46.34)
HH head is leader	29.65 (44.56)	37.13 (541.93)
Received gov. inputs subsidized	14.50* (7.61)	147.41* (76.56)

HH has non-agric. income	5.74 (26.20)	-208.44 (321.81)
Total cocoa area (ha)	-15.78** (5.56)	-172.59** (45.26)
Community has electricity	74.81** (24.94)	654.40* (323.02)
Distance to extension office (km)	1.66 (2.02)	38.10* (15.58)
Distance to tarred road (km)	-1.72 (1.70)	-15.98 (19.18)
Nitosol soil (favorable)	-61.37 (44.47)	-238.98 (433.50)
HH experienced drought	-70.62** (25.05)	-537.91* (296.33)
Share of rich soil	80.28** (29.84)	1094.54** (318.54)
Share cocoa trees < 5 years	-225.74** (43.48)	-2632.58** (721.64)
Share cocoa trees > 25 years	-63.10* (35.55)	-522.01 (346.93)
HH experienced pest attack	-7.07 (36.11)	180.91 (351.38)

Western region	-55.27 (52.19)	-3.52 (566.10)
Brong Ahafo region	-11.88 (67.92)	27.87 (654.14)
Eastern region	123.34* (56.74)	543.40 (555.13)
Central region	17.89 (55.33)	1.13 (555.64)
Constant	381.13** (84.03)	1504.66 (1005.55)
OME1		
HH years of education	-4.40 (4.42)	-3.99 (67.02)
HH head is female	-72.17 (44.70)	-491.89 (567.71)
Age of the household head	-3.02* (1.52)	-15.16 (19.24)
No. of adults in HH	-0.88 (7.41)	1.03 (101.29)
Risk aversion	2.51 (4.71)	29.42 (75.44)
HH head is leader	108.33** (32.22)	1214.23** (436.62)

Received gov. inputs subsidized	9.08 (6.05)	99.04 (89.85)
HH has non-agric. income	-1.99 (36.61)	-443.95 (395.72)
Total cocoa area (ha)	-21.02** (5.72)	-202.98** (63.15)
Community has electricity	73.30* (41.06)	417.75 (539.96)
Distance to extension office (km)	0.22 (1.46)	15.05 (15.16)
Distance to tarred road (km)	-3.88 (3.06)	-30.75 (27.64)
Nitosol soil (favorable)	-39.38 (45.94)	210.58 (446.34)
HH experienced drought	-9.37 (29.53)	-112.36 (412.75)
Share of rich soil	120.34** (41.40)	1243.79* (532.71)
Share cocoa trees < 5 years	-177.89* (85.96)	-2627.66 (1951.88)
Share cocoa trees > 25 years	-31.64 (46.85)	-59.26 (601.75)

HH experienced pest attack	-47.87 (38.67)	-401.36 (458.91)
Western region	-93.60^{*} (39.50)	-721.56 (494.92)
Brong Ahafo region	-51.44 (63.50)	-182.57 (472.69)
Eastern region	238.07^{**} (55.73)	2297.72^{**} (699.04)
Central region	224.74^{**} (72.26)	1884.58^{*} (1022.11)
Constant	544.94^{**} (132.38)	2825.07 (1794.55)
Observations	814	814

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Robust standard errors in parentheses: * p < 0.10, * p < 0.05, *** p < 0.01

Table A3: Association between certification and plot-level data on vegetation structure

	(1) Shade trees per hectare	(2) Shade tree richness
$ADPO^{C}$	-2.71 (5.98)	0.23 (1.17)
Non-certified PO	67.97^{**} (4.52)	14.50^{**} (0.79)
OME0		
HH years of education	-3.24^{**} (1.00)	-0.19 (0.26)

Age of the household head	0.07 (0.30)	-0.06 (0.06)
HH head is female	-22.04* (10.78)	-4.85** (1.75)
No. of adults in HH	-0.22 (2.37)	-0.84* (0.36)
HH head is leader	-18.89* (8.49)	-0.70 (2.29)
Total cocoa area(ha)	-0.27 (1.69)	-0.10 (0.30)
Area of sampled farm (ha)	5.50 (7.57)	2.18 (1.35)
Distance HH to extension office (km) (log)	-3.93* (1.85)	-0.15 (0.61)
Community has electricity	17.89* (10.39)	-6.31** (1.34)
Area of sampled farm (ha)	0.00 (.)	0.00 (.)
Western region	0.42 (9.54)	0.02 (1.60)
Eastern region	16.01 (15.22)	0.31 (2.41)

Central region	-14.98 (14.21)	-1.26 (2.46)
NDVI 2000	-6.83 (24.82)	-0.83 (5.13)
Constant	94.33** (27.36)	28.62** (5.44)
OME1		
HH years of education	2.78** (0.96)	0.11 (0.16)
Age of the household head	-0.08 (0.31)	-0.14** (0.05)
HH head is female	-13.97* (8.35)	-2.94* (1.37)
No. of adults in HH	-1.10 (1.54)	0.54 (0.37)
HH head is leader	-11.79 (9.41)	-4.60** (1.38)
Total cocoa area (ha)	-0.42 (0.96)	0.32 (0.23)
Area of sampled farm (ha)	-0.81 (4.42)	4.55** (0.84)
Distance HH to extension office (km) (log)	1.21 (3.06)	0.84 (0.64)

Community has electricity	-20.75 (17.10)	4.97* (2.71)
Area of sampled farm (ha)	0.00 (.)	0.00 (.)
Western region	22.67** (7.89)	-2.94* (1.57)
Eastern region	-6.24 (13.83)	3.03 (2.77)
Central region	-20.16* (10.34)	-4.71* (2.47)
NDVI 2000	12.52 (14.65)	10.48** (3.72)
Constant	66.50* (28.58)	7.55 (5.72)
Observations	119	119

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Robust standard errors in parentheses: * p < 0.10, * p < 0.05, *** p < 0.01

Table A4: Association between certification and plot-level data on animal diversity

	(1) Bioacoustics Index	(2) Predation rate
Certification status (1/0)	-0.08 (0.06)	-0.05 (0.04)
HH years of education	0.01 (0.02)	0.03** (0.01)
Age of the household head	0.00* (0.00)	0.00 (0.00)
HH head is female	-0.06 (0.08)	0.03 (0.07)
No. of adults in HH	-0.02 (0.02)	0.02* (0.01)
HH head is leader	-0.04 (0.04)	0.09 (0.07)
Total cocoa area (ha)	-0.01 (0.02)	0.00 (0.01)
Area of sampled farm (ha)	-0.02 (0.06)	-0.01 (0.03)
Distance HH to extension office (km) (log)	0.05 (0.04)	0.04 (0.03)
Community has electricity	-0.03 (0.12)	-0.19*** (0.07)
Western region	0.15 (0.1)	0.14** (0.06)

Eastern region	0.51*** (0.11)	0.09 (0.12)
Central region	0.37*** (0.01)	0.05 (0.08)
Age of cocoa trees	0.01 (0.01)	0.00* (0.00)
Surrounding mining area (1km)	0.00 (0.00)	0.00** (0.00)
Distance to primary forest (km)	-0.02** (0.01)	0.00 (0.01)
Distance to road (km)	0.07 (0.12)	0.00 (0.05)
Constant	4.78*** (0.35)	3.69*** (0.24)
Group-level variance	0.00 (0.01)	0.00** (0.00)
Residual variance	3363.65*** (911.11)	290.88*** (43.43)
Observations	115	119

Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table A5: Association between certification and specialization

	(1)	(2)	(3)	(4)
	Total HH income (GHC) (IHS-transformed)	Share cocoa income of total income	Share cocoa land of total land	Agricultural diversification
ADPO^{C}	0.05 (0.32)	0.04* (0.02)	-0.00 (0.02)	0.31* (0.17)
Non-certified PO	9.01** (0.23)	0.63** (0.02)	0.85** (0.02)	6.14** (0.17)
OME0				
HH years of education	0.00 (0.06)	-0.00 (0.00)	-0.00 (0.00)	-0.06* (0.04)
HH head is female	-1.86* (0.85)	-0.02 (0.04)	-0.02 (0.03)	-0.14 (0.32)
Age of the household head	0.03 (0.02)	0.00 (0.00)	-0.00 (0.00)	-0.03* (0.01)
No. of adults in HH	0.21* (0.12)	0.01* (0.01)	0.01 (0.01)	0.02 (0.07)
Risk aversion	0.05 (0.07)	0.00 (0.00)	0.00 (0.00)	-0.03 (0.04)
HH head is leader	0.04 (0.44)	-0.05 (0.03)	-0.02 (0.03)	0.21 (0.40)
Received gov. inputs subsidized	-0.06 (0.10)	0.02** (0.01)	0.01 (0.00)	0.15* (0.07)

HH has non-agric. income	0.75 (0.56)	-0.22** (0.03)	0.02 (0.02)	1.12** (0.24)
Total cocoa area (ha)	0.06 (0.05)	0.01** (0.00)	0.01** (0.00)	0.17** (0.04)
Community has electricity	0.00 (0.83)	0.00 (0.05)	-0.03 (0.03)	-0.82 (0.51)
Distance to extension office (km)	0.03* (0.02)	-0.00 (0.00)	-0.00 (0.00)	-0.00 (0.01)
Distance to tarred road (km)	0.00 (0.02)	-0.00 (0.00)	-0.00 (0.00)	0.01 (0.02)
Nitosol soil (favourable)	0.10 (0.61)	-0.03 (0.03)	-0.09 (0.07)	0.53* (0.24)
Western region	0.05 (0.56)	-0.08** (0.03)	0.02 (0.04)	0.83** (0.31)
Brong Ahafo region	0.57 (0.75)	0.06* (0.03)	0.00 (0.04)	0.23 (0.55)
Eastern region	1.39* (0.56)	-0.08 (0.06)	-0.14** (0.05)	0.97* (0.54)
Central region	0.07 (0.51)	0.02 (0.03)	-0.01 (0.04)	0.93* (0.43)
Constant	5.45** (1.46)	0.65** (0.09)	0.93** (0.09)	6.92** (1.29)

OME1				
HH years of education	0.09 (0.07)	-0.01** (0.00)	0.01 (0.00)	-0.08* (0.04)
HH head is female	0.15 (0.76)	-0.04 (0.04)	0.06* (0.03)	-0.47 (0.33)
Age of the household head	-0.02 (0.03)	0.00 (0.00)	-0.00 (0.00)	-0.03** (0.01)
No. of adults in HH	0.12 (0.16)	0.00 (0.01)	-0.00 (0.00)	0.06 (0.06)
Risk aversion	0.12 (0.08)	-0.01 (0.00)	0.00 (0.00)	0.01 (0.04)
HH head is leader	-0.25 (0.56)	0.03 (0.02)	-0.04* (0.02)	0.60* (0.28)
Received gov. inputs subsidized	0.14 (0.09)	0.00 (0.00)	-0.00 (0.00)	0.03 (0.05)
HH has non-agric. income	0.32 (0.61)	-0.16** (0.03)	-0.01 (0.03)	0.38 (0.29)
Total cocoa area (ha)	-0.06 (0.11)	0.01** (0.00)	0.02** (0.00)	0.16** (0.04)
Community has electricity	0.43 (1.03)	0.02 (0.03)	-0.05* (0.03)	-0.32 (0.41)

Distance to extension office (km)	0.04 (0.03)	0.00** (0.00)	-0.00* (0.00)	0.02 (0.01)
Distance to tarred road (km)	-0.04 (0.04)	0.00 (0.00)	0.00 (0.00)	-0.00 (0.02)
Nitosol soil (favourable)	-0.35 (1.28)	0.03 (0.03)	0.04* (0.02)	-0.43 (0.28)
Western region	-0.96 (0.79)	-0.17** (0.03)	-0.02 (0.03)	0.85** (0.25)
Brong Ahafo region	-0.16 (0.61)	0.01 (0.03)	0.00 (0.05)	-0.31 (0.63)
Eastern region	0.63 (0.60)	0.05 (0.04)	0.04 (0.05)	-0.08 (0.35)
Central region	-0.98 (0.88)	0.11** (0.03)	0.11** (0.03)	-0.25 (0.33)
Constant	7.65** (1.90)	0.73** (0.11)	0.79** (0.07)	7.48** (0.80)
Observations	814	814	814	814

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Robust standard errors in parentheses: * p < 0.10, * p < 0.05, *** p < 0.01

Table A6: Association between certification and dietary diversity and food security

	(1)	(2)	(3)	(4)	(5)
	Diet Quality Questionnaire-All 5 (0/1)	Global Dietary Recommendations Score (0-18)	Non-Communicable Diseases - Protect Score (0-9)	Non-Communicable Diseases - Risk Score (0-9)	HH Food Insecurity Access Scale (0-27)

ADPO^C	-0.05 (0.03)	-0.06 (0.11)	-0.03 (0.12)	0.02 (0.07)	-0.08 (0.20)
Non-certified PO	0.24** (0.03)	11.50** (0.09)	3.00** (0.09)	0.50** (0.06)	2.81** (0.15)
OME0					
HH years of education	0.03 (0.02)	-0.01 (0.02)	0.02 (0.02)	0.03** (0.01)	-0.02 (0.03)
HH head is female	-0.45* (0.26)	-0.54** (0.19)	-0.53** (0.20)	0.01 (0.11)	0.53 (0.36)
Age of the household head	0.01 (0.01)	0.01* (0.01)	0.00 (0.01)	-0.01* (0.00)	0.01 (0.01)
No. of adults in HH	-0.05 (0.07)	-0.02 (0.06)	0.00 (0.06)	0.02 (0.04)	-0.15 (0.12)
No. of HH members	0.03 (0.04)	-0.01 (0.04)	-0.00 (0.04)	0.01 (0.02)	0.34** (0.07)
Risk aversion	0.02 (0.03)	0.02 (0.03)	0.04* (0.02)	0.03 (0.02)	0.01 (0.05)
HH head is leader	0.02 (0.21)	-0.21 (0.19)	0.14 (0.17)	0.34* (0.14)	-0.50 (0.34)
HH has non-agric. income	0.40* (0.17)	0.11 (0.21)	0.48** (0.16)	0.37** (0.08)	-0.44 (0.29)
Total cocoa area (ha)	-0.00 (0.03)	-0.01 (0.03)	-0.03 (0.02)	-0.02 (0.02)	-0.17** (0.05)

Community has electricity	0.46* (0.24)	0.17 (0.19)	0.27 (0.19)	0.09 (0.10)	-0.80* (0.32)
Distance to extension office (km)	0.01 (0.01)	0.01 (0.01)	-0.00 (0.01)	-0.01* (0.00)	-0.00 (0.02)
Distance to tarred road (km)	0.01 (0.01)	0.02* (0.01)	0.02* (0.01)	0.00 (0.01)	0.00 (0.01)
Nitosol soil (favourable)	0.00 (0.20)	0.52** (0.18)	0.20 (0.23)	-0.31** (0.11)	-0.39 (0.46)
Distance to food market (km)	0.00 (0.01)	-0.01 (0.01)	0.00 (0.01)	0.01 (0.01)	-0.01 (0.02)
Western region	-0.20 (0.22)	0.03 (0.21)	-0.33 (0.22)	-0.35** (0.11)	0.52 (0.36)
Brong Ahafo region	-0.64** (0.19)	-0.06 (0.21)	-0.45* (0.21)	-0.39** (0.14)	0.35 (0.55)
Eastern region	-0.59* (0.23)	-0.40* (0.19)	-0.61** (0.17)	-0.21 (0.13)	-0.71* (0.32)
Central region	-0.52** (0.18)	-0.19 (0.21)	-0.65** (0.24)	-0.46** (0.13)	0.83* (0.36)
Constant	-1.90** (0.58)	10.84** (0.62)	2.13** (0.59)	0.30 (0.25)	2.82** (0.87)

OME1

HH years of education	0.01 (0.02)	-0.00 (0.02)	-0.01 (0.02)	-0.01 (0.02)	-0.11** (0.04)
HH head is female	-0.46* (0.26)	-0.16 (0.25)	-0.35* (0.16)	-0.19 (0.14)	0.63 (0.40)
Age of the household head	0.00 (0.01)	0.00 (0.01)	-0.00 (0.01)	-0.01* (0.00)	0.00 (0.01)
No. of adults in HH	0.09 (0.09)	0.00 (0.05)	0.03 (0.06)	0.03 (0.04)	0.06 (0.12)
No. of HH members	-0.10* (0.05)	0.05 (0.03)	0.03 (0.03)	-0.02 (0.03)	0.08 (0.08)
Risk aversion	-0.01 (0.03)	-0.02 (0.03)	-0.01 (0.02)	0.01 (0.01)	0.00 (0.03)
HH head is leader	-0.22 (0.18)	-0.07 (0.16)	0.17 (0.15)	0.24** (0.08)	-0.57* (0.27)
HH has non-agric. income	0.35* (0.16)	-0.09 (0.17)	0.30* (0.12)	0.39** (0.11)	-0.39 (0.29)
Total cocoa area (ha)	-0.00 (0.03)	-0.03 (0.02)	-0.00 (0.02)	0.03* (0.01)	-0.01 (0.05)
Community has electricity	-0.33 (0.31)	-0.60* (0.36)	-0.26 (0.29)	0.34* (0.14)	-0.20 (0.39)
Distance to extension office (km)	0.01 (0.01)	0.01 (0.01)	0.00 (0.01)	-0.01 (0.00)	0.02* (0.01)

Distance to tarred road (km)	-0.01 (0.01)	-0.01 (0.01)	-0.02* (0.01)	-0.01 (0.01)	0.03 (0.02)
Nitosol soil (favourable)	-0.26 (0.24)	0.08 (0.25)	-0.24 (0.18)	-0.33* (0.16)	-0.04 (0.33)
Distance to food market (km)	-0.01 (0.01)	0.00 (0.01)	0.00 (0.01)	-0.00 (0.01)	-0.02 (0.02)
Western region	-0.14 (0.22)	0.01 (0.23)	-0.18 (0.19)	-0.20 (0.14)	-0.54 (0.34)
Brong Ahafo region	-0.91** (0.34)	-0.14 (0.32)	-0.67* (0.33)	-0.53** (0.14)	-0.43 (0.38)
Eastern region	-0.54* (0.22)	-0.15 (0.27)	-0.24 (0.23)	-0.09 (0.17)	-0.87* (0.43)
Central region	-0.27 (0.41)	-0.06 (0.22)	-0.21 (0.25)	-0.14 (0.25)	0.15 (0.66)
Constant	-0.24 (0.65)	11.71** (0.71)	3.37** (0.62)	0.67* (0.35)	3.52** (0.96)
Observations	814	814	814	814	814

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Robust standard errors in parentheses: * $p < 0.10$, * $p < 0.05$, *** $p < 0.01$

Rwanda:

Table A7: Probit regression on the certification decision to derive inverse probability weights

	(Table 8)	(Table 2)	(Table 3a)	(Table 3b)
Male HH head (0/1)	0.07 (0.12)			
Land devoted to agriculture > 50% (0/1)	0.13 (0.08)	0.14 (0.12)		
CWS is cooperatively owned (0/1)	1.53*** (0.14)			
Member of coffee cooperative (0/1)	0.31*** (0.11)			
Distance to input market (km)	0.07*** (0.02)			
Female HH head (0/1)			-0.99*** (0.22)	-0.56** (0.28)
Age of the household head		0.00 (0.01)	0.01 (0.04)	0.01 (0.03)
Literacy (0/1)		0.23** (0.11)	-0.33 (0.54)	0.13 (0.74)
Farmer (1/0)		0.31** (0.14)	-1.05 (0.91)	-1.53*** (0.52)
Years of experience of HHead		0.01 (0.01)	0.04 (0.03)	0.03 (0.03)
If HH is involved in coffee production		0.01 (0.07)	0.11 (0.09)	0.03 (0.07)
No. of HH members		0.00 (0.03)		
All income not coming from coffee		0.00 (0.00)		
Proportion of land ownership		0.10*** (0.04)		
Distance to food market (km)		0.03 (0.02)		
Access to a financial institution (1/0)		0.42*** (0.14)		
Constant	-0.52* (0.29)	-1.86** (0.83)	0.22 (1.37)	0.71 (1.63)
District effects	Yes			
Pseudo R^2	0.198			

chi2	165.44			
P	0.00			
Observations	711	842	96	100

Robust standard errors clustered at the district level in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

Table A8: Association between certification and dietary diversity and food security

	(1)	(2)	(3)	(4)
	Diet Quality Questionnaire- All 5 (0/1)	Global Dietary Recommendations Score (0-18)	Non-Communicable Diseases Protect Score (0-9)	Non-Communicable Diseases - Risk Score (0-9)
ADPO^{C}	0.06*** (0.02)	0.29** (0.15)	0.34** (0.14)	-0.05** (0.02)
Non-certified PO	0.16*** (0.02)	12.40*** (0.15)	3.22*** (0.13)	0.17*** (0.02)
OME0				
Male HH head (0/1)	0.79*** (0.30)	1.04*** (0.16)	0.86*** (0.11)	0.18*** (0.05)
Literacy (0/1)	0.70** (0.28)	0.29** (0.15)	0.12 (0.14)	0.17** (0.07)
Age (years)	0.01 (0.01)	-0.01** (0.01)	-0.01*** (0.00)	0.00 (0.00)
No. of HH members	-0.02 (0.02)	-0.08*** (0.02)	-0.07** (0.03)	-0.02** (0.01)
Single female HH (0/1)	0.06 (0.58)	0.68 (0.43)	0.73* (0.44)	-0.05 (0.04)

Distance to food market (km)	0.00 (0.02)	0.02 (0.02)	0.03 (0.02)	-0.01*** (0.00)
Constant	-2.48*** (0.58)	12.35*** (0.42)	3.41*** (0.34)	-0.07 (0.21)
OME1				
Male HH head (0/1)	0.30** (0.12)	0.27 (0.26)	0.24 (0.23)	0.03 (0.03)
Literacy (0/1)	0.43*** (0.08)	0.61*** (0.18)	0.56*** (0.19)	0.05 (0.05)
Age (years)	-0.00 (0.00)	-0.00 (0.00)	-0.00 (0.00)	-0.00 (0.00)
No. of HH members	-0.06* (0.03)	-0.01 (0.06)	-0.01 (0.05)	0.00 (0.01)
Single female HH (0/1)	0.14 (0.27)	-0.21 (0.27)	-0.15 (0.26)	-0.07 (0.05)
Distance to food market (km)	-0.03 (0.02)	-0.06** (0.02)	-0.07*** (0.02)	0.01 (0.01)
Constant	-0.77* (0.40)	12.46*** (0.54)	3.32*** (0.42)	0.14 (0.19)
Observations	711	711	711	711

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Robust standard errors clustered at the district level in parentheses: * p < 0.10, ** p < 0.05, *** p < 0.01

Table A9: Descriptive Statistics Women's Empowerment (Female respondents only)

	Total (1)		Certified farmers (2)		Non-certified farmers (3)		Mean difference (2)-(3)
	mean	sd	mean	sd	mean	sd	b
Empowerment score (0-11)	6.98	1.93	7.19	1.94	6.68	1.88	-0.51**
Female makes decisions in coffee farming (0/1)	0.79	0.41	0.81	0.39	0.75	0.43	-0.06
Female makes decisions in crops farming (0/1)	0.92	0.28	0.92	0.27	0.92	0.28	-0.00
Female makes decisions in use of income from coffee (0/1)	0.90	0.29	0.91	0.29	0.90	0.30	-0.01
Female makes decisions in use of income from other crops (0/1)	0.49	0.50	0.54	0.50	0.41	0.49	-0.13**
Female makes decisions on income from livestock	0.63	0.49	0.70	0.46	0.54	0.50	-0.16*
Female makes decisions in use of income from employment (0/1)	0.68	0.47	0.65	0.48	0.73	0.45	0.08
Female makes decisions on loans (0/1)	0.47	0.50	0.51	0.50	0.40	0.49	-0.11
Female makes decisions on savings (0/1)	0.90	0.30	0.90	0.30	0.89	0.32	-0.02
Female owns at least two small or one large asset (0/1)	1.00	0.00	1.00	0.00	1.00	0.00	0.00
Workload is < 10.5 hrs (0/1)	0.45	0.50	0.44	0.50	0.46	0.50	0.02
Satisfaction leisure time (0/1)	0.74	0.44	0.76	0.43	0.71	0.45	-0.05
Observations	294		175		119		294

Robust standard errors clustered at the district level in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

Table A10: Descriptives Time Use (Women only)

	Total (1)		Certified farmers (2)		Non-certified farmers (3)		Mean difference (2)-(3)
	mean	sd	mean	sd	mean	sd	b
Women's time spent on domestic work	3.60	2.34	3.62	2.13	3.56	2.66	-0.07
Women's time spent in agriculture	3.39	2.78	3.30	2.66	3.53	2.98	0.23
Women's time spent in off-farm activities	3.07	3.39	3.22	3.40	2.82	3.37	-0.39
Women's time spent on eating and grooming	1.61	1.37	1.46	1.31	1.84	1.43	0.37***
Women's time spent on resting	9.55	2.18	9.41	2.08	9.77	2.34	0.36
Women's time spent on leisure	1.55	1.27	1.52	1.25	1.59	1.29	0.07
Women's overall workload	11.50	7.37	11.74	7.47	11.10	7.22	-0.64
Observations	397		246		151		397

Robust standard errors clustered at the district level in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

Table A11: Descriptive Statistics Dietary Diversity

	Total (1)		Certified farmers (2)		Non-certified farmers (3)		Mean difference (2)-(3)
	mean	sd	mean	sd	mean	sd	b
Food Group Diversity Score (0-10)	4.34	1.68	4.44	1.62	4.18	1.77	-0.26**
Non-Communicable Diseases Protect Score	3.41	1.63	3.56	1.59	3.17	1.67	-0.39***
Non-Communicable Diseases Risk Score	0.14	0.45	0.12	0.42	0.15	0.49	0.03
Global Dietary Recommendations Score	12.54	1.75	12.68	1.69	12.33	1.82	-0.36***
Zero fruit vegetables (0/1))	0.90	0.30	0.91	0.29	0.89	0.31	-0.01

All-5 (0/1)	0.20	0.40	0.22	0.42	0.17	0.38	-0.05
Minimum Dietary Diversity Women (0/1)	0.39	0.49	0.45	0.50	0.32	0.47	-0.14
Observations	711		428		283		711

Robust standard errors clustered at the district level in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

Table A12: Association between certification and economic outcomes

	(1)	(2)
	Net coffee income (RWF/ha)	Coffee production (kg/ha)
$ADPO^C$	642.53*** (181.53)	790.63** (402.56)
Non-certified PO	2115.00*** (141.74)	6693.57*** (323.86)
OME0		
Female HH head (0/1)	237.66 (428.41)	410.38 (613.40)
Age of the household head	-13.62 (18.55)	-54.81 (18.55)
Literacy (0/1)	-240.10 (378.95)	-1111.74 (1201.88)
Farmer (1/0)	532.86 (562.29)	811.98 (873.63)
Years of experience of HHead	1.89 (11.84)	8.04 (29.62)

If HH is involved in coffee production	31.92 (364.00)	-342.62 (1249.77)
No. of HH members	-75.84 (86.18)	-406.50*** (159.29)
All income not coming from coffee	0.28** (0.14)	0.90*** (0.28)
Land devoted to agriculture > 50% (0/1)	-570.63** (240.90)	-705.94** (329.35)
Proportion of land ownership	-109.32 (155.06)	-410.36 (425.19)
Land of the coffee plot in ha	-5660.87*** (941.22)	-15580.23*** (1985.59)
Access to a financial institution (1/0)	-348.67* (178.03)	-1323.93*** (146.01)
Years of coffee plantation	18.70* (9.94)	5.12 (19.05)
Number of coffee trees in the plot	1.41*** (0.32)	3.11*** (0.84)
Rusizi	0.00 (.)	0.00 (.)
Nyamasheke	289.71*** (96.69)	-459.03 (423.62)

Karongi	811.79*** (174.64)	1080.96** (472.82)
Rutsiro	836.38*** (128.44)	1496.79** (605.07)
Huye	0.87 (196.00)	-366.28 (407.81)
Constant	4294.71* (2276.95)	16535.36*** (6017.08)
OME1		
Female HH head (0/1)	143.84 (236.49)	495.54 (476.38)
Age of the household head	-30.39* (16.94)	-68.26* (37.32)
Literacy (0/1)	-63.90 (442.19)	271.36 (807.37)
Farmer (1/0)	128.22 (586.02)	151.91 (1025.49)
Years of experience of HHead	2.65 (7.25)	12.26 (23.09)
If HH is involved in coffee production	-196.01 (599.54)	-995.84 (943.46)
No. of HH members	-0.56 (64.87)	-34.34 (76.98)

All income not coming from coffee	0.36** (0.18)	0.52** (0.24)
Land devoted to agriculture > 50% (0/1)	-342.80 (318.77)	111.90 (447.67)
Proportion of land ownership	350.88*** (103.63)	123.98 (402.93)
Land of the coffee plot in ha	-6243.41*** (1733.08)	-16520.66*** (4534.50)
Access to a financial institution (1/0)	473.18* (272.43)	766.22 (708.87)
Years of coffee plantation	10.54* (5.75)	29.26*** (11.03)
Number of coffee trees in the plot	1.05* (0.59)	3.04** (1.46)
Rusizi	0.00 (.)	0.00 (.)
Nyamasheke	1148.93*** (76.73)	1944.67*** (147.07)
Karongi	648.72*** (62.04)	987.95*** (114.43)
Rutsiro	201.58 (128.84)	846.18*** (238.49)

Huye	542.59*** (179.30)	1082.57*** (202.80)
Constant	2688.42 (2213.43)	8769.50** (3655.77)
Observations	842	842

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. **1 USD = RWF 1.318,51**.

Table A13: Association between certification and plot-level data on vegetation structure

	(1)	(2)
	Shade trees per hectare	Shade tree richness
ADPO^{C}	21.57* (12.69)	0.78*** (0.23)
Non-certified PO	163.93*** (35.25)	3.27*** (0.19)
OME0		
Land of the coffee plot in ha	90.87*** (23.80)	
Number of coffee trees in the plot	-0.06*** (0.01)	-0.00 (0.00)
Years of coffee plantation	5.36*** (1.99)	0.01 (0.02)
Land of the coffee plot in ha		2.60* (1.57)
Constant	21.79 (49.14)	2.63*** (0.37)
OME1		
Land of the coffee plot in ha	-171.24 (240.31)	
Number of coffee trees in the plot	-0.02 (0.11)	-0.00*** (0.00)

Years of coffee plantation	-1.40 (1.13)	-0.02 (0.01)
Land of the coffee plot in ha		13.30*** (1.43)
Constant	266.66*** (48.32)	3.83*** (0.39)
Observations	96	100

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A14: Association between being certified and ecological outcomes related to animal diversity

	(1) Bioacustics Index	(2) Predation rate
Certification status (1/0)	0.064 (0.129)	-2.862 (2.477)
Age of the household head	-0.008 (0.006)	0.154 (0.111)
Female HH head (0/1)	-0.047 (0.149)	0.968 (2.861)
No. of HH members	-0.007 (0.031)	-0.171 (0.600)
Land of the coffee plot in ha	-0.739 (0.533)	-9.623 (10.230)
Number of coffee trees in the plot	0.0002 (0.0002)	0.005 (0.003)
Years of coffee plantation	0.0002 (0.015)	-0.077 (0.294)
Age of coffee plantation	-0.000 (0.0002)	0.001 (0.005)

Percentage of area in a radius of 1 km from the coffee plot covered by trees	-0.008 (0.009)	0.030 (0.171)
Distance to the closest national park	0.041** (0.016)	0.309 (0.314)
Nyamasheke	-0.869*** (0.176)	14.604*** (3.387)
Karongi	-0.838*** (0.235)	6.558 (4.504)
Rutsiro	-0.296 (0.198)	4.926 (3.808)
Huye	-1.331*** (0.363)	-9.016 (6.977)
Constant	3.635*** (0.436)	14.351* (8.376)
Log Likelihood	-75.260	-367.814
Akaike Inf. Crit.	180.520	765.628
Observations	99	99

Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table A15: Association between certification and specialization

	(1)	(2)	(3)
	Total household income (RWF) (HIS-transformed)	Shade coffee income of total income	Agricultural diversification
$ADPO^C$	0.13*** (0.02)	0.02 (0.01)	0.76*** (0.12)
Non-certified PO	14.40*** (0.08)	0.32*** (0.02)	7.04*** (0.06)
OME0			
Female HH head (0/1)	0.44*** (0.08)	-0.01 (0.02)	1.05*** (0.28)
Age of the household head	-0.00 (0.00)	0.00 (0.00)	0.01 (0.01)
Farmer (1/0)	0.15 (0.10)	0.04** (0.02)	0.47 (0.59)
Years of experience of HHead	0.00 (0.00)	-0.00 (0.00)	-0.01 (0.01)
If HH is involved in coffee production	0.07 (0.11)	-0.04** (0.02)	-0.59 (0.49)
No. of HH members	-0.01 (0.02)	0.00 (0.00)	0.14 (0.09)

All income not coming from coffee	0.00*** (0.00)	-0.00*** (0.00)	0.00*** (0.00)
Access to a financial institution (1/0)	0.13 (0.10)	-0.05*** (0.01)	1.40*** (0.19)
Constant	13.40*** (0.22)	0.34*** (0.05)	3.63** (1.55)
OME1			
Female HH head (0/1)	0.22*** (0.08)	-0.01 (0.01)	0.63*** (0.19)
Age of the household head	0.00 (0.00)	0.00 (0.00)	-0.00 (0.01)
Farmer (1/0)	0.15 (0.13)	-0.01 (0.04)	1.43*** (0.22)
Years of experience of HHead	-0.01*** (0.00)	-0.00 (0.00)	-0.00 (0.01)
If HH is involved in coffee production	0.13 (0.08)	-0.02** (0.01)	-0.32 (0.47)
No. of HH members	0.01 (0.01)	-0.00 (0.00)	0.04 (0.04)
All income not coming from coffee	0.00*** (0.00)	-0.00*** (0.00)	0.00*** (0.00)

Access to a financial institution (1/0)	0.19** (0.09)	-0.02 (0.02)	0.73 (0.59)
Constant	13.32*** (0.23)	0.43*** (0.03)	5.12*** (0.58)
Observations	842	842	842

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Peru:

Table A16: Probit regression on the certification decision to derive inverse probability weights

Cocoa manager's years of education	0.02 (0.02)
Female cocoa manager	0.18 (0.27)
Age (years)	0.01 (0.01)
No. of adults in HH	-0.13* (0.06)
HH has non-agric. income	0.00 (0.15)
Years of experience of manager	0.01 (0.01)
Total land area (ha)	-0.00 (0.01)
Wealth index (1-5)	-0.09 (0.08)
Distance to cooperative (min)	0.00 (0.00)
Distance to input market (min)	-0.00 (0.00)
Single female HH (0/1)	-0.46* (0.26)
Cooperative 1	1.01*** (0.18)
Cooperative 2	1.24*** (0.30)
Cooperative 3	-0.34*** (0.12)
Cooperative 4	0.17 (0.14)
Cooperative 5	-0.50*** (0.12)
Cooperative 7	0.58* (0.33)
Cooperative 8	0.19 (0.14)
Cooperative 9	1.45*** (0.33)

Cooperative 10	1.17*** (0.14)
Constant	0.09 (0.46)
Observations	566

Robust standard errors clustered at the district level in parentheses, * p < 0.10, ** p < 0.05, *** p < 0.01

Table A17: Association between certification and economic outcomes

	(1)	(2)
	Yield (kg/ha)	Net cocoa income (PEN/ha)
ADPO[C]	152.66** (65.98)	299.60 (208.88)
Non-certified PO	684.31*** (65.75)	2687.75*** (346.61)
OME0		
Cocoa manager's years of education	-0.76 (9.70)	
Female cocoa manager	-25.34 (235.18)	-1131.78 (693.30)
Age (years)	-4.29* (2.30)	
No. of adults in HH	41.84 (32.14)	93.89 (161.96)
HH has non-agric. income	-57.63 (95.15)	-1003.19** (413.72)

Years of experience of manager	7.15** (3.61)	79.73*** (23.89)
Total land area (ha)	-2.93 (3.51)	-9.23 (22.57)
Wealth index (1-5)	-9.49 (52.20)	-172.85 (214.56)
Distance to cooperative (min)	0.03 (1.30)	6.72 (9.88)
Distance to input market (min)	4.69*** (1.45)	20.51** (8.34)
Single female HH (0/1)	-78.87 (264.73)	-553.84 (1136.18)
Cooperative 1	-225.48 (140.56)	-1682.82** (742.11)
Cooperative 2	87.89 (110.32)	878.72 (629.56)
Cooperative 3	222.02* (120.13)	299.87 (442.99)
Cooperative 4	204.59 (136.37)	817.64* (452.75)
Cooperative 5	285.32** (140.28)	675.24 (514.74)

Cooperative 7	756.22*** (279.24)	-101.96 (1587.56)
Cooperative 8	24.23 (125.37)	-485.78 (580.90)
Cooperative 9	605.42** (241.93)	593.80 (1159.87)
Cooperative 10	226.59* (137.14)	2283.40** (1007.17)
Constant	471.10* (271.05)	1098.89 (696.62)
OME1		
Cocoa manager's years of education	1.13 (6.26)	
Female cocoa manager	-219.58** (106.79)	-1566.12*** (492.05)
Age (years)	-4.95** (2.28)	
No. of adults in HH	-79.14* (45.50)	-242.71 (186.04)
HH has non-agric. income	190.16 (136.44)	-255.60 (410.77)
Years of experience of manager	-3.74 (5.22)	-41.44*** (12.80)

Total land area (ha)	1.32 (2.68)	5.95 (9.35)
Wealth index (1-5)	91.36*** (21.53)	286.23*** (59.54)
Distance to cooperative (min)	5.23*** (1.92)	14.45** (6.79)
Distance to input market (min)	-2.63 (1.62)	-7.63 (4.79)
Single female HH (0/1)	-83.31 (127.61)	-659.91* (392.22)
Cooperative 1	252.59*** (74.66)	586.97*** (126.98)
Cooperative 2	591.53*** (94.53)	2685.41*** (319.71)
Cooperative 3	274.42*** (69.17)	628.93*** (126.73)
Cooperative 4	260.70*** (80.71)	1525.52*** (209.13)
Cooperative 5	495.73*** (78.34)	772.92*** (176.32)
Cooperative 7	575.58*** (176.69)	1412.26* (794.10)

Cooperative 8	338.93*** (77.55)	1418.22*** (178.98)
Cooperative 9	469.44*** (125.84)	2043.05*** (308.55)
Cooperative 10	828.35*** (67.50)	3164.50*** (119.05)
Constant	536.32*** (166.15)	1614.67*** (476.69)
Observations	566	566

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Robust standard errors clustered at the district level in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A18: Association between organic certification and gender-specific labor demand in Peru

	(1)	(2)	(3)	(4)
	Women's cocoa labor days per ha	Men's cocoa labor days per ha	Ratio women's labor days on men's labor days	Share of women's labor days out of total family days
ADPO^{C}	5.36** (2.10)	-1.55 (2.22)	0.30*** (0.09)	0.07*** (0.03)
Non-certified PO	13.20*** (1.59)	29.62*** (1.83)	0.52*** (0.06)	0.30*** (0.03)
OME0				
Female cooperative member (0/1)	2.28 (1.42)	-0.08 (3.01)	0.08 (0.07)	0.01 (0.03)
Total cocoa area (ha)	-0.26 (0.43)	-3.43*** (0.63)	0.10*** (0.02)	0.02*** (0.01)
Total land area (ha)	-0.41*** (0.08)	-0.37*** (0.12)	0.00 (0.00)	-0.00 (0.00)
HH has other non-cocoa plot(s) (1/0)	5.79*** (2.11)	-2.38 (2.18)	-0.03 (0.09)	0.05 (0.03)
Household owns small livestock	-1.00 (4.20)	-1.50 (1.64)	0.15 (0.14)	0.03 (0.07)
Age (years)	-0.18 (0.13)	-0.60** (0.30)	0.00 (0.01)	0.00 (0.00)
Cocoa manager's years of education	-0.24 (0.30)	-1.18** (0.50)	0.01 (0.01)	0.01 (0.01)

Years of experience of manager	0.22 (0.14)	0.65*** (0.24)	0.00 (0.01)	0.00 (0.00)
HH size	-2.16*** (0.56)	-4.02*** (1.35)	-0.02 (0.03)	-0.01 (0.01)
Ind has non-agric. income	0.53 (5.35)	5.05 (6.62)	0.14 (0.23)	0.03 (0.08)
Wealth index (1-5)	0.35 (1.04)	-0.33 (0.72)	-0.02 (0.02)	-0.00 (0.01)
Distance to cooperative (min)	0.02 (0.05)	-0.07 (0.07)	0.00 (0.00)	0.00** (0.00)
Cooperative 1	6.88** (3.42)	8.52 (6.72)	0.02 (0.12)	0.00 (0.06)
Cooperative 2	2.52 (2.37)	12.81** (6.02)	0.11 (0.08)	0.01 (0.06)
Cooperative 3	7.35** (3.30)	13.54** (6.29)	0.39*** (0.13)	0.13** (0.06)
Cooperative 4	5.64** (2.50)	2.86 (5.49)	0.30*** (0.10)	0.14* (0.09)
Cooperative 5	9.58*** (2.44)	9.73* (5.14)	0.42*** (0.10)	0.19*** (0.05)
Cooperative 7	17.35 (15.43)	56.56*** (8.67)	0.01 (0.39)	-0.03 (0.15)

Cooperative 8	10.43*** (3.32)	14.23** (5.89)	0.28** (0.12)	0.10* (0.06)
Cooperative 9	10.68*** (2.25)	16.24** (6.81)	0.26 (0.19)	0.14* (0.08)
Cooperative 10	28.52*** (2.62)	35.59*** (7.62)	0.55*** (0.09)	0.22*** (0.05)
Constant	21.06*** (7.41)	83.20*** (22.03)	-0.14 (0.42)	0.02 (0.14)
OME1				
Female cooperative member (0/1)	5.52** (2.51)	-4.26** (1.97)	0.71** (0.32)	0.11*** (0.03)
Total cocoa area (ha)	-1.56*** (0.47)	-2.14*** (0.50)	-0.01 (0.02)	-0.00 (0.01)
Total land area (ha)	-0.07 (0.09)	-0.19*** (0.07)	-0.00 (0.00)	-0.00 (0.00)
HH has other non-cocoa plot(s) (1/0)	-1.52 (1.83)	-0.99 (2.14)	0.12 (0.08)	-0.00 (0.02)
Household owns small livestock	7.20 (7.12)	8.56** (3.79)	-0.20 (0.13)	-0.01 (0.03)
Age (years)	-0.21*** (0.07)	-0.21** (0.08)	-0.00 (0.01)	-0.00 (0.00)
Cocoa manager's years of education	-0.97** (0.42)	-0.65 (0.44)	-0.03* (0.02)	-0.01*** (0.00)

Years of experience of manager	0.14 (0.16)	0.09 (0.15)	0.00 (0.01)	0.00 (0.00)
HH size	-2.47*** (0.50)	-1.74*** (0.65)	-0.05 (0.04)	-0.02*** (0.01)
Ind has non-agric. income	1.27 (3.92)	-3.68 (2.61)	0.31 (0.31)	0.08 (0.06)
Wealth index (1-5)	0.23 (0.60)	-0.38 (0.64)	0.04 (0.06)	0.02*** (0.01)
Distance to cooperative (min)	-0.00 (0.03)	0.02 (0.03)	0.00 (0.00)	0.00 (0.00)
Cooperative 1	6.08 (4.00)	-4.23 (6.02)	-0.05 (0.32)	-0.04 (0.05)
Cooperative 2	1.13 (3.99)	-7.80 (6.03)	0.07 (0.32)	-0.02 (0.05)
Cooperative 3	1.65 (4.14)	4.38 (6.06)	-0.23 (0.32)	-0.06 (0.05)
Cooperative 4	-7.06 (4.49)	-9.21 (5.90)	-0.33 (0.40)	-0.12* (0.06)
Cooperative 5	3.26 (4.49)	2.22 (6.34)	-0.27 (0.32)	-0.04 (0.05)
Cooperative 7	-4.59 (4.20)	-9.19 (7.13)	-0.34 (0.33)	-0.06 (0.07)

Cooperative 8	1.97 (4.40)	2.75 (6.57)	0.05 (0.42)	-0.09* (0.05)
Cooperative 9	0.41 (4.03)	-6.23 (6.35)	-0.14 (0.34)	-0.04 (0.06)
Cooperative 10	7.20* (4.01)	1.42 (6.04)	0.10 (0.31)	0.00 (0.05)
Constant	48.00*** (6.92)	64.57*** (11.76)	1.14* (0.62)	0.54*** (0.09)
Observations	484	484	476	481

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A19: Association between certification and specialization

	(1) Total HH income (PEN) (IHS-transformed)	(2) Share cocoa income of total income	(3) Share cocoa land of total land	(4) Agricultural diversification
ADPO^{C}	-0.02 (0.04)	0.03 (0.03)	-0.02 (0.03)	-0.72** (0.36)
Non-certified PO	10.44*** (0.11)	0.51*** (0.03)	0.81*** (0.02)	6.35*** (0.42)
OME0				
Cocoa manager's years of education	0.02 (0.02)	-0.01 (0.00)	0.00 (0.01)	-0.24* (0.12)
Single female HH (0/1)	-0.08 (0.13)	-0.28*** (0.07)	0.05 (0.05)	-3.29*** (1.08)
Age (years)	-0.01*** (0.00)	-0.01** (0.00)	-0.00 (0.00)	0.01 (0.01)
No. of adults in HH	0.00 (0.05)	-0.05** (0.03)	0.02 (0.03)	-0.21 (0.27)
Cocoa manager with leader role (1/0)	0.31** (0.14)	-0.12 (0.08)	-0.07 (0.06)	1.15** (0.53)
Ind has non-agric. income	0.27** (0.13)	-0.21** (0.10)	0.10 (0.09)	-1.41 (0.99)
Total land area (ha)	0.03*** (0.01)	-0.00 (0.00)	-0.01*** (0.00)	0.04** (0.02)

Total cocoa area (ha)	0.03 (0.04)			
Distance to cooperative (min)	0.00 (0.00)	0.00*** (0.00)	0.00 (0.00)	-0.01 (0.01)
Cooperative 1	-0.50*** (0.08)	-0.08** (0.04)	0.08 (0.05)	2.65*** (0.69)
Cooperative 2	0.07 (0.10)	0.03 (0.04)	0.01 (0.06)	3.29*** (0.55)
Cooperative 3	0.19 (0.13)	0.09 (0.08)	-0.04 (0.06)	0.40 (0.50)
Cooperative 4	0.29** (0.11)	0.17 (0.11)	0.01 (0.05)	1.16** (0.47)
Cooperative 5	0.26** (0.13)	0.09 (0.06)	-0.05 (0.05)	1.03** (0.45)
Cooperative 7	-0.00 (0.17)	-0.18 (0.15)	-0.12 (0.11)	3.68*** (1.19)
Cooperative 8	0.25*** (0.09)	-0.06 (0.06)	0.00 (0.06)	1.13** (0.56)
Cooperative 9	0.68*** (0.12)	0.05 (0.04)	0.14*** (0.05)	2.64 (1.95)
Cooperative 10	0.12 (0.10)	0.13 (0.11)	-0.03 (0.08)	-0.27 (1.12)

Wealth index (1-5)		-0.05* (0.02)	0.00 (0.02)	-0.16 (0.35)
Years of experience of manager		0.01*** (0.00)	0.01 (0.00)	-0.03 (0.04)
Constant	10.09*** (0.31)	1.03*** (0.23)	0.85*** (0.18)	7.53*** (2.39)
OME1				
Cocoa manager's years of education	0.03*** (0.01)	-0.00 (0.00)	0.00 (0.00)	-0.02 (0.04)
Single female HH (0/1)	-0.29*** (0.08)	-0.21*** (0.04)	0.03 (0.03)	-0.12 (0.35)
Age (years)	-0.01*** (0.00)	-0.00 (0.00)	-0.00 (0.00)	0.01 (0.01)
No. of adults in HH	-0.01 (0.05)	-0.01 (0.02)	0.00 (0.01)	0.44*** (0.14)
Cocoa manager with leader role (1/0)	0.12* (0.06)	0.07 (0.06)	0.01 (0.04)	0.63 (0.70)
Ind has non-agric. income	0.16 (0.12)	-0.10 (0.07)	0.03 (0.07)	-0.03 (0.77)
Total land area (ha)	0.01*** (0.01)	-0.00 (0.00)	-0.01*** (0.00)	0.02* (0.01)
Total cocoa area (ha)	0.11*** (0.01)			

Distance to cooperative (min)	0.00*** (0.00)	0.00 (0.00)	-0.00*** (0.00)	0.00 (0.00)
Cooperative 1	-0.02 (0.12)	-0.12** (0.06)	-0.15*** (0.03)	2.87*** (0.32)
Cooperative 2	0.51*** (0.11)	0.09 (0.07)	-0.08*** (0.03)	1.77*** (0.52)
Cooperative 3	0.18* (0.10)	-0.01 (0.05)	-0.10*** (0.02)	2.13*** (0.55)
Cooperative 4	0.63*** (0.07)	0.05 (0.07)	-0.11*** (0.03)	0.16 (0.68)
Cooperative 5	0.16 (0.11)	-0.04 (0.06)	-0.08*** (0.03)	0.76** (0.35)
Cooperative 7	0.51*** (0.12)	0.07 (0.09)	-0.02 (0.06)	0.74 (0.78)
Cooperative 8	0.56*** (0.12)	-0.03 (0.07)	-0.15*** (0.03)	1.01 (0.66)
Cooperative 9	0.27** (0.12)	0.24*** (0.07)	0.01 (0.03)	2.17*** (0.43)
Cooperative 10	0.45*** (0.13)	0.25*** (0.06)	0.03 (0.03)	1.64*** (0.35)
Wealth index (1-5)		-0.00 (0.01)	-0.01* (0.01)	0.54*** (0.16)

Years of experience of manager		0.00 (0.00)	0.00 (0.00)	0.06** (0.03)
Constant	9.60*** (0.19)	0.58*** (0.06)	1.06*** (0.06)	-0.54 (0.92)
Observations	566	566	566	566

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A20: Association between certification and dietary diversity and food security

	(1)	(2)	(3)	(4)	(5)
	Diet Quality Questionnaire-All 5 (0/1)	Global Dietary Recommendations Score (0-18)	Non-Communicable Diseases - Protect Score (0-9)	Non-Communicable Diseases - Risk Score (0-9)	HH Food Insecurity Access Scale (0-27)
ADPO^C	0.04 (0.07)	-0.02 (0.24)	-0.18 (0.24)	-0.16 (0.14)	-0.34 (0.61)
Non-certified PO	0.45*** (0.05)	12.26*** (0.18)	4.38*** (0.21)	1.12*** (0.18)	6.21*** (0.86)
OME0					
Cocoa manager's years of education	0.06 (0.03)	0.01* (0.00)	0.02*** (0.01)	0.00 (0.02)	-0.05*** (0.02)
Age (years)	-0.03** (0.01)	0.00 (0.00)	-0.00 (0.00)	-0.02*** (0.01)	-0.00 (0.01)
Female cocoa manager	0.35 (0.53)	0.12** (0.05)	0.23 (0.14)	-0.55** (0.26)	-0.10* (0.05)
HH size	0.21* (0.11)	0.01 (0.01)	0.02 (0.03)	-0.00 (0.08)	0.08* (0.04)

Cocoa manager with leader role (1/0)	-0.26 (0.23)	-0.10** (0.05)	-0.00 (0.08)	0.72*** (0.17)	0.05 (0.13)
Ind has non-agric. income	0.04 (0.72)	-0.16* (0.09)	-0.14 (0.23)	0.71 (0.45)	-0.26 (0.36)
Total land area (ha)	0.01 (0.01)	0.00** (0.00)	0.01* (0.00)	-0.02 (0.02)	0.01 (0.01)
Wealth index (1-5)	0.35*** (0.12)	0.03** (0.01)	0.11** (0.05)	0.13 (0.14)	0.10 (0.06)
Cooperative 1	-0.29 (0.44)	0.02 (0.05)	0.01 (0.12)	0.05 (0.39)	0.67*** (0.19)
Cooperative 2	-0.38 (0.46)	0.04 (0.04)	0.01 (0.08)	-0.13 (0.25)	-0.08 (0.18)
Cooperative 3	-0.43 (0.33)	-0.02 (0.05)	-0.21** (0.08)	-0.45* (0.24)	-0.05 (0.21)
Cooperative 4	-1.07*** (0.27)	0.02 (0.04)	-0.06 (0.06)	-0.28 (0.32)	-0.05 (0.22)
Cooperative 5	-0.48 (0.34)	-0.05 (0.04)	-0.30*** (0.08)	-0.46*** (0.15)	-0.21 (0.21)
Cooperative 7	4.59*** (0.52)	0.26*** (0.06)	0.52*** (0.13)	-0.64 (0.47)	-1.07 (0.93)
Cooperative 8	-0.19 (0.34)	-0.02 (0.05)	-0.15 (0.10)	-0.15 (0.23)	-0.44* (0.24)

Cooperative 9	-1.08*** (0.35)	-0.10 (0.08)	-0.59*** (0.15)	-0.78 (0.56)	-0.38 (0.31)
Cooperative 10	-2.29*** (0.37)	-0.02 (0.08)	-0.33*** (0.11)	-0.97** (0.46)	-0.65** (0.33)
Constant	-0.25 (0.95)	2.27*** (0.09)	1.10*** (0.24)	1.28** (0.59)	1.76*** (0.52)
OME1					
Cocoa manager's years of education	-0.01 (0.02)	0.00 (0.00)	0.01*** (0.00)	0.02 (0.02)	-0.02** (0.01)
Age (years)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	-0.01** (0.00)	0.00 (0.00)
Female cocoa manager	-0.11 (0.21)	-0.04* (0.02)	-0.13** (0.05)	0.01 (0.17)	-0.13 (0.14)
HH size	0.09* (0.05)	0.01** (0.00)	0.03* (0.01)	-0.05 (0.03)	0.05*** (0.01)
Cocoa manager with leader role (1/0)	0.56* (0.29)	-0.03 (0.03)	0.02 (0.06)	0.29*** (0.09)	0.10 (0.14)
Ind has non-agric. income	0.26 (0.33)	-0.01 (0.04)	-0.01 (0.07)	-0.00 (0.19)	-0.24 (0.25)
Total land area (ha)	0.01 (0.01)	0.00 (0.00)	0.00** (0.00)	0.00 (0.00)	-0.00 (0.00)
Wealth index (1-5)	0.06 (0.08)	-0.00 (0.01)	0.03 (0.02)	0.12*** (0.04)	-0.10*** (0.02)

Cooperative 1	0.34** (0.13)	-0.04 (0.07)	-0.05 (0.15)	0.34 (0.38)	-0.01 (0.09)
Cooperative 2	1.19*** (0.17)	0.05 (0.07)	0.27* (0.15)	0.35 (0.38)	-0.26** (0.13)
Cooperative 3	1.22*** (0.19)	0.12 (0.07)	0.30** (0.15)	-0.43 (0.37)	-0.10 (0.10)
Cooperative 4	1.27*** (0.15)	0.11 (0.07)	0.36** (0.16)	0.07 (0.34)	-0.20** (0.10)
Cooperative 5	0.60*** (0.15)	0.11 (0.07)	0.28* (0.15)	-0.39 (0.36)	0.03 (0.12)
Cooperative 7	1.08*** (0.30)	0.05 (0.07)	0.29* (0.15)	0.43 (0.45)	-0.74*** (0.15)
Cooperative 8	1.14*** (0.21)	0.13* (0.07)	0.34** (0.16)	-0.33 (0.36)	-0.20 (0.13)
Cooperative 9	0.93*** (0.18)	0.07 (0.08)	0.17 (0.16)	-0.25 (0.39)	-0.34*** (0.12)
Cooperative 10	1.35*** (0.16)	0.11 (0.07)	0.31** (0.15)	-0.19 (0.37)	-0.28*** (0.10)
Constant	-1.64*** (0.43)	2.32*** (0.07)	0.90*** (0.15)	0.10 (0.44)	2.27*** (0.17)
Observations	566	566	566	566	558

PO: predicted outcome, ADPOC: average difference in predicted outcome for certified farmers under certification and hypothetical non-certification, OME0: outcome model estimation for non-certified, OME1: outcome model estimation for certified, Standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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