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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 in meeting the growing demand for food in an equitable way while mitigating environmental impacts such as deforestation, soil degradation, and climate change. Over the past few decades, voluntary sustainability standards (VSS) have proliferated as a potential instrument to promote more sustainable global value chains and sourcing practices. Although the body of impact evaluations on VSS has grown, most studies focus on single outcome dimensions, leaving interactions between dimensions underexplored. In this study, we use a conceptual framework to assess the relationships between VSS interventions and key sustainable food system outcomes across multiple dimensions. Our study focuses on economic prosperity, healthy ecosystems, gender equality, and food security, with a particular emphasis on identifying potential trade-offs and synergies between these dimensions. To illustrate the interactions identified in our framework, we present empirical data from three case studies in Ghana, Rwanda, and Peru. Our findings underscore the importance of balancing trade-offs and fostering synergies to advance sustainability across multiple dimensions. This study contributes to ongoing discussions on the effectiveness of VSS in promoting sustainability by highlighting their potential impacts, as well as the trade-offs that must be managed, to achieve more sustainable food systems.

JEL Classification: Q01, Q13, Q57, J22

1 | 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 production 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 (Garrett et al. 2021; Meemken et al. 2021; Starobin 2021). These issues are further exacerbated by climate change, which threatens to make many current growing areas unsuitable for production (Ariza-Salamanca et al. 2023; Grüter et al. 2022). This places immense pressure on the environment and rural livelihoods, disproportionately affecting women (Andrijevic et al. 2020).

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In light of these challenges, a transition towards more sustainable food systems ranks high on the policy agenda and is central to achieving the UN Sustainable Development Goals (SDGs) (Ambikapathi et al. 2022). Sustainable food systems aim to ensure food security and nutrition for all without compromising the economic, environmental, and social capacity to do so in the future (FAO 2018b). However, achieving sustainable food systems requires balancing often competing goals in multiple dimensions of sustainability. Trade-offs between economic and environmental outcomes are well-documented, particularly in the context of agricultural intensification (Phalan et al. 2011), and have been explicitly analyzed in tropical cash crop agriculture (Daum et al. 2023; Wenzel et al. 2024). Although less studied, interactions between other dimensions, such as social and equity outcomes, are also relevant for sustainable food systems (Rubio-Jovel 2023).

In this context, voluntary sustainability standards (VSS) have emerged as a promising tool to promote more sustainable food systems and reconcile competing sustainability outcomes (Traldi 2021). A growing body of literature evaluates the impact of VSS on economic, environmental, and social outcomes. Yet, most studies focus on a single dimension at a time, which risks overlooking the potential trade-offs and synergies that exist between sustainability outcomes (Barbier and Burgess 2019; Garrett et al. 2021; Rubio-Jovel 2023; Rubio-Jovel et al. 2024). This study seeks to address this gap by examining whether VSS can effectively support sustainable food system outcomes for smallholder farmers in international cash crop sectors, considering multiple dimensions of sustainability and exploring the interactions between them. We conceptually illustrate the mechanisms through which VSS influence multiple dimensions of sustainability, highlighting key trade-offs and synergies between them. Using primary data from three case studies—Ghana, Rwanda, and Peru—we provide empirical evidence on how VSS can balance these multiple and often competing goals.

Most VSS relevant for tropical cash crops, such as Fairtrade, Rainforest Alliance, or Organic, were initially developed with a specific goal in mind focusing, for example, on environmental or social aspects only. In recent decades, VSS have been further developed and have gradually converged in their objectives to encompass comprehensive sustainability goals in multiple dimensions (Lambin and Thorlakson 2018; Meemken et al. 2021). Traldi (2021) provides an overview of 13 major international agricultural VSS, including, for example, Fairtrade, Organic, and Rainforest Alliance, 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, including Rainforest Alliance, Bird Friendly, and Roundtable on Sustainable Palm Oil (RSPO), among others. All of these VSS encourage the adoption of sustainable farming practices to improve soil health, increase biodiversity, and reduce environmental impact. They also facilitate access to inputs or price premiums to increase agricultural productivity and economic prosperity of farming households. Furthermore, VSS typically commit to social and equity goals, for example, supporting gender equity by enacting human and labor rights and offering gender-sensitive training (Garrett et al. 2021; Meemken and Qaim 2018; Traldi 2021). While VSS have become more comprehensive in the sustainability dimensions they address, most evaluation studies still focus on only one outcome dimension, thereby overlooking these complexities.

Numerous studies assess the impact of VSS on economic outcomes, including yields, prices, net crop income, and total household income (Beuchelt and Zeller 2011; Boonaert and Maertens 2023; Iddrisu et al. 2020; Meemken 2020). Recent reviews by Meemken et al. (2021) and Oya et al. (2018) conclude that the overall economic impacts of VSS on farm households appear to be moderately positive. However, the underlying mechanisms that lead to the improvements in economic outcomes, in terms of the services provided and practices promoted, often vary between VSS (Boonaert and Maertens 2023; Meemken et al. 2021), and, accordingly, may affect environmental outcomes in different ways. Yet, few studies examine economic and environmental outcomes simultaneously (Garrett et al. 2021).

One of the few studies to collect both economic and environmental data from the same farm households is Vanderhaegen et al. (2018), who analyze certification among coffee farmers in Uganda. This study finds trade-offs between economic and environmental dimensions that vary by VSS. Fairtrade/Organic double certification has positive effects on shade tree crown cover, shade tree diversity, and invertebrate diversity, but negative effects on coffee yields, labor productivity, and income. In contrast, UTZ/Rainforest Alliance/4C triple certification has positive effects on the economic outcomes, but negative effects on most environmental outcomes, except for shade tree diversity. Another example is Haggar et al. (2017), who find positive effects of VSS on many, but not all, environmental outcomes and on some economic outcomes for coffee farmers in Nicaragua. They find general trade-offs between tree diversity and economic outcomes, but these trade-offs are somewhat mitigated for certified farmers who receive higher prices. Lastly, a study by Thompson et al. (2022) assesses the effects of VSS for cocoa farmers in Ghana on economic and environmental outcomes. They find mixed effects on yields, depending on the type of VSS and regional context, but no effects on shade tree cover or diversity. In general, VSS seem to perform well in either economic or environmental dimensions, but rarely in both, which may partly be due to the original focus of the VSS under study or the local context. Overall, there is still too little evidence to draw firm conclusions.

Evidence on the impact of VSS is even more limited for social sustainability dimensions such as gender equality, worker health, child labor and education, and food security (Akoyi et al. 2020; Schleifer and Sun 2020; Sellare et al. 2020). From a sustainable food systems perspective, ensuring food security is a key objective, but a recent review by Schleifer and Sun (2020) concludes that evidence on the impact of VSS on food security is relatively scarce and mixed. While some studies show a positive relationship between VSS, income, and food security (Becchetti and Costantino 2008; Meemken et al. 2017; Schleifer and Sun 2020), several others show no or even negative effects on food security and dietary quality, despite positive effects on yields and income (Dompreh et al. 2021; Iddrisu et al. 2020; Knößlsdorfer et al. 2021; Meemken et al. 2017). A key insight from these studies is that higher incomes associated with certification do not automatically translate into better food security outcomes. A better understanding of the underlying mechanisms and

interactions between economic, environmental, and social outcomes is therefore needed.

This requires that VSS evaluation studies consider multiple sustainability outcomes, including those that have received less attention to date. In a recent article, Rubio-Jovel (2023) systematically reviews the evidence on the contribution of VSS to the achievement of the Sustainable Development Goal (SDGs) and identifies research gaps in key sustainability dimensions, in particular, gender equality (SDG 5) and reduced inequalities (SDG 10). Similarly, Traldi (2021), in her systematic review of VSS impacts on different sustainability dimensions, concludes that evidence on gender outcomes is scarce. While gender equality is a goal in its own right, it is also instrumental in achieving food security and healthy diets for all. For example, Chiputwa and Qaim (2016) show that certification is associated with higher intra-household bargaining power of women, which is positively related to improved nutritional intake. Although other important social dimensions remain under-researched, we focus on gender equality in our study to illustrate the importance of considering trade-offs and synergies between different sustainability dimensions.

The contribution of this study is twofold. First, it highlights the importance of considering multiple dimensions of sustainability when evaluating VSS. While the relevant outcomes and indicators may vary from case to case, we argue that assessing sustainable food system outcomes requires an interdisciplinary approach that looks beyond a narrowly defined outcome dimension. Second, our study provides illustrative evidence of trade-offs and synergies between relevant food system dimensions, including economic, environmental, and social dimensions.

In the next section, we introduce our conceptual framework, which brings together relevant dimensions of sustainable food systems—healthy ecosystems, economic prosperity, gender equity, and food security—and identifies key trade-offs and synergies between them. We then present data from Ghana, Rwanda, and Peru to provide empirical evidence on how VSS balance these multiple and often competing objectives inherent in sustainability efforts. The final section discusses implications for future certification efforts and for future research evaluating such efforts.

2 | Conceptual Framework

In this study, we aim to assess whether VSS can contribute to more sustainable food systems. A central objective of sustainable food systems is ensuring food security and nutrition for all, which is represented as the ultimate outcome in our conceptual framework (Figure 1). In addition to food security, we examine other key sustainability dimensions: healthy ecosystems, economic prosperity, and gender equality. These dimensions are not only goals in their own right but also play an instrumental role in achieving food security. For example, healthy ecosystems are essential for resilience to extreme weather events and are critical for sustaining long-term agricultural productivity (Tscharntke et al. 2024). Similarly, economic prosperity ensures that food remains affordable and accessible to all. Gender equality is crucial for providing equal opportunities in accessing food, as well as in the control over resources and decision-making related to food production and consumption. While our study focuses on these selected dimensions, we acknowledge that sustainable food systems encompass a broader range of outcomes and therefore do not claim our framework to be exhaustive.

VSS can influence sustainable food system outcomes through various types of interventions (Boonaert and Maertens 2023), which are depicted on the left side of our conceptual framework. These interventions encompass the rules, regulations, requirements, and support measures implemented by VSS. We categorize these interventions into three broad sustainability dimensions: environmental, economic, and social, and provide several examples. Environmental interventions include zero-deforestation regulations, training on sustainable practices, and the provision of native tree seedlings, all of which generally aim to improve ecosystem health (Garrett et al. 2021; Krumbiegel and Tillie 2024). Economic interventions range from training and agrochemical input provision to price premiums and are designed to improve economic outcomes (Boonaert and Maertens 2023). Social interventions cover a wide range of different measures aimed at improving social aspects of sustainability, such as equity, working conditions, and health (Krumbiegel et al. 2018; Schuster and Maertens 2017). As outlined above, in this study we focus on gender equality as one aspect of social sustainability. Relevant interventions include providing gender awareness training, supporting women's farmer groups, and strengthening women's representation in cooperatives,[1] which aim to contribute to better gender equality outcomes (Meemken and Qaim 2018; Morgan and Zaremba 2023). It is important to note that interventions are often delivered as bundled packages (e.g., training on multiple practices) or serve multiple purposes (e.g., credit that supports both production and livelihood improvement). As a result, a single intervention may ultimately affect multiple sustainability outcomes simultaneously.

The middle part of our conceptual framework illustrates the impact pathways through which VSS, with their specific sets of interventions, influence food system outcomes. It is important to emphasize that these are examples chosen for illustrative purposes and do not cover all potential impact pathways. In addition, contextual factors such as the landscape and policy context, market environment, and climate conditions (as represented by the background illustrations in Figure 1) shape the linkages between VSS interventions and sustainable food system outcomes.

Within each sustainability dimension, the impact pathways are relatively straightforward. In the environmental dimension, for example, training in sustainable practices and provision of native tree seedlings are expected to lead to the adoption of sustainable practices, more shade trees, and more diversification on farms (Gather and Wollni 2022; Haggar et al. 2017; Ibanez and Blackman 2016), leading to healthier soils and more biodiversity, contributing to healthier ecosystems that are more resilient to weather extremes, thus helping to ensure food security (Poppy et al. 2014). In the economic dimension, access to inputs and credit as well as price premiums is expected to lead to higher input use (Sellare et al. 2020), output prices, and profitability (Boonaert and Maertens 2023). As a result of increased profitability, farmers may choose to specialize in the certified crop (Vellema et al. 2015), allowing them to take advantage of economies of scale

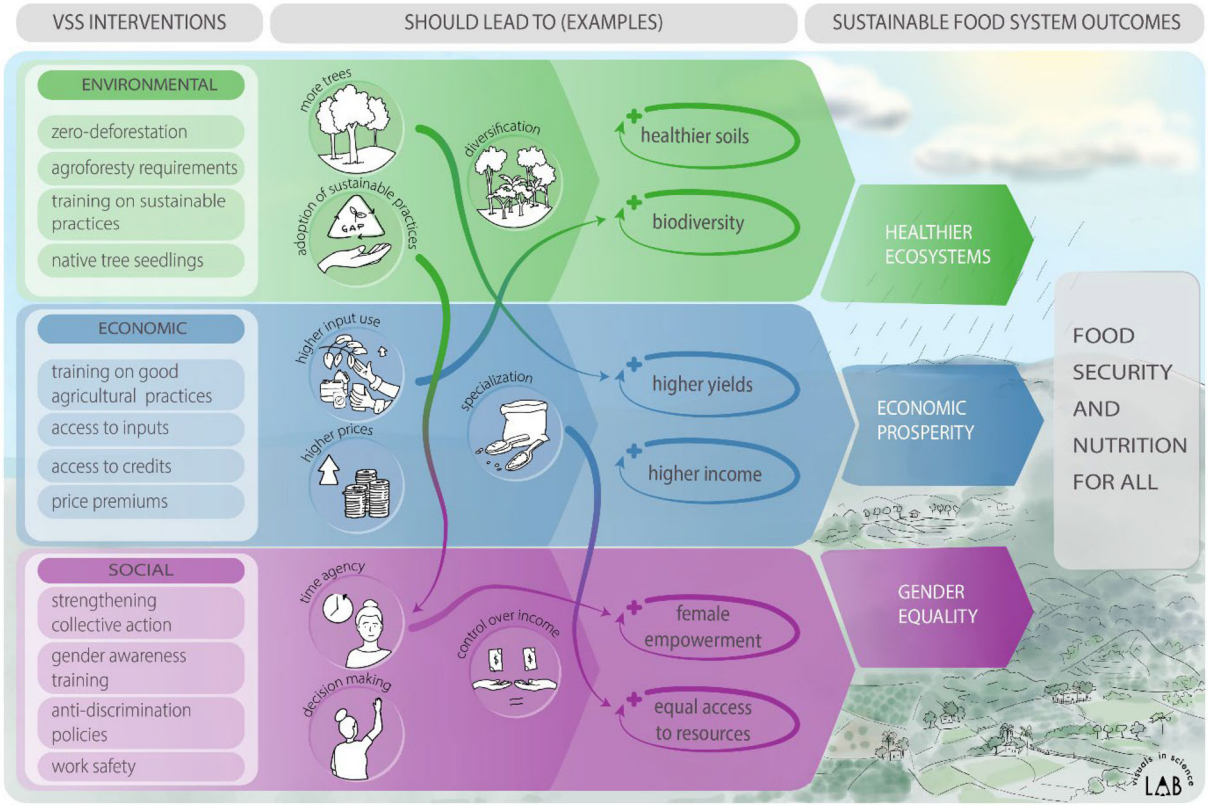

FIGURE 1 | Conceptual framework. Graphical design by Visuals in Science LAB (www.visualsinscience.com).

and thus achieve higher yields and incomes, contributing to household food security and dietary quality (Sibhatu et al. 2015). In the social dimension, interventions such as capacity building, promotion of equal pay and leadership opportunities for women, and mandatory formation of gender committees in cooperatives are expected to influence perceptions of gender roles in the household and community. This can improve women's participation in decision-making and increase their time agency and control over income, which are associated with women's empowerment and more equal access to resources within the household, including equal access to food security and dietary quality.

However, changes in one dimension are likely to interact with outcomes in other dimensions, as shown by the cross-dimension arrows in Figure 1. These interactions can be positive, implying synergies between sustainability goals, where achieving one goal makes it easier or more likely to achieve another. But interactions can also be negative, implying trade-offs between sustainability goals, where an improvement in one goal is associated with a decrease in another (Rubio-Jovel et al. 2024). In the following, we discuss potential trade-offs and synergies between sustainability outcomes that may arise in the context of VSS interventions, with a focus on the examples outlined in Figure 1.

Previous studies examining both economic and environmental impacts often find that VSS improve only one of the two dimensions (Haggar et al. 2017; Vanderhaegen et al. 2018). This outcome may stem from inherent environmental-economic trade-offs. For instance, most VSS promote sustainable agricultural practices, such as agroforestry, in cash crop plantations to enhance ecosystem health (Thompson et al. 2022). However, these practices can sometimes reduce yields, as shade trees and cash crop trees may compete for nutrients (Asitoakor et al. 2022; Blaser et al. 2018). Conversely, VSS that encourage the use of agrochemical inputs to boost agricultural yields (Sellare et al. 2020) may inadvertently harm biodiversity. Despite these trade-offs, synergies are also possible. For example, promoting sustainable practices like composting can simultaneously improve soil health and enhance long-term productivity.

Most evaluation studies of VSS are conducted at the household level, leaving the intra-household distribution of certification-related costs and benefits largely unexplored (Traldi 2021). Yet, from an equity perspective, understanding distributional outcomes is critical. For example, when VSS promote labor-intensive sustainable agricultural practices, trade-offs can arise between environmental and gender objectives. Labor-intensive practices can disproportionately increase women's workloads and limit their time agency, particularly in contexts where social norms prescribe a gendered division of labor (Arora and Rada 2020; Bolwig 2012; Lyon et al. 2017). Evidence, though limited and mostly qualitative, suggests that women often bear a higher time burden due to their responsibility for many labor-intensive tasks associated with certification (Bolwig 2012; Lyon et al. 2017, 2010). However, synergies are also possible. Greater involvement in certified crop production can empower women by enabling more active participation in decision-making and greater control over crop income (Meemken and Qaim 2018). This is particularly significant in contexts where cash crop income is typically controlled by men (Chiputwa and Qaim 2016).

Potential trade-offs and synergies between economic and gender objectives are particularly relevant when considering food security. For instance, increased profitability of the certified crop can encourage specialization and the reallocation of resources toward these crops (Vellema et al. 2015). However, this shift may exacerbate intra-household inequalities, as resource distribution within households often reflects existing gender dynamics (Doss 2013; Malapit and Quisumbing 2015). Research shows that positive income effects of VSS do not always translate into improved food security. Knößlsdorfer et al. (2021) highlight the critical role of gender in this context, noting that income controlled by women has been found to contribute more significantly to food security and nutrition than income controlled by men (Doss 2013; Malapit and Quisumbing 2015). Consequently, it is important to consider equity-related outcomes and assess whether income gains benefit all household members equitably. While the literature on the links between certification, female empowerment, and nutrition remains limited, notable exceptions exist. For example, Chiputwa and Qaim (2016) demonstrate that women's empowerment serves as an important pathway through which VSS can enhance household dietary quality. This underscores the need for further research on the interplay between certification, gender dynamics, and food security.

The different examples discussed here underscore the need for further research on the interplay between certification and various food system outcomes, including economic prosperity, ecosystem health, gender dynamics, and food security. In line with Barbier and Burgess (2019), our conceptual framework emphasizes the importance of explicitly considering trade-offs and synergies between different sustainability goals.

3 | Empirical Evidence From Three Case Studies

In the following sections, we present data from three case studies, namely Ghana, Rwanda, and Peru, to explore the interactions between sustainability dimensions identified in our conceptual framework. All three case studies were designed to assess the relationships between VSS and 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 subset of households, whereas the study from Peru provides in-depth insights into gender equality outcomes. More detailed analyses and case study descriptions are provided elsewhere (Bohn et al. 2024; Paz et al. 2024; Santalucia and Wollni 2024; Wätzold et al. 2025). The focus here is on describing and comparing a selection of indicators, guided by our conceptual framework.

3.1 | Description of Data and Case Study Contexts

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 based on existing population census data. The number of villages in each region was chosen based on their 2019 production volumes (Ghana Cocoa Board 2025). We then randomly selected 17 to 18 cocoa households per village based on existing lists provided by extension officers. 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 (LBCs) that are typically linked to an international trader or chocolate company and are responsible for sourcing cocoa in Ghana. To reach out to farmers, LBCs 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 LBCs. 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 cover 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 (CWSs). 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 geographic location and requires farmers to sell their coffee cherries only to the designated CWS. 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% of total cocoa production in Peru. We first selected ten cooperatives in our research area and then applied stratified random sampling to select around 30 male members and 30 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.

3.2 | Methods

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, gender, and food security 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 (GLMMs). GLMMs 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 (Krumbiegel et al. 2018; Rana and Sills 2024). More detailed descriptions of the GLMM estimator and the IPWRA method are provided in Appendix A.

4 | Comparative Results

4.1 | Certification and Farm Management in Ghana, Rwanda, and Peru

VSS interventions such as training, input provision, or environmental regulations (see Figure 1) are expected to lead to changes in agricultural practices among certified farmers (Thompson et al. 2022). We use descriptive statistics to compare certified and non-certified households in the three case studies in terms of agricultural practices (Table 1). In Ghana, certified farmers tend to use inputs more intensively. On average, a higher proportion of certified farmers use conventional fertilizer, organic fertilizer, and mulching than non-certified farmers. Also, a significantly higher proportion of certified farmers adopt sustainable agricultural practices like pruning and integrated pest management, compared to non-certified farmers. Regardless of certification status, almost all cocoa farmers in Ghana have shade trees on their cocoa farms. In Rwanda, a significantly smaller proportion of certified farmers apply conventional fertilizer, but a significantly higher proportion of certified farmers adopt sustainable practices like organic fertilizer, mulching, shade trees, and integrated pest management on their coffee plots, compared to non-certified farmers. In Peru, a smaller proportion of certified organic farmers use conventional fertilizers and mulching than non-certified farmers. Overall, conventional fertilizer use is low in the Peruvian sample: even in the non-certified sample, only 14% of the farmers use it. For other practices, such as shade trees and organic fertilizer, there are no significant differences between certified and non-certified farmers in Peru.

4.2 | Certification and Economic Outcomes

We use IPWRA to analyze how certification relates to economic outcomes (Table 2). Despite differences in the agricultural practices used in the three case studies (Table 1), certification is associated with significantly higher yields in all three case studies. However, only in the case of Ghana and Rwanda is certification also associated with higher net cash crop income per hectare. These results are generally in line with the literature, which finds largely positive, albeit moderate, economic effects of certification at the farm level (Meemken 2020).

Our data do not provide strong evidence that certification is associated with substantial income gains at the household level (total household income) nor with pronounced agricultural specialization (share of cash crop income in total income, share of cash crop land in total land) across the case studies. The observed increases in net cash crop income associated with certification in Ghana and Rwanda translate into higher total household income for certified households only in the case of Rwanda. 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. This suggests little evidence of agricultural specialization in the certified crop among certified farmers, which is also supported by the finding that there is no significant difference in the share of land devoted to cocoa between certified and non-certified farmers in Ghana and Peru (data not available for Rwanda). Rather than agricultural specialization, certification in Ghana and Rwanda is associated with a significant increase in agricultural diversification (measured as the number of different agricultural activities at the farm level).

4.3 | Certification and Environmental Outcomes

As illustrated in the conceptual framework, a critical question is whether the economic gains are achieved at the expense of healthy ecosystems. Tables 3 and 4 present associations between

TABLE 1 | Descriptive statistics of agricultural practices.

	Certified farmers		Non-certified farmers		Mean difference
	Mean	SD	Mean	SD	
Ghana	$N = 338$		$N = 476$		
Conventional fertilizer (0/1)	0.65		0.51		0.15***
Organic fertilizer (0/1)	0.07		0.02		0.05***
Mulching (0/1)	0.36		0.26		0.10***
Shade trees (0/1)	0.99		0.98		0.01
Pruning (0/1)	0.81		0.77		0.04
Manual weeding (0/1)	1.00		0.99		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		0.93		−0.07***
Organic fertilizer (0/1)	0.75		0.64		0.11 ***
Mulching (0/1)	0.96		0.91		0.04**
Shade trees (0/1)	0.98		0.74		0.24***
Pruning (0/1)	0.94		0.91		0.04
Manual weeding (0/1)	0.94		0.95		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		0.14		−0.12**
Organic fertilizer (0/1)	0.47		0.42		0.05
Mulching (0/1)	0.84		0.91		−0.07*
Shade trees (0/1)	0.77		0.77		0.00
Pruning (0/1)	0.94		0.94		0.00
Manual weeding (0/1)	0.99		0.98		0.01

Note: SD = standard deviations (not reported for binary variables). *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. IPM refers to the following four practices: monitor insects before treatment, maintain habitat for insects/predators, cut and burn infested material, sanitary harvest and pruning.

certification and ecological plot-level data on vegetation structure and animal diversity for Ghana and Rwanda. As indicators of vegetation structure, we chose the number of shade trees per hectare and the number of different shade tree species counted in each plot. As indicators of animal diversity, we chose the bioacoustics index and biological control rates. The bioacoustics index is based on animal sounds recorded in the plot (Dröge et al. 2021), and biological control rates are based on predation rates of fake caterpillars that were deployed in each plot (Howe et al. 2009). In Ghana, the differences in vegetation structure between certified and non-certified plots are small and not significant (Table 3). Conversely, in Rwanda, certified farmers have significantly more shade trees per hectare and a greater number of shade tree species. However, these positive results for vegetation structure in Rwanda are not reflected in higher animal diversity on certified plots (Table 4). In the case of Ghana, certified plots have, on average, a lower bioacoustics index and lower biological control rates compared to non-certified plots, but these differences are not statistically significant.

The finding that the positive associations between certification and vegetation structure in Rwanda do not translate into higher animal diversity on certified plots may be explained by the important role of landscape factors in shaping environmental outcomes at the plot level (Ocampo-Ariza et al. 2024; Tscharntke et al. 2015). Our data reveal positive correlations between the bioacoustics index and the surrounding landscape. In Ghana, the bioacoustics index increases with the proximity of plots to primary forests. In Rwanda, we observe a positive correlation between the bioacoustics index and the Enhanced Vegetation Index, a satellite-based measure of vegetation health and density measured within a 500-meter radius of the plot. These findings highlight the importance of evaluating VSS performance within the broader context of national and regional policies that influence the landscape conditions in which VSS operate.

To what extent can VSS in Ghana and Rwanda simultaneously achieve economic and environmental improvements at the farm level? Our data confirm positive associations between certification and production-related economic outcomes for the two

TABLE 2 | Association between certification and economic outcomes.

	Non-certified PO	ADPO^C	*p* value	N
Ghana				
Yield (kg/ha)	355.79	64.83	0.02	814
Net cocoa income (GHC/ha)	2298.86	663.86	0.02	814
Total household income (GHC) (IHS-transformed)	9.01	0.05	0.88	814
Share cocoa income in total income	0.63	0.04	0.03	814
Share cocoa land in total land	0.85	−0.00	0.84	814
Agricultural diversification (range: 1–19)	6.14	0.31	0.07	814
Rwanda				
Yield (kg/ha, fresh cherries)	6693.57	790.62	0.05	842
Net coffee income (RWF/ha)	2,788,649.69	847,177.91	0.00	842
Total household income (RWF) (IHS-transformed)	14.40	0.13	0.00	842
Share coffee income in total income	0.32	0.02	0.18	842
Agricultural diversification (range: 0–16)	7.04	0.76	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
Total household income (PEN) (IHS-transformed)	10.48	−0.06	0.35	566
Share cocoa income in total income	0.52	0.02	0.46	566
Share cocoa land in total land	0.82	−0.03	0.33	566
Agricultural diversification (range: 0–23)	5.51	0.12	0.76	566

Note: 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 Nov 1. 2022 for Rwanda and Ghana, May 1 2023 for Peru). IHS refers to inverse hyperbolic sine transformation; approx. percentage changes of IHS-transformed values are calculated as described in Bellemare and Wichman (2020). Agricultural diversification is measured as the number of different agricultural activities at the farm-level. This includes all crop species (including intercrops) and animal species (where each animal species is counted as one).

TABLE 3 | Association between certification and plot-level data on vegetation structure.

	Non-certified PO	ADPO^C	*p* value	N
Ghana				
Shade trees per hectare	68.0	−2.71	0.65	119
No. of shade tree species	14.5	0.23	0.84	119
Rwanda				
Shade trees per hectare	163.9	21.6	0.09	96
No. of shade tree species	3.27	0.78	0.00	100

Note: 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.

case studies (Table 2). In Ghana, where certified households are characterized by higher levels of intensification (Table 1), 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, at least in terms of plot-level vegetation structure.

4.4 | Certification and Gender Equality Outcomes

Many of the agricultural practices promoted by VSS, such as organic fertilization, mulching, and integrated pest management, aim to improve soil health 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), when certification is associated with the adoption

TABLE 4 | Association between certification and plot-level data on animal diversity.

	Certification coefficient (GLMM)	Robust std. err.	*p* value	N
Ghana				
Bioacoustics index	−0.08	0.06	0.18	119
Biological control rates	−0.05	0.04	0.24	119
Rwanda				
Bioacoustics index	0.06	0.12	0.62	99
Biological control rates	−2.86	2.47	0.25	99

Note: Coefficient estimates from generalized linear mixed effects models (GLMM). Full regression tables with all control variables can be found in Appendix C.

TABLE 5 | Association between organic certification and gender-specific labor demand in Peru.

	Non-certified PO	ADPO^{C}	*p* value	N
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 man'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

Note: 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 ($N = 484$).

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 is associated with an increase in women's, but not men's, labor use in cocoa production within certified households (Table 5). These results suggest that the increased labor demand in cocoa production associated with organic certification is mostly met by women within the household.

How this increased use of labor in cash crop production affects women's overall well-being depends on several factors. First, it depends on how their overall workload and time use are affected. Second, increased involvement in cash crop activities may also be linked to empowerment, as women may gain more opportunities to participate in decision-making and exercise greater control over cash crop income (Meemken and Qaim 2018). Table 6 provides descriptive results from Peru and Rwanda, comparing women's time use and empowerment in certified versus non-certified households.

Drawing on the Women's Empowerment in Agriculture Index (Alkire et al. 2013; Malapit and Quisumbing 2015), we calculated an aggregate empowerment score to measure the extent to which women can participate in decision-making related to agricultural production, income, financial and physical assets, and time use. In Peru, our findings indicate that, on average, there is no significant difference in women's empowerment between certified and non-certified households. While women in certified households have greater decision-making power over cocoa and other crop production, as well as the income derived from these activities (consistent with their higher labor supply, as shown in Table 5), they show less agency in other domains, particularly those related to credit and savings. The time use data suggest that, as women supply more labor to cocoa production, they spend significantly less time in off-farm activities, and the proportion of women who receive individual incomes from these activities is significantly lower in certified households than in non-certified households. This indicates a shift in the activities where women participate and exercise control. The overall welfare effect will ultimately depend on the relative benefits of certified cash crop activities compared to the available off-farm opportunities.

In the case of Rwanda, women's empowerment scores are significantly higher in certified households than in non-certified households, indicating that, on average, women in certified households are more actively involved in decision-making and have more control over resources. The individual indicators show that significantly more women in certified households are involved in decision-making about 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.

In summary, these findings highlight the importance of considering the gender implications of certification to ensure that the adoption of labor-intensive sustainable practices promoted by VSS does not exacerbate intra-household inequalities. The

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		0.86		0.10**	0.81		0.75		0.06
Makes decisions about other crop production (0/1)	0.78		0.69		0.09*	0.92		0.92		0.00
Makes decisions about income from cocoa/coffee (0/1)	0.75		0.63		0.11**	0.91		0.90		0.01
Makes decisions about income from other crops (0/1)	0.63		0.53		0.10*	0.54		0.41		0.13**
Makes decisions about income from livestock (0/1)	0.27		0.21		0.06	0.70		0.54		0.16*
Makes decisions about income from employment (0/1)	0.10		0.14		−0.04	0.65		0.73		−0.08
Makes decisions about credit (0/1)	0.42		0.55		−0.14**	0.51		0.40		0.11
Makes decisions about savings (0/1)						0.90		0.89		0.02
Owns a savings account (0/1)	0.37		0.45		−0.08*					
Owns at least two small or one large asset (0/1)	0.98		1.00		−0.02	1.00		1.00		0.00
Workload is < 10.5 hrs (0/1)	0.52		0.51		0.01	0.44		0.46		−0.02
Satisfied with leisure time (0/1)	0.14		0.15		−0.01	0.76		0.71		0.05
Time use										
Woman's overall workload (hours)	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 (hours)	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 (hours)	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		0.25		−0.09*					

Note: SD = standard deviations (not reported for binary variables). *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. The Rwandan sample used in this analysis includes only female respondents ($N = 294$).

TABLE 7 | Association between certification and dietary quality and food security.

	Non-certified PO	ADPO[C]	*p* value	N
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

Note: 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 quality and food security are provided in Appendix B.

case of Rwanda suggests that certification can act as a lever to promote women's empowerment. In Rwanda, VSS have played a key role in promoting gender awareness and fostering equal rights and opportunities. Some VSS, such as Rainforest Alliance and Fairtrade, have implemented explicit gender policies, including mandates for equal pay and leadership opportunities. They also provide capacity-building programs on business management, negotiations, and financial literacy explicitly targeting women and require the formation of gender committees that engage with local women's organizations. These activities align well with the Rwandan government's goal to increase women's participation in leadership roles (Niyonkuru and Barrett 2021). In the coffee sector, the government supports socially inclusive value chains, where women take critical roles within the value chain, including all stages from cultivation to export, thereby integrating economic empowerment and social development (van Kollenburg and van Weert 2024).

4.5 | Certification and Food Security and Dietary Outcomes

We have examined how VSS relate to key sustainable food system dimensions, including economic prosperity, healthy ecosystems, and gender equality, which are not only goals in their own right but also play an instrumental role in achieving food security (see Figure 1). In this section, we present results on the relationships between certification and food security and dietary outcomes (Table 7). To measure dietary outcomes, we used the Dietary Quality Questionnaire (DQQ), a standardized tool for assessing dietary adequacy (Global Diet Quality Project 2022b; Herforth et al. 2019) that collects information on food groups consumed the previous day or night. Several indicators are constructed based on the count of different food groups consumed. The *All-5* indicator is a binary variable equal to one for respondents who consumed all five food groups typically recommended for daily consumption in food-based dietary guidelines. The Non-Communicable Diseases—Protect Score (NCD-P) measures dietary factors protective against non-communicable diseases and includes nine food groups associated with meeting World Health Organization (WHO) recommendations on fruits, vegetables, whole grains, pulses, nuts and seeds, and fiber. The Non-Communicable Diseases—Risk Score (NCD-R) reflects dietary risk factors for non-communicable diseases, based on eight food groups negatively associated with meeting WHO recommendations on free sugar, salt, total and saturated fat, and red and processed meat. Finally, the Global Dietary Recommendations Score (GDR) combines NCD-P and NCD-R. A higher GDR score indicates a greater likelihood of meeting dietary recommendations for healthy diets (Global Diet Quality Project 2022a). Food insecurity was measured using the Food Insecurity Experience Scale (FAO 2018a) in Ghana and Rwanda and the Household Food Insecurity Access Scale (Coates et al. 2007) in Peru. Additional details about these indicators are provided in Appendix B.

Our results indicate that significant associations between certification and indicators of dietary quality and food security are observed only in Rwanda, while no such significant associations are found in Peru and Ghana (Table 7). This aligns with previous research, which has also produced mixed results regarding the

relationships between certification, food security, and nutrition (Schleifer and Sun 2020). The finding that income increases do not consistently lead to improvements in food security suggests the influence of additional factors. These factors may include agricultural diversification, specialization, and the resulting variations in resource access among household members. For example, agricultural specialization might create trade-offs, such as reduced access to resources for women.

In our case studies in Ghana and Peru, the lack of association between VSS, food security, and dietary outcomes may stem from several factors. First, certification is primarily linked to improvements in production-related economic outcomes—such as yields and, to some extent, crop income—but these gains do not translate into increased overall household income. Second, in Peru, organic certification does not appear to be associated with higher average women's empowerment scores. While women in certified-organic households gain control over cocoa income, they lose access to individual off-farm income, credit, and savings. This finding is important in this context, as previous studies (Chiputwa and Qaim 2016; Knößlsdorfer et al. 2021) have emphasized the critical role of women in achieving food security. In contrast, the case of Rwanda presents a different picture. Here, certification is associated with increased yields, greater shade tree diversity, more agricultural diversification, and higher average women's empowerment scores. These factors, when combined, may contribute to the positive outcomes for food security and dietary quality observed in our data.

4.6 | Balancing Trade-Offs and Synergies Across Multiple Sustainability Dimensions

The previous sections show how outcomes across different sustainability dimensions interact, often leading to trade-offs and synergies. In Ghana, VSS are associated with input intensification and higher cocoa yields, but similar improvements do not extend to environmental benefits. Despite increased cocoa income, certified households in Ghana do not experience significantly higher overall household income, food security, or dietary quality. Similarly, in Peru, organic certification is associated with higher yields, but not with increases in household income, food security, or dietary quality. In addition, our data in Peru suggest that increased demand for labor associated with organic certification creates trade-offs with women's time use and control over resources. In contrast, the Rwanda case study suggests a more positive scenario. Here, VSS seem to foster synergies between economic, environmental, and gender outcomes and are ultimately associated with greater dietary quality and food security among certified households.

Similar to the approach taken in the previous sections, most studies on VSS performance focus on identifying improvements in sustainability outcomes attributable to certification. However, it may not be possible or necessary to achieve significant increases in all sustainability outcomes at the same time. Instead, it may be more important to achieve and maintain minimum levels in all dimensions. To illustrate this point, we define minimum levels for the environmental, economic, and social dimensions of sustainability. Note that the minimum levels chosen are for illustrative purposes only, as they should ideally be the result of a participatory process involving different stakeholders and taking the local context into account.

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 minimum level 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 8). 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 to define whether households are classified as poor or non-poor. Finally, for the social dimension, we consider food security, in line with our previous analysis[2]. From a sustainable food systems perspective, VSS should contribute to ensuring that all household members have equal access to sufficient and diverse food. We define minimum levels based on the Food Insecurity Experience Scale (Ghana, Rwanda) and the Household Food Insecurity Access Scale (Peru) to classify households as moderately food secure or food insecure (see Table 8).

Table 8 presents descriptive statistics comparing certified and non-certified households with respect to the minimum levels in the three sustainability dimensions. The results are broadly consistent with our earlier findings regarding absolute increases in sustainability outcomes. In Ghana, a significantly larger proportion of certified households are non-poor compared to non-certified households. For the other two indicators, adoption of agroforestry systems and attainment of food security, there are no significant differences between certified and non-certified households in Ghana, although there is certainly room for improvement in both dimensions. In Peru, there are no significant differences between certified and non-certified households for any of the minimum levels in the three dimensions. In Rwanda, certified households perform better on all three dimensions, consistent with our earlier findings. A larger proportion of certified households practice agroforestry, are non-poor, and achieve at least moderate food security compared to non-certified households. Despite the better results 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 minimum levels in the three dimensions and the extent of overlaps (Figure 2).[3] These overlaps indicate that households meet minimum levels 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 social dimensions on the other hand. Additionally, the share of households reaching or exceeding all three minimum levels is higher among certified households (12%) than non-certified households (4%). To fully appreciate the impact of VSS on minimum levels 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.

TABLE 8 | Descriptive statistics of minimum thresholds for sustainable food system indicators.

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

Note: Standard deviations not reported for binary variables. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. Definition of minimum levels: Diverse agroforestry system (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 binary poverty variable is defined based on the national poverty lines (2022): for Ghana 8.8 GHC/capita/day; for Rwanda 689 RWF/capita/day; for Peru 13.83 PEN/capita/day. The minimum level for food security for Ghana and Rwanda is based on FIES: households are moderately food secure if their FIES score is < 4 (FAO 2018a); for Peru we use the Household Food Insecurity Access Prevalence (HFIAP) that is derived from HFIAS: Households who are at least moderately food secure 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).

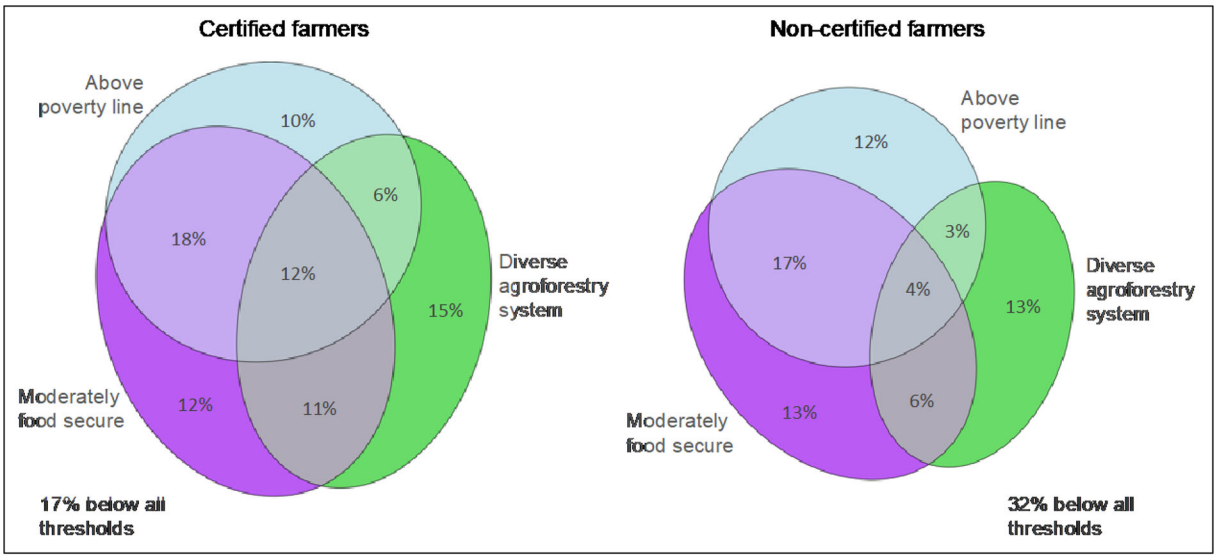

FIGURE 2 | Achievement of minimum levels in three sustainability dimensions—Rwanda.

5 | Conclusions

This study examines the associations between VSS and sustainable food system outcomes across multiple dimensions, including economic, environmental, gender, and food security outcomes. By considering these diverse dimensions, we aim to uncover potential trade-offs and synergies between them. Our analysis draws on original survey data from three case studies in Ghana, Rwanda, and Peru, offering comparative evidence on how VSS are linked to sustainability outcomes. The findings reveal complex interactions between these dimensions, with trade-offs and synergies varying across contexts. In Ghana, positive associations between VSS and economic outcomes are not accompanied by similar improvements in environmental and food security outcomes. In Peru, the increased labor demands associated with organic certification lead to trade-offs with respect to women's time use and control over resources. In contrast, Rwanda demonstrates a more balanced scenario, where VSS appear to successfully integrate achievements across all sustainability dimensions, leveraging synergies between them. These results

underscore the importance of comprehensive assessments that account for multiple sustainability dimensions. Research that focuses on a single dimension risks overlooking the broader impacts of VSS and may fail to identify barriers to achieving wider welfare outcomes.

The results demonstrate that the impacts, trade-offs, and synergies associated with VSS are highly context-dependent and vary across the three case studies. This highlights the importance of evaluating VSS within broader policy and landscape contexts that influence the conditions under which they operate. Understanding these contextual factors is crucial for interpreting the variations in outcomes observed across different cases. For example, the government of Rwanda has implemented reforestation policies (Rwanda Ministry of Environment 2019; Rwanda Ministry of Lands and Forestry 2018) that foster favorable conditions for agroforestry. These policies are well aligned with VSS requirements, such as the cultivation of coffee within agroforestry systems. By establishing market channels for agroforestry products such as fruit and timber, these initiatives make agroforestry systems more attractive and economically viable for certified coffee producers. Conversely, adverse policy and market environments can limit the effectiveness of VSS in achieving sustainability goals. In Ghana, for example, certified farms are often located near (illegal) small-scale mining sites, which cause significant environmental damage (Attuquayefio et al. 2017), and thereby could undermine the environmental improvements promoted by VSS.

Differences in impacts, trade-offs, and synergies observed across the case studies may also be influenced by variations in the types of VSS analyzed. Previous research has shown that the impacts of VSS often depend on the specific standard being implemented (Meemken et al. 2017; Vanderhaegen et al. 2018). In Ghana and Rwanda, the range of VSS includes certifications such as Rainforest Alliance and Fairtrade. In contrast, the case study in Peru focuses on organic certification, which imposes stricter requirements, particularly regarding the use of agrochemicals. For example, while Rainforest Alliance emphasizes continuous improvement and allows for gradual adjustments, organic certification enforces more rigid compliance standards. These differences in requirements may contribute to variations in outcomes. Organic certification, for instance, has often been associated with yield reductions (Meemken 2020), which has implications for its broader impact on sustainability. As a result, findings related to specific VSS may not be universally applicable across different contexts or standards.

In recent years, most VSS have been further developed to encompass a broad range of interventions addressing multiple sustainability dimensions (Lambin and Thorlakson 2018). Against this backdrop, they have been proposed as a promising tool to support the achievement of the SDGs. Evaluating the extent to which VSS can contribute to multiple sustainability dimensions is therefore essential. While we have provided comparative evidence from three case studies, the body of literature assessing VSS performance across multiple dimensions remains limited. Further research on the multifaceted impacts of VSS would contribute to this sparse literature and facilitate meta-analyses to identify broader, underlying factors that influence impacts, trade-offs, and synergies. Future studies could also broaden the scope of inquiry to include under-researched dimensions of sustainable food systems, such as child labor and education, health, and working conditions. Expanding the assessment of VSS to incorporate these dimensions would deepen our understanding of their potential and limitations to contribute to sustainable food systems in multiple dimensions. Achieving this requires interdisciplinary collaboration, as the complexity of evaluating diverse sustainability outcomes benefits from integrating insights from multiple fields of expertise.

A limitation of our study is that it focuses solely on the relationships between VSS and various sustainability outcomes without assessing their cost-effectiveness in achieving these outcomes. While more comprehensive rules and requirements in VSS may lead to improved sustainability outcomes, they also increase the costs associated with training, monitoring, and enforcement. Future research should incorporate these implementation costs and compare the cost-effectiveness of achieving sustainable food system outcomes between VSS and other policy instruments or interventions. For instance, certain sustainability dimensions might be addressed more cost-effectively through alternative programs or projects. Another challenge lies in the higher costs associated with more comprehensive and rigorous standards, which can lead to increased consumer prices. Since VSS depend on consumer willingness to pay, highly effective standards with substantial benefits across multiple dimensions might achieve only limited market penetration due to their cost. Understanding these trade-offs between effectiveness, cost, and market accessibility is crucial for designing VSS and complementary policies that maximize impact while remaining economically viable.

Another promising direction for future research is to investigate the role of midstream actors—such as traders, intermediaries, and buyer-processors—who play a critical role in the implementation of VSS. Like much of the existing literature, our study focuses primarily on the producer level, without explicitly accounting for the influence of other food system actors. However, VSS are inherently value chain mechanisms that link various actors within the food system, each of whom can significantly shape sustainability outcomes. Understanding the diversity of intermediaries and the specific roles they perform is essential (Barrett and Gómez 2024; Marx et al. 2024). By capturing the heterogeneity of midstream actors, future research can provide deeper insights into the factors that influence the implementation and effectiveness of VSS. Such studies will be critical for understanding how these actors mediate trade-offs and synergies and for designing interventions that enhance the sustainability outcomes of VSS across the value chain.

Acknowledgments

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Endnotes

[1]VSS like Rainforest Alliance and Fairtrade have adopted comprehensive strategies to address gender equality. For Fairtrade see https://www.fairtradenapp.org/gender/; for Rainforest Alliance see https://www.rainforest-alliance.org/resource-item/whats-in-our-2020-certification-program-gender-equality/.

[2] We do not consider gender here, as our data do not allow us to define a reasonable cut-off or "minimum level" of gender equality. The food security indicators used assess access to food at the household level ("did you or any household member…"), and thus consider, at least to some extent, equal access.

[3] We focus here on Rwanda, since the differences between certified and non-certified households in Ghana and Peru are mostly not significant (Table 8).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.