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ANALYSIS

Do voluntary sustainability standards improve socioeconomic and ecological outcomes? Evidence from Ghana's cocoa sector

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ABSTRACT

Voluntary sustainability standards offer potential for sustainable development by improving the livelihoods of smallholder farmers while conserving biodiversity. However, their overall implications remain poorly understood, as studies have mostly focused on assessing their effects on single sustainability dimensions. Here, we use an interdisciplinary approach to understand the simultaneous effects of sustainability standards (e.g. Fairtrade, Rainforest Alliance, Cocoa Life) on socioeconomic and ecological outcomes in Ghana's cocoa sector. Our study is based on a rich dataset comprising household data from 814 smallholder cocoa-producing households from five major cocoa regions and ecological data from 119 cocoa plots. Results from the endogenous switching regression approach suggest that sustainability standards have positive effects on socioeconomic outcomes such as cocoa yield, net cocoa income and returns to land. However, using generalized linear mixed effects models, we do not find any significant associations with ecological outcomes related to vegetation structure and animal diversity. Our results indicate that sustainability standards in Ghana's cocoa sector lead to socioeconomic benefits but not to ecological benefits for the plot environment. Nevertheless, yield increases do not come at the expense of biodiversity. We conclude that sustainability standards have the potential to improve socioeconomic outcomes, without significantly creating trade-offs with ecological outcomes.

1. Introduction

The commodity crop production sector in many developing countries is associated with low productivity and low prices leading to poverty for smallholder farmers (FAO, 2017). At the same time, it is a major contributor to climate change, deforestation, biodiversity loss and land degradation (Grass et al., 2020; Meyfroidt et al., 2014). Meanwhile, demand for sustainably produced products is growing, as consumers in many rich countries are increasingly concerned about how commodities such as tea, coffee or cocoa are produced (Tscharntke et al., 2015). In response, voluntary sustainability standards have emerged as a promising market instrument to address the challenges of unsustainable production (Dietz et al., 2022; Milder et al., 2015). Sustainability standards are sets of social, economic and environmental criteria that define practices of agriculture to increase productivity while reducing environmental impacts and supporting rural livelihoods (Milder et al., 2015). If farmers comply with the criteria set by the sustainability standard, they are promised to receive benefits such as price premiums (DeFries et al., 2017), market access (Oya et al., 2018) or training and agricultural inputs (Sellare et al., 2020b).

Understanding the overall effects of sustainability standards for households and their plot ecosystems is pertinent because sustainability standards can only contribute to sustainable development if their adoption is economically and environmentally viable. However, whether sustainability standards can achieve these goals simultaneously is still unclear (Meemken et al., 2021). The empirical literature has

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mainly focused on assessing their effects on either socioeconomic (see review by Meemken (2020) and Oya et al. (2018)) or ecological outcomes (see review by Tscharntke et al. (2015) and more recent studies by Asigbaase et al. (2019), Hardt et al. (2015) and Pico-Mendoza et al. (2020)); whereby studies that assess both effects are limited (Garrett et al., 2021). Therefore, in this study we seek to analyze the simultaneous effects of sustainability standards on socioeconomic outcomes and plot-level ecological outcomes. Our study uses household data from 814 cocoa farming households across five major cocoa producing regions in Ghana and ecological data based on a subsample of 119 cocoa plots from our household sample.

We use the endogenous switching regression approach to account for potential self-selection to evaluate the effects of sustainability standards on household socioeconomic outcomes including cocoa yield, net cocoa income and returns to land (i.e. the total income derived from all cultivated crops from the cocoa plots). We use generalized mixed effects models to estimate the association between being certified and plot-level vegetation structure such as shade tree crown cover, shade tree diversity and herbaceous ground cover and plot-level animal diversity such as bird abundance, bird richness, biological predation rates and the Bioacoustic index.

The primary contributions of this study to the literature are threefold. First, instead of relying on reported practices that are hypothesized to improve biodiversity (Gather and Wollni, 2022; Ibanez and Blackman, 2016; Mitiku et al., 2018), we use ecological data derived from extensive plot inventories based on a subsample of 119 cocoa plots. This allows for a reliable assessment of the association between sustainability standards on several ecological indicators.

Second, our household sample based on 814 cocoa farmers comes from a large geographic area that covers five major cocoa producing regions in Ghana and different agro-ecological zones. Apart from Meemken (2021) and Boonaert and Maertens (2023) who use a representative household dataset of Peru, we are not aware of any sustainability standard study covering such a large geographic area. Additionally, our ecological sample covers four cocoa regions. To our knowledge such a large geographic area surpasses previous sustainability standard studies using ecological data.

Third, most previous studies purposely select a few cooperatives or companies from which they sample certified and non-certified farmers and are therefore not fully representative of farmers in that country (Haggar et al., 2017; Mitiku et al., 2018; Vanderhaegen et al., 2018). Additionally, in such cases, bias may occur because cooperatives or companies potentially differ in how well they function, making it difficult to differentiate between certification and other cooperative or company specific factors (Sellare et al., 2020b). In our study, we randomly select farmers from randomly selected communities within our study regions. This makes our sample representative of the five cocoa regions, thereby increasing the external validity of our results.

2. Background

2.1. Conceptual framework and theoretical expectations

Sustainability standards include a bundle of interventions, such as training, provision of inputs or access to credit, that are intended to enhance social, economic and environmental sustainability of agricultural producers (Meemken et al., 2021). To facilitate a better understanding on how sustainability standards, through their interventions, may affect different outcomes at the plot and household level, we develop the following conceptual framework (Fig. 1). Considering previous research by Boonaert and Maertens (2023), we relate 1. Price-related interventions, 2. Production-related interventions, and 3. Environment-related interventions to immediate socioeconomic and ecological outcomes, as well as to wider sustainability goals.

2.1.1. Price-related interventions

Price-related interventions relate to minimum floor prices or additional price premiums that farmers receive based on the amount of certified harvest they sell into the certified market (Oya et al., 2018) and are expected to increase net income of the certified crop (Boonaert and Maertens, 2023). While the enhanced access of farmers to additional niche markets in addition to the conventional ones is considered a risk-reducing strategy for producers, we acknowledge the caveat that markets for certified products are based on consumer demand. There may be occasions where farmers are unable to sell their certified cocoa to the certified market. However, new mechanisms like mass balance sourcing[1] allow for a more consistent demand for certified crops and therefore increasingly alleviate this limitation. We therefore expect certified producers to have higher net incomes of the certified crop through receiving price premiums.

2.1.2. Production-related interventions

Production-related interventions include farmer training, group formation and improved access to agrochemical inputs (Oya et al., 2018; Sellare et al., 2020a). The training offered to farmers includes topics such as farm business management, record keeping and “Good Agricultural Practices” (GAP) (Schulte, 2020). The farm business management and record keeping helps farmers to better plan their farm business, such as making responsible investment decisions, and therefore is expected to increase net crop income. GAP refer to a set of sustainable agricultural farming practices that aim to increase productivity while maintaining on-farm ecosystem health (Asare and David, 2011). Examples of GAP include adequate fertilizer and agrochemical use, soil management practices such as mulching, integrated pest and weed management and agroforestry or intercropping practices (in the context of cocoa or coffee) (Schulte, 2020). Furthermore, sustainability standards sometimes support farmer group formation to support collective action (Oya et al., 2018). Farmer groups allow the exchange of information regarding better agricultural practices, joint saving accounts to collectively purchase agrochemicals and the sharing of farming equipment (Abdul-Rahaman and Abdulai, 2018). In some cases, sustainability standards also facilitate access to agrochemical inputs through purchases on credit, subsidized distribution and other forms of financial support (Schulte, 2020).

These production-related interventions are likely to increase productivity through more and better applied GAP and inputs, which in turn are expected to increase yield and net crop income. Increases in productivity can be associated with decreases in ecological outcomes because some yield-enhancing practices have detrimental effects on the environment (Bisseleua et al., 2009). However, potential negative effects should be outweighed by positive effects from environment-related interventions, as explained in the following.

2.1.3. Environment-related interventions

To receive or maintain their certification status, farmers must comply with specific requirements, ranging from the prohibition of child labour or fulfilling hired labour conditions (Oya et al., 2018) to the avoidance of deforestation (Garrett et al., 2021). In this paper, we focus on environmental requirements. For instance, sustainability standards promote the correct application of agrochemicals and prohibit the use of certain agrochemicals (Sellare et al., 2020a). Moreover, most sustainability standards strongly encourage agroforestry practices (e.g. Rainforest Alliance, 2023a or Cocoa Life, 2023b) by distributing shade tree seedlings (Schulte, 2020). Sustainability standards also offer training on

[1] Mass balance sourcing, as compared to segregated sourcing, allows certified and non-certified crops to be mixed at different stages of the supply chain. This makes it more affordable for companies to source certified crops because they do not need to keep separate tanks or silos and thus is expected to increase demand for certified crops at the farm level (Rainforest Alliance, 2023b).

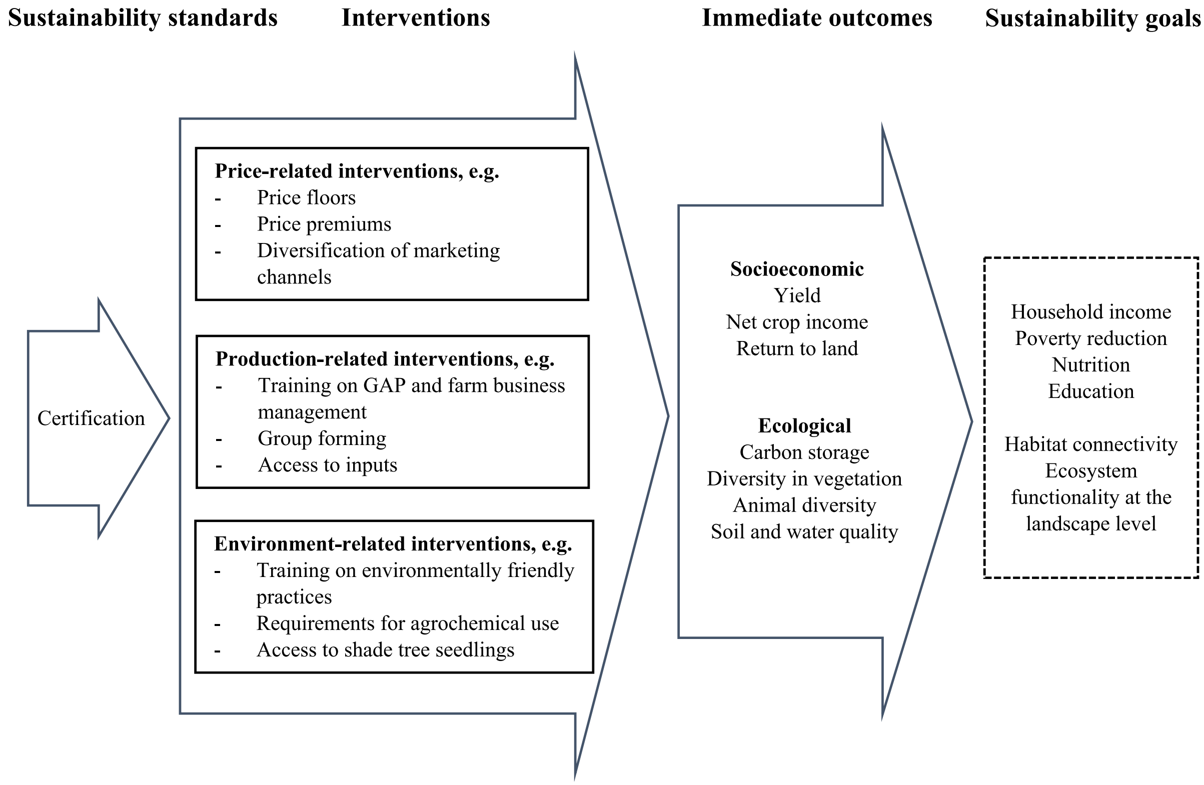

Fig. 1. Conceptual framework on the effects of sustainability standards.

environmentally-friendly practices such as integrated pest management to help farmers reduce the use of agrochemicals and adopt practices that increase biological control agents such as maintaining habitats for beneficial predators on their plots (Rainforest Alliance, 2023a).

However, while such environment-related interventions aim to improve or maintain biodiversity and ecosystem health at the plot level, they could also have negative effects on yield and net income of the certified crop. For example, resource competition with shade trees might negatively affect yields (Abdulai et al., 2018b). In addition, higher opportunity costs of household labour or additional hired labour costs needed to perform environmentally friendly practices might reduce total net income (Hörner and Wollni, 2021). On the other hand, improved ecosystem health reduces the risk of pest and disease pressures and the resulting yield loss (Ocampo-Ariza et al., 2023). Moreover, shade trees can improve soil fertility and provide erosion control (Tscharntke et al., 2011). Given that environment-related interventions may have both negative and positive effects on socioeconomic outcomes we expect that their overall effects on socioeconomic outcomes are neutral and socioeconomic outcomes are primarily affected positively by the production and price-related interventions.

The expected outcomes will depend to a certain extent on the local context. For instance, in countries with highly volatile price fluctuations, Fairtrade's price floors play a crucial role. However, in countries with very regulated markets, where governments set the farm gate price, as in Ghana for cocoa, or minimum support prices, as in India for cotton (ICAC, 2023), price-related interventions may be less significant. In this paper, we assess immediate socioeconomic and ecological outcomes that are particularly relevant in the context of Ghana's cocoa sector. We will discuss these in detail in Section 3.1.

While the focus of this paper is on the immediate effects, enhanced socioeconomic outcomes have the potential to contribute to broader sustainability goals related to household welfare, such as increasing household living standards (Knößlsdorfer et al., 2021), reducing poverty (Akoyi and Maertens, 2018), and improving nutrition and education (Meemken et al., 2017). Similarly, improved ecological outcomes at the plot level can foster habitat connectivity for wildlife and contribute to the development of healthy landscapes, thereby enhancing the functioning of landscape-level ecosystem services (Tscharntke et al., 2015).

2.2. *Study context*

2.2.1. *Cocoa production*

Ghana is the world's second largest cocoa producer, yet cocoa yields per hectare remain among the lowest globally (FAO, 2023). Reasons for low productivity are linked to lack of knowledge on agricultural technologies and practices, lack of agrochemical inputs, aging cocoa trees, depleted soils and high pest and disease pressures (Schroth et al., 2016; Bymolt et al., 2018). Low productivity coupled with low commodity prices lead to poverty among smallholder cocoa farmers (Boysen et al., 2023) and poses environmental challenges such as land degradation (Ruf et al., 2015), land-use change connected to illegal cocoa-driven deforestation (Ruf et al., 2015; Kalischek et al., 2023) and illegal artisanal mining (Attuquayefio et al., 2017).

Traditionally, farmers in Ghana cultivate cocoa under the shade of native forest trees or other crop trees, or a combination of both (Sanderson et al., 2022). While these agroforests cannot fully replace native forests, they play a crucial role in conserving biodiversity by hosting species found in natural forests (Deikumah et al., 2017) and serving as habitat corridors between forest fragments (Asare et al., 2014). Beyond biodiversity conservation, cocoa agroforests can provide a range of beneficial provisioning ecosystem services. For example, shade trees provide fruits, fuelwood, traditional medicine, fodder and building material (Abdulai et al., 2018a). In addition, selected shade tree species have the potential to improve yields compared to full-sun cocoa plantations under low-input systems (Asare et al., 2017; Asitoakor et al., 2022).

However, many farmers reduce the number of shade trees on their cocoa plots, fearing that these compete with cocoa trees for light, water and nutrients (Asitoakor et al., 2022). These fears arise because under certain conditions, when hybrid cocoa genotypes are planted or extensive agrochemicals are used, low or no-shade cocoa farming may yield more but have a shorter lifespan compared to agroforestry systems (Asare et al., 2019). Moreover, there is a widespread perception among farmers that agroforestry systems create microclimates suitable for pests and disease (Armengot et al., 2016).

2.2.2. Cocoa supply chain and sustainability standards

Major international traders and chocolate companies drive the demand for certified cocoa in Ghana. These companies operate through affiliated government-licensed buying companies (LBCs) that locally source cocoa and are responsible for implementing the desired sustainability standard (Gockowski et al., 2013). LBCs reach out to the farmers through their purchasing clerks: middlemen and women who usually live in the same community, buy cocoa directly from the farmers and channel it to their LBC on a commission basis (Nitidae and EFI, 2021).

There is strong competition between purchasing clerks and LBCs to buy cocoa from farmers. Since the government decides and sets the value of the farm gate price at which cocoa farmers can sell their cocoa each season, the purchasing clerks and LBCs cannot compete by offering high prices, so they sometimes offer other incentives to attract farmers. Independent of the certification status, the purchasing clerks offer incentives such as loans or guarantees of timely payment, and the LBCs offer benefits such as training, group formation, price premiums, and agricultural inputs. Farmers often sell to several purchasing clerks and LBCs to maximize the number of benefits they receive.

Currently, several types of sustainability standards operate in Ghana (Thompson et al., 2022) that differ in their governance structure. First-party certification schemes are private initiatives, where monitoring is based on self-assessment by the company. Second-party certification schemes are governed by interest groups such as industry associations or NGOs. Third-party certification involves governance by external, independent groups who monitor implementation of and compliance with the criteria set by the standard (Steering Committee of the State-of-Knowledge Assessment of, 2012). While the primary goal of all standards is to enhance sustainable productivity, initially, some standards used to have a specific focus. Fairtrade, for example, emphasized social aspects such as labour rights and fair prices (Fairtrade, 2023b), while the Rainforest Alliance concentrated on environmental conservation and forest protection (Rainforest Alliance, 2023c). Over time and in alignment with global sustainability objectives, these standards have evolved to address a broader spectrum of sustainability challenges, and their goals have converged (Lambin and Thorlakson, 2018; Meemken et al., 2021). Now the sustainability standards present in Ghana all claim to improve productivity and profits by promoting GAP and offering price premiums as well as taking environmental considerations into account to protect biodiversity[2] (Cocoa Life, 2023b; Fairtrade, 2023a; Lindt and Sprüngli Farming Program, 2023; Rainforest Alliance, 2023a).

3. Materials and methods

3.1. Sampling, data collection and measurement of variables

3.1.1. Sampling and household data collection

A main motivation for our study design was to create a representative sample of five main cocoa growing regions within Ghana. Additionally, we aimed to increase external validity by capturing the heterogeneity of sustainability standards, operational units of LBCs and geographic regions. Therefore, we applied a two-stage sampling strategy in which we randomly selected communities based on existing population census data. To ensure that regions with higher production levels were proportionately represented, the number of communities in each region was identified based on their 2019 production volumes (Cocobod, 2024). We randomly selected 18–19 cocoa farming households in each community based on existing lists that extension officers provided. In total, we selected 839 households in 46 communities, 24 districts, and five regions (Fig. 2).[3]

We collected household data from November 2022 to January 2023. A team of local enumerators, who the first author trained, monitored and accompanied throughout the data collection, conducted computer-assisted personal interviews with the heads of the cocoa farming households. Our questionnaire focused on household demographics, community characteristics, detailed questions about the characteristics of all cocoa plots under cultivation, general cocoa farm management activities, agricultural practices, cocoa marketing and other agricultural and non-agricultural income generating activities.

To understand the local context and gain an overview of the LBCs operating in each of the sampled communities, as well as whether these LBCs implemented sustainability standards, the first author, along with a local assistant, conducted a mix of qualitative and quantitative interviews with different stakeholders. Using open-ended questions, we asked the responsible extension officer or community leader about the operations of the LBCs and their respective purchasing clerks in each community. With their help, we then located the respective purchasing clerks and conducted short quantitative interviews with them about the sourcing activity of their LBC and the type of services offered to farmers. In cases where a purchasing clerk was unavailable, our local assistant conducted a separate phone survey with him or her. Altogether, we spoke to 75 purchasing clerks in person and 101 by phone. In addition to improving our understanding of the local context, we used this information to construct key variables, which we discuss later.

Our ecological data collection lasted from November 2022 to March 2023. Four of the co-authors of this paper are ecologists or agricultural scientists and were responsible for supervising and implementing the ecological data collection. From the household sample, we collected ecological data on a subset of 119 cocoa plots.[4] In total, our ecological sample includes 65 plots from certified cocoa farming households and 54 plots from non-certified cocoa farming households in 18 communities, located in 10 districts and four of the five initially sampled regions (see Fig. 2). The fifth region, which was the Brong Ahafo region, had the least sampled communities and therefore was excluded due to logistic constraints. Table A1 in the supplementary material shows the differences in means between the household sample and the ecological subsample. The ecological data collection required repeated travelling to the study sites and long walking distances from the community to the cocoa plots. Therefore, we had to exclude some of the very remote communities that were too difficult to access. As a result, we observe significant differences in characteristics related to infrastructure and accessibility of the community between the ecological subsample and the full sample. Besides these differences, the ecological subsample has similar average characteristics to the full sample.

3.1.2. Treatment variable "certification"

Although farmers are aware of the LBCs' sustainability program activities, they are sometimes not well informed that this is part of a "formal" sustainability standard scheme and are therefore unaware of their certification status (Bymolt et al., 2018). Therefore, simply asking

[2] This does not apply to Organic certification, which differs from other sustainability standards by prohibiting the use of all agrochemicals (Ibanez and Blackman, 2016).

[3] For details regarding the household sample size calculation, please refer to the Appendix A.1.

[4] For details regarding the ecological sample size calculation, please refer to the Appendix A.1.

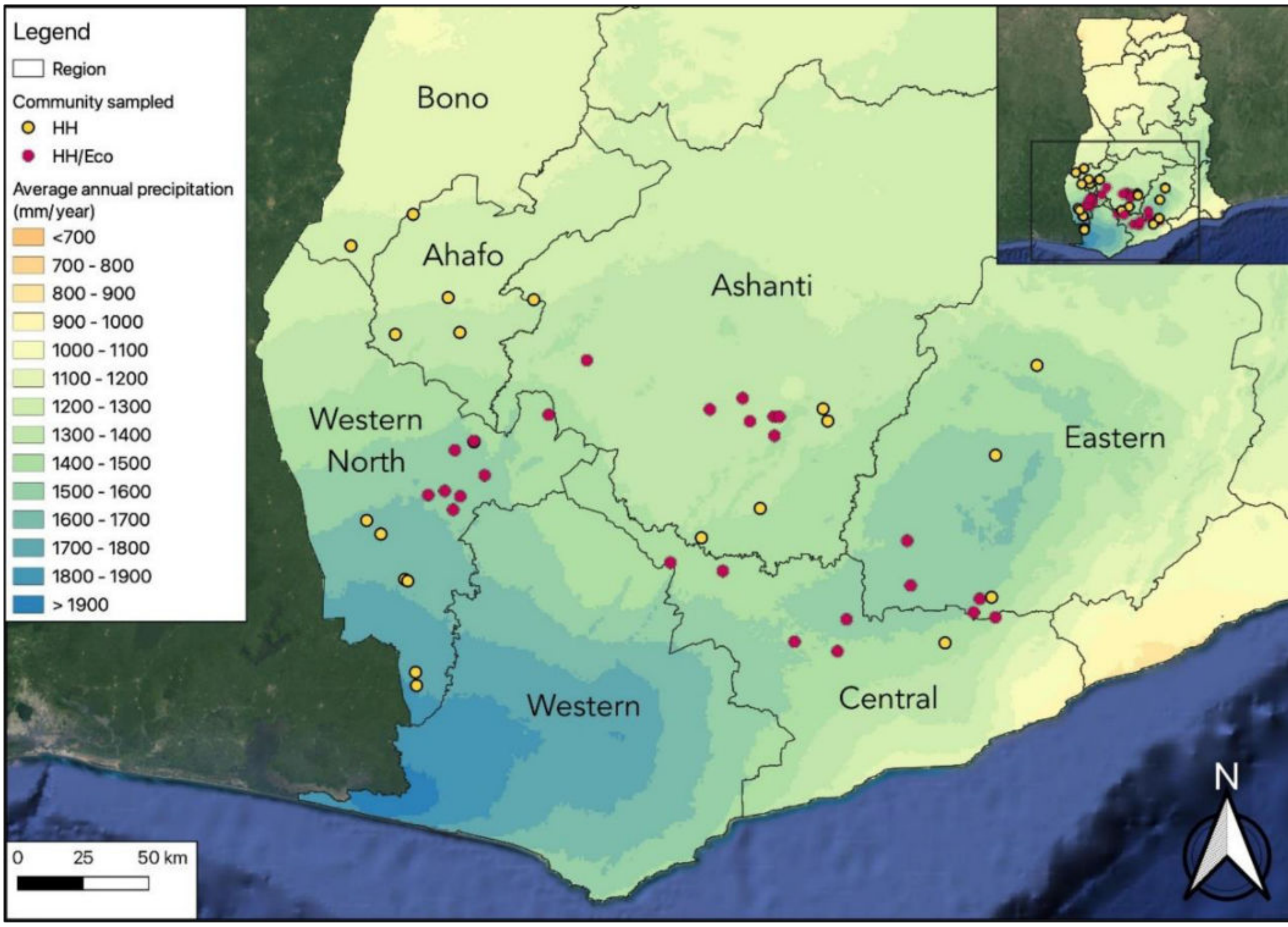

Fig. 2. Map of sampled communities in Ghana. Yellow circles indicate communities where only household data was collected and are labelled as "HH" in the legend. Red circles indicate that additional ecological data was collected and are labelled as "HH/Eco" in the legend. Note: Ghana recently divided the Brong Ahafo region into the Bono and Ahafo regions; these were considered as one region at the time of the sampling. The map was created using publicly available rainfall data from Fick and Hijmans (2017). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

farmers about their certification status may result in underreporting. To address this challenge, we established two conditions that must be fulfilled jointly to consider a farmer as certified.

The first condition is that the cocoa farmer sells their cocoa to a certified purchasing clerk and LBC. During the survey, we asked the farmers the names of the purchasing clerk purchasing their cocoa and the names of the LBCs employing the purchasing clerks. Based on community-level interviews with purchasing clerks, extension agents and community leaders, as well as publicly available information provided by some sustainability standards, we identified the LBCs operating in each community, their certification status and the names of their purchasing clerks.

Fulfilling only the first condition is insufficient to consider a farmer as being certified, because certified purchasing clerks often buy cocoa from certified as well as non-certified farmers. To ensure that only registered certified farmers are included in our treatment group, the second condition requires that the farmer selling to the certified purchasing clerk reports his or her participation in at least one of three certification activities: 1) signing a registration form provided by their purchasing clerk, 2) that staff from their LBC has geo-mapped the farmer's cocoa plot or 3) inspected the farmer's cocoa plots.[5] In total, we identified 338 certified farmers and 476 non-certified farmers,[6] resulting in 65 certified and 54 non-certified plots. The distribution of certified and non-certified cocoa farmers in our household sample seems largely representative for Ghana's cocoa sector, since according to Nitidae and EFI (2021) about 38 % of Ghana's cocoa is certified.[7] Our random sample covers a wide range of different sustainability standards, such as Fairtrade, Rainforest Alliance, Cocoa Life, Cocoa Horizon, Lindt

[5] Robustness checks confirm that reporting to participate in at least two or three certification activities leads to the same direction of the estimates. However, since we rely on reported data, it could be possible that we incorrectly categorized a few truly certified farmers as non-certified: this holds for registered certified farmers that did not report to have participated in any of the mentioned activities and that we therefore categorize as non-certified.

[6] We omitted 25 farmers from the sample because we could not identify their certification status. This was because 1) the farmers did not know to which LBC they were selling and could not provide the name of their purchasing clerk 2) we could not verify that the LBC they mentioned existed in the community, or 3) we could not verify if the LBC was certified because the purchasing clerks, extension officers or community leaders were uncertain about the status.

[7] We could not find the exact numbers of farmers officially certified in Ghana, however, the estimate of Nitidae and EFI (2021) seems consistent with the share of 41 % of certified farmers found in our sample.

and Sprüngli Farming Program and Cargill Cocoa Promise. Organic was not sampled, which is likely because Organic represents less than 1 % of the sustainability standards in Ghana (Thompson et al., 2022) and is mainly sourced in a district that was not on our sampling list.

While some purchasing clerks informed us that their LBC was sourcing certified cocoa and offering the typical sustainability standard interventions, they were unable to specify the name of the sustainability standard. Consequently, we group all sustainability standards into a single category, similar to (Krumbiegel and Tillie, 2024). We do not expect that differentiating between the different sustainability standards would lead to very different results in our study context. As mentioned earlier, overall, the various sustainability standards that exist in the Ghanaian cocoa sector are similar in scope and have converged in their objectives over time (Meemken et al., 2021). The focus of the sustainability standards included in our study is on encouraging the use of good agricultural practices to increase productivity without harming the environment (Schulte, 2020).[8] Some of the standards (e.g. Fairtrade and the Rainforest Alliance) have explicit requirements regarding, for example, the ban of certain hazardous agrochemicals, while other standards (e.g. Cocoa Life and Lindt & Sprüngli Farming Program) do not address this explicitly. However, given the generally low use of pesticides in our research context (Danso-Abbeam and Baiyegunhi, 2018), the requirements related to the use of hazardous agrochemicals are unlikely to have a substantial effect. Furthermore, most sustainability standards strongly recommend and encourage farmers to plant shade trees; however, they do not establish strict requirements on shade tree level thresholds for individual smallholder farmers belonging to a certified group of farmers. The Rainforest Alliance sets an optimal required natural vegetation cover of 15 %. However, it is unclear whether this requirement applies at the group level (i.e., a group of smallholder farmers supplying to one purchasing clerk must collectively reach 15 % natural vegetation cover across all their farms) or to individual smallholders within a certified group (Rainforest Alliance, 2023a). Lastly, our community-level interviews did not indicate any differences in the implementation across sustainability standards.

3.1.3. Socioeconomic outcome variables

We use three indicators to measure the immediate socioeconomic effects of sustainability standards: cocoa yield, net cocoa income and returns to land. As mentioned earlier, the average cocoa yield in Ghana is very low in world-wide comparison (FAO, 2023). Reducing the yield gap is essential to support livelihoods. However, inputs for cocoa production are very costly, and their effective use requires careful planning and good management skills. Net cocoa income per hectare therefore reflects the profit made from cocoa production. In addition to income from cocoa, the livelihoods of cocoa farming households often depend on a variety of food crops, such as plantain, cassava, and cocoyam, as well as fruit trees such as mango, avocado, and coconut, which are grown on the same plots. To capture the total economic value of all the crops grown on the cocoa plots, our third socioeconomic indicator is returns to land.

Cocoa yield is measured as the quantity of dried[9] cocoa beans in kilogram per hectare produced on productive cocoa area during the past 12 months. We asked farmers how many bags they harvested during the last light and main seasons (covering the previous 12 months) and inquired about the size of each plot, allowing farmers to provide the measurement in their preferred units (acres, hectares or traditional poles). We then multiplied the number of total harvested cocoa bags with the standardised weight of the bags and divided it by the size of all plots that we converted into hectares.

Net cocoa income is measured in the local currency Ghanaian cedis (GHC) per hectare of productive cocoa area and is calculated as the total sales value in GHC of cocoa harvested minus the production-, and land-related costs plus any additional price premiums that were received during the year preceding the survey date. To obtain accurate estimates of production-related costs, we asked detailed questions about the costs of different fertilizers and pesticides applied on each plot, as well as use of and daily cost of hired labour for various agricultural activities. For land-related costs, we account for in-cash or in-kind expenses incurred when land was rented or under a sharecropping agreement.

Returns to land, measured in GHC per hectare of productive cocoa area, incorporates additional income sources by adding the revenue from all intercrops and fruits from shade trees planted on the cocoa plots to the net cocoa income. To estimate the revenue from these intercrops and fruits, we asked farmers about the other crops and fruit trees planted on their cocoa plots and how much of the harvest was consumed at home or sold in the market during the last 12 months. For the valuation of these products, even if consumed at home, we used market prices.

3.1.4. Ecological outcome variables

We categorize the ecological outcome variables into indicators related to the plot's vegetation structure and indicators related to the plot's animal diversity. Indicators that relate to cocoa plot vegetation structure include shade tree crown cover, shade tree diversity and herbaceous ground cover. We chose these ecological indicators because more and diverse shade trees are expected to improve animal diversity and ecosystem functioning (Tscharntke et al., 2011). Herbaceous ground cover is a good indicator of resources available for ground-nesting and flying arthropods (Landis et al., 2005). A detailed description of how we collected and processed the data for our ecological outcome variables is provided in the Appendix A.2.

Shade tree crown area is defined as the crown area of all shade trees in m^2 per ha. We used the Shannon and Simpson diversity indices as measures of shade tree diversity. We chose these indices for their complementary aspects of measuring diversity. The Shannon index emphasizes the richness component and gives more weight to rare shade tree species than the Simpson index, which is a measure of evenness and is weighted by the abundances of dominant species (Magurran, 2007).

The Shannon index typically ranges from 1.5 to 3.5 when using empirical data and indicates the uncertainty in identifying the species of a random shade tree with higher values suggesting higher diversity (Magurran, 2007). The Simpson index ranges from 0 to 1, representing the likelihood that two randomly selected trees are of different species; higher values denote greater diversity (since it is more likely to have two selected trees belonging to different shade tree species when there is greater diversity) (Magurran, 2007). Herbaceous cover is measured as the proportion of meters covered with herbaceous plants on transects that we laid in each plot.

The indicators that capture animal diversity include bird abundance and species richness, biological predation rates and the Bioacoustic index. They are influenced by the cocoa plot's prevailing vegetation structure, as well as landscape factors such as the surrounding landscape composition (Sanderson et al., 2022). The chosen animal diversity variables are good indicators for ecosystem functioning and overall biodiversity because bird communities and predators respond quickly to changes in the environment and changes in species compositions are early signs of biodiversity loss and ecosystem functioning (Duffy, 2002). Additionally, we recorded the soundscape of each cocoa plot to calculate the Bioacoustic index. The Bioacoustic index indicates the animal diversity on the cocoa plot by including the sounds of all animals within the recorded frequency range such as birds, insects, mammals, and amphibians (Boelman et al., 2007; Bradfer-Lawrence et al., 2020).

We assessed bird diversity metrics from short recordings of the soundscapes. Abundance corresponds to the total number of birds heard in the recording, while richness is the total number of bird species heard on the cocoa plots. Predation rates are measured as the share of predated fake plasticine caterpillars that we deployed in each plot (Schwab et al.,

[8] Apart from Organic which is not part of our sample.

[9] In Ghana, cocoa farmers ferment and dry the wet cocoa beans themselves before selling them in standardised 64 kg bags.

2021). The Bioacoustic index is measured as a function of the total sound level and number of frequency bands used by the animals (Boelman et al., 2007).

3.2. Estimation methods

3.2.1. Endogenous switching regression approach for estimating socioeconomic outcomes

Certification as a treatment variable is potentially endogenous and prone to selection bias when estimating socioeconomic outcomes. This is because sustainability standards are not randomly assigned, since farmers voluntarily decide to which purchasing clerk(s) they sell; and if they want to become certified with the respective purchasing clerk. For instance, very motivated and capable farmers are more likely to sell to a certified purchasing clerk in order to benefit from the offered interventions. At the same time, these more capable farmers may also perform better in certain income-enhancing agricultural activities. Additionally, selection bias might occur if purchasing clerks or LBCs purposely target farmers who are already performing well or meeting the necessary environmental criteria.

In order to account for this potential endogeneity bias, we use the endogenous switching regression (ESR) approach (Maddala, 1983) to estimate the effect of sustainability standards on socioeconomic outcomes. We estimate the ESR with the survey data of the full sample. The ESR is a two-stage parametric approach that has been widely applied for impact assessments (Abdulai, 2016; Noltze et al., 2013), including certification impact assessments (Kleemann et al., 2014; Krumbiegel and Tillie, 2024). In the first stage, a probit model of selection into treatment is estimated. The second stage estimates outcome equations for the treatment and control group and includes corresponding inverse mills ratios from the first stage as additional covariates.

Based on a utility maximization function, in the first stage, we use a probit model to estimate a farmer's probability of being certified:

$$VSS_i = Z_i\gamma + n_i \tag{1}$$

where VSS_i relates to the voluntary sustainability standard certification status, Z_i is a vector of explanatory control variables, including at least one instrument, γ is a parameter to be estimated and n_i is an error term with mean zero and variance σ^2.

In the second stage, we use a switching-regression model which specifies two separate equations for certified households (2.1) and non-certified households (2.2):

$$Y_{i,VSS} = X_{i,VSS}\beta_{VSS} + \sigma_{VSS,n}\lambda_{i,VSS} + \vartheta_{i,VSS} \text{ if } VSS_i = 1 \tag{2.1}$$

$$Y_{i,N} = X_{i,N}\beta_N + \sigma_{N,n}\lambda_{i,N} + \vartheta_{i,N} \text{ if } VSS_i = 0 \tag{2.2}$$

where $Y_{i,N}$ and $Y_{i,VSS}$ are outcome variables for certified and non-certified farmers, respectively; X_i is a vector of control variables and β is a vector of parameters to be estimated. To address selection bias due to unobservable factors, following Heckman (1978), we include the inverse mills ratios from the selection equation (Eq. (1) represented by $\lambda_{i,VSS}$ for certified and $\lambda_{i,N}$ for non-certified farmers, and the covariance terms $\sigma_{VSS,n}$ and $\sigma_{N,n}$. Finally, $\vartheta_{i,VSS}$ and $\vartheta_{i,N}$ are the error terms with conditional zero means.

At the household level, we control for the household head's level of education, age and sex and the number of adults, total cocoa land cultivated and whether the household receives non-agricultural income. Additionally, we incorporate characteristics that may capture unobservable traits, including leadership status and individual risk aversion.[10] At the plot level, we control for whether the farm has experienced a pest or disease attack or drought within the past 12 months. Moreover, we control for the share of cocoa trees under 5 years and above 25 years of age to account for lower productivity levels and for the share of fertile soil reported by the farmer. At the community level, we control for the availability of electricity and the distance to nearest agricultural input shop and tarred road. We control for regional characteristics by including regional dummy variables. Additionally we create a dummy variable for farmers located in areas with Nitisols,[11] which are considered favourable soils for cocoa (FAO, 2015).

While the variables in Eq. (1) and Eqs. (2.1) and (2.2) are allowed to overlap, there should be at least one or more variables that appear in Z_i but not in X_i for the model to be identified correctly. This implies that the choice criterion function is estimated based on control variables plus one or more instruments (Abdulai, 2016). A valid instrument that fulfils the exclusion restriction is defined as an instrument that influences the probability of being certified but does not directly influence the outcome variables (Wooldridge, 2013). We include the following two instruments: 1) the share of certified farmers living within a radius of 1 to 3 km and 2) the share of certified LBCs buying in the community.

The first instrument, the share of certified farmers living within a radius of 1 to 3 km, captures social network effects and is adapted from Di Falco et al. (2020). The share of certified farmers is derived using GPS data from our household sample which is representative of each community. This variable is calculated by subtracting the share of certified farmers in a 1 km radius of each farmer *i* from the share of certified farmers in a 3 km radius of farmer *i*. The assumption is that farmer *i* interacts with farmer *j* who lives within the 1 km radius of farmer *i*, but not with farmer *k* who lives outside the 1 km radius, whereas *j* interacts with *k* since they live in proximity. If farmer *k* is certified, farmer *j*, being farmer k's neighbour, is more likely to learn about sustainability standard interventions and their possible benefits. Farmer *j* may become interested in selling to purchasing clerks offering these services and become certified as a result. Farmer *j*'s choice subsequently influences farmer *i*. We therefore assume that farmer *i*'s choice of being certified is influenced by farmer *k*, through farmer *j*. We display robustness checks testing different distance thresholds in Table A3 in the supplementary material.

The second instrument is defined as the share of certified LBCs operating in each community. Using the information gathered from our interviews with purchasing clerks, we were able to determine the number of certified and non-certified LBCs in each community. We expect that if more certified LBCs are operating in a community, it is more likely that farmers learn about the benefits of sustainability standards and will sell to purchasing clerks working for these certified LBCs in order to benefit from the interventions.

A simple falsification test proposed by Di Falco et al. (2011) gives some indication that the exclusion restriction holds for the instruments used in the household analyses (see Table A2 in the supplementary material). Using the Wald test, we show that our instruments are jointly significantly correlated with being certified and not with the outcome variables.

We estimate the ESR model using a full-information maximum likelihood method (Lokshin and Sajaia, 2004) to simultaneously estimate the selection and outcome equations with standard errors clustered at the community level. We use this procedure to compute the average treatment effect on the treated (ATT) which is the expected effect of being certified. The ATT (Eq. (3.3)) is calculated as the difference between expected outcomes of actual certified farmers (Eq. (3.1)) and their hypothetical counterfactuals (hypothetical non-certified farmers) (Eq. (3.2)) as follows:

$$E\left(Y_{i,VSS} | VSS_i = 1\right) = X_{i,VSS}\beta_{VSS} + \sigma_{VSS,n}\lambda_{i,VSS} \tag{3.1}$$

[10] Following Dohmen et al. (2011) respondents could rate their own perceived level of risk aversion on a scale from 1 to 10. The concept of incorporating risk aversion as a control variable is taken from Sellare et al. (2020a).

[11] Soil types were identified in QGIS using publicly available data from Dewitte et al. (2013).

$$E(Y_{i,N}|VSS_i = 1) = X_{i,N}\beta_N + \sigma_{N,n}\lambda_{i,VSS} \tag{3.2}$$

$$ATT = E(Y_{i,VSS}|VSS_i = 1) - E(Y_{i,N}|VSS_i = 1) \tag{3.3}$$

$$= X_{i,VSS}(\beta_{VSS} - \beta_N) + \lambda_{i,VSS}\ (\sigma_{VSS,n} - \sigma_{N,n})$$

3.2.2. Generalized linear mixed effects models for estimating ecological outcomes

We use ecological data and survey data from our subsample of 119 cocoa plots to estimate the ecological outcomes. Estimations with ecological outcome variables are less prone to endogeneity in our research context. This is because the farmers' unobservable characteristics that are correlated with being certified are more likely correlated with outcomes that will increase the farmer's welfare rather than the biodiversity in their plot. Moreover, due to their spatial vicinity, environmental outcomes within cocoa plots coming from the same community are more likely correlated than outcomes across communities, leading to correlation in the error term. To account for this we follow Krumbiegel et al. (2018) and Rana and Sills (2024) and use generalized linear mixed effects models (GLMM) to estimate the association[12] between sustainability standards and ecological outcome variables. GLMM relax the assumption of no linear dependence in the error term.

In the GLMM estimations we include the community as a random effect and use different specifications for different outcome variables depending on the nature of the data. We use Poisson GLMM for the bird richness and abundance estimations as these are count variables and Gamma GLMM for the herbaceous cover estimation since the data is non-normally distributed. For all other outcomes, we use Gaussian GLMMs since the data is normally distributed. For all models we use a log-link function for easier interpretation and robust standard errors to account for potential overdispersion. The GLMM takes the following form:

$$Ecol_{i,p,c,l} = \mu_0 + \mu_1 VSS_{i,p,c,l} + \mu_2 HH_{i,p,c,l} + \mu_3 P_{i,p,c,l} + \mu_4 L_l + C_c + \epsilon_{i,p,c,l} \tag{4}$$

where $Ecol_{i,p,c,l}$ refers to the respective ecological outcome variable of cocoa plot p from household i in the community 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 which we derive from the household survey and are most likely to affect vegetation structure and animal diversity. These are the household head's level of education, age, sex and leadership status, number of adults in the household, total area cultivated and if the community has electricity and distance to the nearest extension office. $P_{i,p,c,l}$ refers to a set of cocoa plot-level control variables such as the age of the cocoa trees which we derive from the household survey and the area of the sampled plot in hectare which we measured with a GPS device. For the shade tree crown area estimations, we additionally include the cocoa plot's mean normalized difference vegetation index (NDVI) from the year 2000 (Landsat – 7, 2024) as a lagged control variable. We use this variable as a proxy to account for differences in shade tree levels before the farmers became certified[13,14] L_l are regional dummy variables. For the animal diversity estimations, we include control variables at the landscape level since landscape factors might influence animal diversity on the plots. These relate to the distance to primary forest in kilometres, the distance to tarred road in kilometres and the area in m^2 covered in small-scale gold mining sites[15] within a 1 km radius. C_c are community-level random effects and $\epsilon_{i,p,c,l}$ refers to the error term.

As discussed earlier it is unlikely that selection bias among farmers with respect to ecological outcomes is prevalent in our research context. However, the possibility still exists for outcomes related to vegetation structure. For instance, farmers with existing extensive shade tree coverage on their cocoa plots may be more likely to join certification because their costs of meeting the requirements of the sustainability standard are lower compared to farmers who would require additional investments in planting shade trees. Although we try to account for this by including the NDVI from the year 2000 as a lagged variable, we estimate our indicators related to vegetation structure using an instrumental two stage least squares (IV-2SLS) approach as a precautionary robustness check.[16] The two instrumental variables utilized in our socioeconomic regressions do not consistently satisfy the criteria outlined in the falsification test proposed by Di Falco et al. (2011) for our subsample. Consequently, we opt for the instrument that meets the criteria and use it for the IV-2SLS estimation. Table A4 in the supplementary material shows the results of the falsification test for the instruments applied for each estimation.

Since we observe significant differences in characteristics related to infrastructure and accessibility of the community between the ecological subsample and the full sample, we apply inverse probability weights (Wooldridge, 2002) in our ecological estimations as a further robustness check. By applying inverse probability weights, we give more weight to observations that are similar to the full sample, making the subsample more representative of the household sample. Following Wooldridge (2002), we run a probit regression to determine the probability of being in the ecological subsample over all control variables used. The inverse of the estimated probability is the adjusted weight which we add to the ecological estimations.

4. Results

4.1. Sample characteristics

Table 1 shows the descriptive statistics of the outcome variables and our sample's characteristics. Certified farmers have higher average cocoa yields, net cocoa incomes and returns to land compared to non-certified farmers. On average, certified farmers have 1.58 more years of education compared to their non-certified counterparts. Furthermore, certified farmers have a 7 % lower prevalence of female-headed households and a 11 % higher prevalence of household heads holding leadership positions[17] in the community. Overall, certified farmers seem to have a locational advantage, since they are at a shorter distance from tarred roads, more often located in communities with electricity and more often located on Nitisols soils, which are favourable for cocoa cultivation. Access to input, however, is not conclusive. While certified farmers are located further away from input shops than non-certified farmers, on the average, they have more often received subsidized input applications by governmental extension officers in the year

[12] Due to the comparably small plot sample size, it is not possible to apply the ESR approach. We therefore avoid the term "effect" which would imply a causal relationship.

[13] NDVI measures surface reflectance and gives a quantitative estimation of vegetation growth and biomass (Jiang et al., 2006). This means that the NDVI does not only relate to shade trees but also to cocoa tree health, hence the values of this variable only serve as a rough proxy. Mean NDVI values from 2000 were calculated in QGIS.

[14] Due to data limitations we do not know the exact year in which each farmer became certified. Therefore, we choose the year 2000 since this was roughly the time before most sustainability standards were introduced in Ghana.

[15] The distance to primary forest and the tarred road and mining sites were mapped in QGIS using Google Earth Imagery, 2023.

[16] The IV-2SLS approach has the disadvantage that it does not account for the similar environmental characteristics of plots within one community and for this reason we use the GLMM approach as our main model.

[17] Leadership position refers to positions such as community chiefs, landlords, community chief farmers, executives of farmer groups, assemblymen/women or similar.

Table 1
Descriptive statistics of variables used in all estimations.

	Certified farmers		Non-certified farmers		Mean difference
	mean	sd	mean	sd	
Household variables					
Socioeconomic outcomes					
Yield (kg/ha)	420.62	336.61	340.00	288.03	80.62***
Net cocoa income (GHC/ha)	2986.48	3921.68	2172.31	3473.80	814.17***
Returns to land (GHC/ha)	6568.03	6173.13	5531.19	5559.75	1036.84**
Household characteristics					
HH years of education	10.33	3.53	8.74	4.37	1.58***
HH head is female	0.15	0.36	0.22	0.42	0.07**
Age of HH head	54.23	12.92	54.02	13.71	0.22
No. of adults in HH	3.41	1.91	3.20	1.85	0.21
Risk aversion	5.13	3.31	5.11	3.33	0.02
HH head is leader	0.28	0.45	0.17	0.37	0.11***
Received gov. inputs subsidized	2.27	2.49	1.97	2.46	0.29*
HH has non-agric. income	0.59	0.49	0.58	0.49	0.01
Total cocoa area (ha)	4.36	3.38	4.02	3.23	0.35
Location characteristics					
Community has electricity	0.92	0.28	0.83	0.37	0.09***
Distance HH to input shop (km)	11.25	11.74	9.29	9.83	1.95**
Distance HH to tarred road (km)	5.43	7.48	6.63	10.27	1.19*
Nitisol soil (favourable)	0.19	0.39	0.13	0.34	0.06**
Cocoa plot characteristics					
HH experienced drought	0.43	0.50	0.45	0.50	0.02
HH experienced pest attack	0.48	0.50	0.54	0.50	0.06*
Share of rich soil	0.77	0.39	0.79	0.37	0.03
Share cocoa trees <5 years	0.02	0.10	0.06	0.21	0.04***
Share cocoa trees >25 years	0.27	0.38	0.20	0.36	0.06**
Regions					
Western region	0.26	0.44	0.33	0.47	0.07**
Brong Ahafo region	0.12	0.32	0.07	0.26	0.04***
Eastern region	0.14	0.35	0.22	0.41	0.08***
Central region	0.12	0.33	0.14	0.35	0.02
Ashanti region	0.36	0.48	0.23	0.42	0.12***
Instrumental variables					
Share cert. farmers between 1 and 3 km	0.17	0.33	0.06	0.20	0.11***
Share cert. LBCs in community	0.64	0.27	0.40	0.29	0.25***
Observations	338		476		814
Ecological Variables					
Vegetation structure outcomes					
Shade tree crown area (m^2/ha)	3086.19	1222.03	3078.95	1242.96	7.24
Shade tree diversity - Simpson index	0.77	0.19	0.81	0.10	0.04
Shade tree diversity - Shannon index	2.08	0.66	2.14	0.49	0.06
Herbaceous cover†	0.24	0.19	0.31	0.25	0.08*
Animal diversity outcomes					
Bird abundance	35.44	11.04	36.71	9.51	1.27
Bird richness	16.85	4.30	17.51	4.56	0.66
Predation rate	59.28	20.01	62.04	18.49	2.76
Bioacoustic index†	178.85	83.38	212.79	66.54	33.94**
Additional (non-HH) control variables					
Mining area (m^2) within 1 km of plot	96,953.68	237,349.40	4238.41	15,850.74	92,715.27***
Area of sampled farm (ha)	1.17	0.78	1.05	1.02	0.13
Distance to primary forest (km)	6.14	5.09	4.77	4.05	1.37
Distance to road (km)	0.61	0.44	0.61	0.44	0.00
Mean NDVI from 2000	0.22	0.16	0.20	0.16	0.02
Observations	65		54		119

Note: sd = standard deviations. * $p < .1$, ** $p < .05$, *** $p < .01$. 1 GHC ≈ 0.08 Euro at the time of the data collection. † For herbaceous cover $N = 118$ and for Bioacoustic index $N = 115$.

preceding the survey date.

In our subsample of 119 cocoa plots, the data shows that the average values for most outcome variables related to vegetation structure and animal diversity are relatively similar between certified and non-certified plots. The exceptions are significant differences for herbaceous cover and the Bioacoustic index: certified plots have, on average, significantly less herbaceous cover, indicating more intensive weed management, and lower values for the Bioacoustic index. Certified plots are on average further away from primary forests and are on average located in places with larger areas of artisanal mining in their surroundings. Lastly, there is no significant difference in NDVI on the cocoa plot from the year 2000. This suggests that selection based on existing shade tree levels into certification is unlikely.

4.2. Participation in sustainability standard interventions

To gain a better understanding of the extent to which certified farmers in our research setting participate in the different sustainability standard interventions that we discussed in Section 2.1, we descriptively show the mean differences in participation in price, production and environment-related interventions between certified and non-certified farmers (Table 2). In our exchanges with the purchasing clerks we learned that non-certified LBCs also offer different types of price- and production-related interventions to their farmers. However, our data shows that certified farmers benefit more from such interventions compared to non-certified farmers. Certified farmers have significantly better access to price premiums than non-certified farmers. The value of the price premium per standardised 64 kg bag of cocoa is on average 8.6 GHC which relates to 1.3 % of the government set farm gate price of 660 GHC per bag. Given the small magnitude of the price premiums, they seem to serve more as an incentive to join the certified purchasing clerk rather than being able to substantially affect welfare outcomes. Moreover, the relatively large standard deviation shows that the value of the price premiums is not consistent but varies a lot between certified farmers. 21 % of certified farmers report that receiving price premiums are linked to meeting certain requirements, such as attending training, having their farming practices checked or following regulations on their farm. In terms of production-related interventions, certified farmers participate on average in 1.6 more training sessions per year compared to non-certified farmers. A higher proportion of certified farmers (9 %) have access to agrochemical inputs that are either subsidized or purchased on credit by their LBC compared to non-certified farmers (3 %). In addition, 33 % of certified farmers belong to farmer groups initiated by their LBC compared to 9 % of the non-certified group. In terms of environment-related interventions, 24 % of certified farmers have received training in biological pest, disease or weed control. 28 % of certified farmers have received free or subsidized shade tree seedlings, compared to 20 % of non-certified farmers.

Table 2
Descriptive statistics of participation in sustainability standard interventions.

	Certified farmers		Non-certified farmers		Mean difference
	mean	sd	mean	sd	
Price-related interventions					
Access to price premiums	0.70	0.46	0.23	0.42	0.47***
Price premiums (GHC/64 kg bag)	8.59	17.45	2.32	11.54	6.26***
Price premiums linked to requirements	0.21	0.41	0.01	0.11	0.20***
Production-related interventions					
No. of trainings attended	3.08	3.88	1.48	2.28	1.60***
Received subsidized agrochemicals	0.09	0.29	0.03	0.18	0.06***
Part of an LBC group	0.33	0.47	0.09	0.29	0.23***
Environment-related interventions					
Training on biological controls	0.24	0.43	0.14	0.34	0.11***
Received subsidized/free shade tree seedlings	0.28	0.45	0.20	0.40	0.07**
Observations	338		476		814

Note: sd refers to standard deviations. * $p < .1$, ** $p < .05$, *** $p < .01$.

4.3. Effects on socioeconomic outcomes

We used the ESR approach to estimate the effects of sustainability standards on socioeconomic outcomes. Table A5, Table A6 and Table A7 in the supplementary material present the estimated coefficients of the first stage selection equations, as well as the estimates of the separate outcome functions for certified and non-certified households. Table 3 shows the average treatment effects of the treated (ATT) on the socioeconomic outcome variables. The results suggest an ATT of 46 kg per hectare for cocoa yield, an ATT of 311 GHC per hectare for net cocoa income and an ATT of 895 GHC per hectare for returns to land. These results correspond to an average increase of 12.4 % in yield per hectare, an average increase of 11.6 % in net cocoa income per hectare and an average increase of 15.8 % increase in returns to land per hectare compared to the counterfactual of hypothetical non-certified farmers. All our socioeconomic results are statistically significant at the 1 % level and therefore provide evidence for a positive effect of sustainability standards on socioeconomic outcomes.

4.4. Associations between certification and ecological outcomes

Table 4 presents the results of the GLMM estimations that show the associations between being certified and outcomes related to vegetation structure based on the ecological subsample. The GLMM results show that being certified is associated with more shade tree crown area, and negatively associated with both shade tree diversity indices (Simpson and Shannon). Furthermore, being certified is associated with less herbaceous cover. The estimated associations are mostly small in magnitude and do not reach conventional levels of statistical significance. The results of our robustness check using the IV-2SLS approach are very similar to the GLMM estimations (see Table A9 in the supplementary material). When applying inverse probability weights to the GLMM estimations, the results remain robust (see Table A10 in the supplementary material). The positive association between being certified and shade tree crown area even increases slightly in magnitude and turns significant, albeit only at the 10 % level.

Table 5 presents the results of the GLMM models estimating the associations between sustainability standards and animal diversity. Being certified is associated with less bird abundance, bird richness, predation rates and lower values for the Bioacoustic index. Similar to the

Table 3
Expected ATT for socioeconomic outcomes for total household sample.

Outcomes	Certified	Hyp. non-certified	ATT	*P*-value	N
Yield (kg/ha)	420.62	374.13	46.49	0.00	814
Net cocoa income (GHC/ha)	2986.48	2675.60	310.87	0.00	814
Returns to land (GHC/ha)	6568.02	5672.58	895.44	0.00	814

Table 4
Association between being certified and vegetation structure for ecological subsample.

Outcome	GLMM certification coefficient	Robust standard error	P-value	N
Shade tree crown area	0.07	0.07	0.34	119
Shade tree diversity -Simpson index	−0.06	0.04	0.11	119
Shade tree diversity -Shannon index	−0.02	0.05	0.63	119
Herbaceous cover	−0.20	0.16	0.22	118

Full regression output is presented in Table A8 in the supplementary material.

vegetation structure results, these associations do not reach conventional levels of statistical significance. The results of the estimations with the inverse probability weights remain the same as the main estimations (see Table A12 in the supplementary material). In conclusion, our results fail to generate evidence supporting a clear link between certification and ecological indicators.

5. Discussion and conclusion

In this study, we assessed the socioeconomic and ecological effects of sustainability standards in the cocoa sector of rural Ghana. Conceptually, we discussed the support that sustainability standards can offer to certified farmers to improve socioeconomic and plot-level ecological outcomes. The pathways we identified fall into the categories of price-, product- and environment-related interventions. Empirically, our results strongly indicate that sustainability standards have positive effects on cocoa yield, net cocoa income and returns to land. Returns to land which includes revenue from intercrops and shade trees, shows the highest increase, suggesting that certified farmers are able to economically leverage their intercrops and shade trees more effectively. Such knowledge could have been acquired through training on resilience and livelihood diversification strategies that some sustainability standards advocate (Rainforest Alliance, 2023c).

Certified farmers benefit from different interventions (Table 2) which can contribute to positive socioeconomic effects. Indeed, we find significant positive correlations between production-related interventions and socioeconomic outcomes (see Table A13 in the supplementary material). Price premiums (GHC/bag) do not correlate with socioeconomic outcomes, likely due to their relatively small value, suggesting that in Ghana, socioeconomic outcomes are primarily driven by production-related interventions. Overall, our socioeconomic results align with the literature that finds positive socioeconomic effects of voluntary sustainability standards for cocoa farmers in West Africa (Dompreh et al., 2021; Iddrisu et al., 2020; Sellare et al., 2020b).

In contrast to the socioeconomic results, we do not find any clear associations with the ecological outcomes. Many of the GLMM certification coefficients are negative. This points towards a trend that certification is associated negatively with these outcomes. Our ecological results differ to studies by Asigbaase et al. (2019), Pico-Mendoza et al. (2020) and Hardt et al. (2015) who all find significant positive associations between sustainability standards and vegetation structure for cocoa pots in Ghana, coffee plots in Costa Rica and animal diversity for coffee plots in Brazil, respectively. However, the results should be compared with caution since these three ecological studies are based on purposely selected study sites and do not control for any household characteristics in their analysis.

Table 5
Association between being certified and animal diversity for ecological subsample.

Outcome	GLMM certification coefficient	Robust standard error	P-value	N
Bird abundance	−0.06	0.05	0.25	119
Bird richness	−0.02	0.05	0.67	119
Predation rate	−0.05	0.04	0.20	119
Bioacoustic index	−0.08	0.06	0.20	115

Full regression output is presented in Table A11 in the supplementary material.

Our ecological results are not necessarily in line with our expectations, as certification schemes claim to provide training to farmers on environmentally friendly practices such as agroforestry practices or integrated pest and disease management. However, ecological effects may need a longer time to materialize than socioeconomic benefits. For instance, although descriptive results show that certified farmers have better access to shade tree seedlings (Table 2), sustainability standards might have provided farmers with these shade tree seedlings only recently. Hence, the resulting expected increases are not yet reflected in higher shade tree crown area on their cocoa plots. Moreover, nationwide biodiversity initiatives may be confounding the differences between certified and non-certified farms. For example, government extension officers are actively promoting agroforestry practices nationwide as part of climate change mitigation efforts (Ghana Cocoa Board, 2018) which could result in similar levels of shade tree crown area on all cocoa plots regardless of the certification status.

Additionally, environmentally friendly practices may be insufficiently reinforced to observe positive outcomes. It is more often recommended (rather than required) to perform certain environmental-friendly practices (Cocoa Life, 2023a; Lindt and Sprüngli Farming Program, 2023). Interviews with extension officers and community leaders revealed that the enforcement of requirements tends to be weak and compliance checks of little consequence for the farmers regarding certification status or price premium distribution. This is further reflected by our descriptive statistics which show that only 21 % of the certified farmers report that they need to fulfil certain requirements in order to receive price premiums (Table 2). Moreover, Ghanaian farmers who are struggling with dwindling yields, may prioritize the application of yield-enhancing practices rather than on biodiversity-enhancing practices.

Comparing our results with the three other existing studies assessing the simultaneous effects of sustainability standards on socioeconomic and ecological plot-level outcomes, we find mixed results. Our findings are similar to those of another study on the cocoa sector in Ghana by Thompson et al. (2022), who conclude that sustainability standards contribute to cocoa yield increases but not to shade tree cover. In other contexts, our findings diverge. For example, Haggar et al. (2017) find that sustainability standards are significantly positively associated with both socioeconomic and ecological outcomes for coffee farmers in Nicaragua. In Uganda, Vanderhaegen et al. (2018) find that coffee certification creates trade-offs between socioeconomic outcomes and ecological outcomes. Our findings suggest that the way in which sustainability standards are currently being implemented in Ghana mainly leads to economic benefits for farmers, rather than ecological benefits for the plot environment. However, yield increases do not come at great cost to the farm biodiversity. Although in smallholder settings it is sometimes possible to combine high yields with high levels of biodiversity (Wurz et al., 2022; Clough et al., 2011), there is a risk and general trend that increased intensification leading to higher yields comes at the expense of biodiversity, resulting in trade-offs between these two dimensions (Daum et al. 2023; Grass et al., 2020). In our study, where high yield gaps and low prices are a major concern for Ghanaian cocoa farmers' livelihoods, sustainability standards improve socioeconomic outcomes, without exhibiting strong trade-offs with ecological outcomes.

Our paper is not without shortcomings that could be addressed in future research. We only consider participation and non-participation in certification schemes, whereas the length of participation would have more explanatory power for certain outcome variables. In addition, it would be of great interest to investigate the heterogeneous effects of different types of sustainability standards, such as first, second, and third-party certification. A panel rather than a cross-sectional dataset would allow for longer-term outcome measures. A larger ecological sample, although costly, would allow for the use of more advanced econometric approaches. In addition, future research could explore the effects of sustainability standards on biodiversity at the landscape level rather than at the plot level, as the landscape serves as a more comprehensive habitat than a single plot. Nonetheless, to date and to the best of our knowledge, this study is one of the few studies on sustainability standards to combine socioeconomic and ecological datasets, and our dataset surpasses those of other interdisciplinary studies in terms of sample size and geographical coverage.

Disclaimer

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CRediT authorship contribution statement

Marlene Yu Lilin Wätzold: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Issaka Abdulai:** Writing – review & editing, Investigation. **Amanda Cooke:** Writing – review & editing, Methodology, Investigation, Data curation. **Katharina Krumbiegel:** Writing – review & editing, Methodology, Conceptualization, Investigation. **Carolina Ocampo-Ariza:** Writing – review & editing, Methodology, Investigation, Data curation. **Arne Wenzel:** Writing – review & editing, Methodology, Investigation, Data curation. **Meike Wollni:** Writing – review & editing, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2024.108474.

Data availability

Data will be made available on request.

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