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Implementation and effectiveness of corporate-driven smallholder cocoa certification schemes in Indonesia

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Abstract

Voluntary sustainability standards (VSS) are a popular instrument in corporate social responsibility strategies of food processing and distribution companies. Yet, concerns emerge about companies capitalizing on VSS as a reputation-building and product-differentiation tool without investing in strong sustainability commitments on the ground. This article explores how the heterogeneity in interventions across three corporate-driven Rainforest Alliance cocoa certification schemes in South Sulawesi, Indonesia, shapes farm-level socioeconomic impacts. We conceptualize the implementation of VSS interventions along three mechanisms—i.e., control, market-based incentives, and capacity-building interventions—and into measurable farm-level indicators. We use primary survey data from 458 smallholder producers and a propensity score matching approach to estimate farm-level effects of certification. Results reveal large differences in farm-level interventions across certification schemes and positive effects on farm production and producer income in those schemes with the strongest interventions. Results point to the complementarity of control, market-based incentives, and capacity-building interventions in delivering beneficial farm-level effects. We highlight the role of processing and distribution companies, as operators of certification schemes, in effectively implementing VSS to deliver improved sustainability outcomes. Improved monitoring and enforcement of VSS implementation is needed to improve accountability in the transition toward sustainable food systems.

Keywords: Certification, Rainforest Alliance, Farm-level interventions, Propensity score matching, Cocoa, Indonesia

Introduction

Sustainability concerns in global food systems have prompted a proliferation of voluntary sustainability standards (VSS) as a non-state, market-based governance instrument to address environmental, social, and economic issues in agri-food value chains (Marx and Wouters 2015; UNFSS 2022). Especially in tropical agricultural sectors, VSS coverage is widespread. Over 20% of the global cocoa and coffee area is VSS-certified (Kemper et al. 2023). Consumer demand and willingness to pay for sustainably produced food products are growing, with countries in the European Union and North America

being the most important markets for certified cocoa (Kemper et al. 2025). For example, imports of certified cocoa in Germany increased with 33% between 2015 and 2019, and consumption of Fairtrade-certified cocoa in Canada and the United States of America has seen an annual growth of 13% and 11%, respectively, in recent years (CBI 2020; Fairtrade America 2022; Fairtrade Canada 2023). Food processing and distribution companies are increasingly relying on VSS in their corporate responsibility strategies (Grabs et al. 2024; Meemken et al. 2021; Piracci et al. 2024).

However, the effectiveness of VSS in delivering improved sustainability outcomes in the agri-food sector remains challenged. Some studies report considerable sustainability gains from certification, for example, in terms of reduced poverty (Ayuya et al. 2015), health benefits (Sellare et al. 2020a), or improved nutrition and gender equity (Chiputwa and Qaim 2016). Other authors point to a lack or even negative impacts of VSS, for example, Boonaert and Maertens (2023) who observe no income effects of certification in Peru as price increases do not offset increased costs, and Haggar et al., (2017) who find that UTZ certification reduces coffee yield and income in Nicaragua. Other concerns about VSS include the potential marginalization of poor producers who face entry barriers due to high investment and certification costs, as well as knowledge and labor constraints (Beghin et al. 2015; Chiputwa and Qaim 2016; Irawan et al. 2024). Additionally, VSS may undermine local and culturally-defined food systems by prioritizing global market demands, encouraging specialization in export commodities and monocultures, and thereby restricting food sovereignty (Cadavid et al. 2024; Jacobi et al. 2023; Vellema et al. 2015). Recent review studies highlight that the impact of VSS is highly context-dependent and shaped by institutional and economic environments (Dietz et al. 2022; Meemken 2020; Oya et al. 2018). Yet, little effort has been made to empirically examine institutional and value chain determinants of VSS effectiveness in delivering improved smallholder welfare. Insights on when, where, and why VSS work remain limited (Marx et al. 2022; Oya et al. 2018).

Certification is increasingly buyer-driven, and downstream supply chain actors, such as traders or processing companies, often take the role of operators of smallholder group certificates (Grabs et al. 2024; Grabs and Carodenuto 2021). In the capacity of certificate operators, companies are in charge of operationalizing and implementing VSS on the ground, requiring them to organize the delivery of farm-level VSS interventions, such as training, audits, and premium payments. Yet, against the backdrop of heterogeneous VSS impacts, concerns have been raised that food processing and distribution companies use VSS to improve their reputation or increase profits through product differentiation without investing in sustainability improvements on the ground (Dauvergne 2018; Daviron and Vagneron 2011; Grabs and Carodenuto 2021; Solér et al. 2017). Heterogeneity in sustainability investments across companies contributes to disparities in VSS impacts across different corporate-driven certification schemes. However, the role of processing and distribution companies in implementing VSS is often overlooked in the literature (Grabs et al. 2024; Grabs and Carodenuto 2021). In addition, implementation of VSS interventions might be heterogeneous across producers within a single certification scheme. Companies often rely on a (large) network of intermediaries for the implementation of VSS, leaving room for implementation failure at each node of the network, including non-adoption of interventions by producers (Dietz and Grabs 2022).

In this article, we study heterogeneity in the implementation of interventions across different corporate-driven VSS certification schemes and investigate how compliance interventions shape farm-level socioeconomic outcomes. We rely on a recent VSS design framework by Depoorter and Marx (2023) to identify farm-level interventions and define indicators that allow us to measure their implementation. We focus on the cocoa sector in South Sulawesi, Indonesia, where three different primary data from 458 cocoa-producing households who sell to procurement agents associated to these companies or to independent (village) collectors or traders. We first explore how intervention implementation differs across certification schemes. We then adopt a propensity score matching approach to estimate effects on various production and income indicators in each certification scheme and empirically investigate how different farm-level interventions shape these outcomes.

This paper makes an innovative contribution to the literature. To date, the VSS impact literature has mostly explored the heterogeneity of different VSS in single country-crop settings (e.g., Estrella et al. 2022; Rubio-Jovel et al. 2024; Vanderhaegen et al. 2018) or of a single VSS across different settings (e.g., Akoyi et al. 2020; Arnould et al. 2009; Jena and Grote 2022; Ruben et al. 2009) and relies on hypotheses to explain the observed variation in effects. Most studies disregard or ill-describe factors related to institutional and value chain environments (Meemken 2020)—with a few exceptions (Boonaert and Maertens 2023; Grabs 2020; Jena et al. 2012; Sellare et al. 2020b). We contribute to the VSS impact literature by taking into account the heterogeneity in the implementation of farm-level interventions within a single VSS country-crop setting. In addition, our research presents original insights into the performance of processing and distribution companies as key sustainability governance actors, thereby addressing the need for more research on the role of traders as key sustainability governance actors in value chains (Grabs et al. 2024; Grabs and Carodenuto 2021).

The focus of this paper is relevant from a policy-perspective. We investigate the effects of RA certification on the economic performance of cocoa producers in South Sulawesi, Indonesia. While Indonesia is the third-largest cocoa exporter globally, cocoa productivity is declining in the region, and cocoa plots are increasingly converted to other commodities such as palm oil (Dröge et al. 2024). This research carries insights into the potential of VSS to bring additional benefits to cocoa farming in the region and make it a viable livelihood strategy. Moreover, understanding how the operationalization (i.e., organization in the field) of certification schemes and farm-level interventions determines production and welfare impacts of VSS is relevant for various stakeholders, including VSS design organizations, companies and NGOs implementing certification schemes, donors financing certification schemes, and organizations such as farmer associations facilitating certification scheme implementation.

VSS implementation and smallholder welfare

VSS aim to improve sustainability in value chains by steering production toward more sustainable practices, specified in the standard's producer requirements. In addition, they define a set of farm-level interventions that aim to foster producer compliance with these production requirements. The VSS governance literature identifies three mechanisms through which VSS ensure compliance (Depoorter and Marx 2023; Grabs 2020).

The control mechanism centers around the enforcement of rules through monitoring and verification of compliance and sanctioning of noncompliance (Gunningham et al. 2010; Locke 2013). The market-based incentives mechanism, on the other hand, focuses on rewarding compliance rather than sanctioning noncompliance (Grabs 2020; Yu and Bouamra-Mechemache 2016), while the capacity-building mechanism revolves around the facilitation of compliance (Macdonald 2020; Schleifer et al. 2019).

A recent framework by Depoorter and Marx (2023) materializes each of these mechanisms into identifiable attributes with measurable indicators at the level of VSS to evaluate their design and investigate differences in design across VSS. We build on this framework to measure the implementation of VSS design at the farm level, as policy-practice decoupling can occur. The way VSS design is implemented may not always align with intended form or can vary across certification schemes and farms (Nava and Tampe 2023). For each of the attributes in the framework of Depoorter and Marx (2023), we identify associated farm-level interventions and define 17 indicators to measure their implementation in a smallholder setting. This is documented in Table 1. In brief, indicators for control interventions pertain to the number and nature of audits, reporting of audit results, complaint systems, and the request for and verification of corrective actions. Indicators for the market-based incentives measure implementation in terms of cash and in-kind premium payments and improved export market access through direct sales to trading company procurement agents. Indicators for capacity-building interventions relate to the frequency of training and the provision of guidance documents and material and financial support. We disregard the VSS design attributes in Depoorter and Marx (2023) that do not directly relate to producer-level interventions: for example, attributes concerning the performance oversight of third-party auditing bodies, the implementation of traceability systems, or the sample size for (external) audits cannot be observed at the farm level.

Figure 1 depicts how VSS, through these compliance interventions, affect smallholder production and income. VSS influence certified crop production and marketing (area, tree density, yield, cost, and price), and thereby, affect certified crop productivity and income (crop income, return to land, return to labor), and ultimately, household income and welfare (total household income, per adult eq. household income, and nonmonetary welfare). Control interventions mainly affect production and marketing by improving compliance with VSS production requirements, geared toward more sustainable practices production. Altering production practices might impact tree density, yields, prices (e.g., through quality-upgrading), and production costs. Yet, the direction and magnitude of effects depend on the content of the required practices and how these align with pre-certification production practices (Meemken 2020).

Market-based incentive and capacity-building interventions, in addition to fostering compliance, influence certified crop production and marketing more directly. In terms of market-based incentives, cash premium payments directly increase prices, while in-kind premium payments, often provided in the form of fertilizers, pesticides, or planting material, affect tree density, prices, costs, and yields. Increased market access through vertical integration, especially in high-value export chains, is argued to affect prices, costs, and yields (Barrett et al. 2001; Swinnen 2016). In addition, these economic benefits might incentivize cocoa production expansion (or continuation)

Table 1 Conceptual framework identifying farm-level compliance interventions along three compliance mechanisms

Compliance Mechanism	Attribute name	VSS design attribute definition	Farm-level intervention indicator	Focus in the analysis
Control	Regular on-site audit	Audits are performed on-site […], including recertification audits and surveillance audits, after the initial certification audit	Frequency of audits received: At least once	Included
			Frequency of audits received: Annual	Included
			Frequency of audits received: More than annual	Included
	Unannounced audits	Certification bodies conduct unannounced (or "surprise," "short-notice") audits to avoid cosmetic compliance	At least one unannounced audit received	Included
	Certification/compliance status outcome transparency	Information on the certification status and compliance level of certified entities is publicly available	Ever received audit report after audit	Included
	Complaint and dispute settlement system	Complaint and dispute settlement system allows for any stakeholder to raise issues on certified entities'compliance or implementation of the standards	Ever had a complaint filed against certification status	Excluded; too little variation (11%)
	Corrective actions	In case of noncompliance, the certified entity is required to undertake actions to mitigate noncompliance which are verified	Ever required to take corrective actions to address noncompliance	Excluded; too little variation (11%)
			In case of noncompliance; ever verification of implementations of corrective measure	Excluded; too little variation (5%)
Market-based incentives	Price premium	Producers receive a price premium for the sale of certified products	Cash premium received in last 12 months	Included
			In-kind premium received in last 12 months	Included
	Marketing	Certified products can be marketed with a consumer-facing (B2C) label, as opposed to B2B certificates	Main buyer is procurement agent of trading company operating certificate in last 12 months	Included
Capacity-building	Training and technical support	Certified entities have access to training and technical support to implement the standards	Frequency of training received: At least once	Included
			Frequency of training received: Annual	Included
			Frequency of training received: More than annual	Included

Table 1 (continued)

Compliance Mechanism	Attribute name	VSS design attribute definition	Farm-level intervention indicator	Focus in the analysis
	Financial and material assistance	Certified entities have access to financial assistance or material support to implement the standards	Ever received input support from trading company	Included
			Ever received financial support from trading company	Excluded; too little variation (5%)
	Guidance documents on requirements and procedures	Guidance documents on standards and procedures provide further information to certified entities on how to interpret and implement the standards	Ever received guidance documents for the implementation of VSS	Included

The three compliance mechanisms and VSS-level attributes (names and definitions) for each of these mechanisms are reproduced from the framework by Depoorter and Marx (2023). For each of these attributes, farm-level interventions are identified through which the compliance attribute is put into practice. Attributes that cannot be related to farm-level compliance interventions are excluded

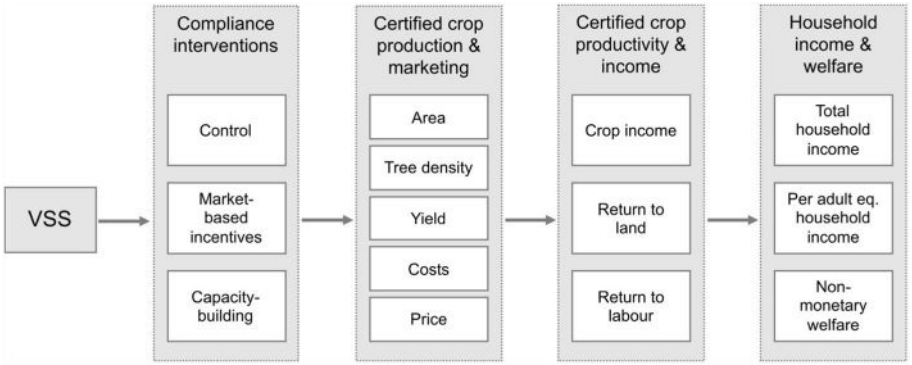

Fig. 1 Conceptual framework on farm-level compliance interventions through which VSS affect farm production and farm-household income

and affect decisions on land and labor allocation and production intensity (Vellema et al. 2015). Regarding capacity-building interventions, training interventions are often not restricted to instructing VSS production requirements but can also include information on, for example, good agricultural practices (GAPs), farm management practices, and financial literacy, and, as such affect household income and nonmonetary welfare not only through crop production and marketing, but also through other (indirect) pathways. The provision of input and financial support aims to decrease costs and increase investment opportunities.

These effects unfold over different time scales. For example, premium payments and input provision are expected to have immediate effects, while training and audit interventions target (sustained) behavioral changes in production practices which require longer timeframes to materialize. Effects on cocoa income through prices and costs emerge in the short run, while effects through yields, and through changes in cocoa tree density and area are expected to emerge in the medium to long run. Unfortunately, an exploration of these temporal aspects of VSS and their farm-level interventions is precluded by the cross-sectional nature of the data used in this paper.

Empirical evidence on the relationship between VSS governance and VSS sustainability outcomes in smallholder farm settings is scant (Marx et al. 2022). Dietz et al. (2021) investigate the relationship between VSS interventions and producer compliance by comparing five VSS in the Honduran coffee sector. They measure market-based incentives and capacity-building interventions at farm level and control interventions through audit implementation at VSS level. Their findings suggest that higher prices are strongly associated with improved compliance, while the effects of control and capacity-building interventions are more limited. Similarly, Grabs (2020) finds a positive relation between premium prices and compliance in a study covering multiple VSS in the coffee sector in Honduras, Colombia, and Costa Rica. They find no significant effect of training interventions. Boonaert et al. (2024) is the only study that directly examines the impact of VSS interventions, measured at farm level, on producer welfare. Their research on multiple VSS and sectors in Peru reveals that capacity-building interventions improve producer compliance with GAP without significantly affecting net farm revenue, while capacity-building and market-based incentives positively influence net farm income.

In short, few studies empirically investigate the impact of VSS interventions on smallholder welfare, mostly focusing on different VSS or settings. No study has yet analyzed the role of farm-level control interventions in delivering improved producer welfare. This article aims to assess how control, market-based incentives, and capacity-building interventions affect various socioeconomic performance and producer welfare indicators by exploiting heterogeneity in implementation within a single VSS and setting while controlling for confounding factors that differ over VSS, such as production requirements.

Cocoa and VSS in Indonesia

After a'cocoa boom'in the 1980 s & 1990 s, Indonesia became a major player in the global cocoa market (Neilson 2007). Despite large production declines in recent years—attributed to declining productivity and land conversion to other crops—Indonesia remains the third-largest cocoa producer in the world, supplying over 650 tons of cocoa in 2022 (FAO 2025). The sector is dominated by smallholder producers (> 99%), cultivating cocoa areas smaller than 2 hectares (BPS-Statistics Indonesia 2023). Indonesian cocoa is mainly sold in bulk and, due to its high fat-content, mainly used as filler by chocolate-producing companies (Moriarty et al. 2014). In 2010, the government introduced a progressive tax on the exports of raw cocoa beans, which spurred investments of multinational companies in local cocoa grinding capacities and stronger value chain integration (Mithöfer et al. 2017). Currently, cocoa is mostly exported after primary processing (Hasibuan and Sayekti 2018; WITS 2024). In 2022, over half of the exports were directed toward only four countries for further processing and potentially reexports to other major chocolate consuming markets: India (18% of total cocoa volume exported in cocoa bean equivalent,[1] mostly cocoa powder), the United States (14%, mostly butter), Malaysia (11%, mostly beans and paste), and China (10%, mainly powder, butter, and paste) (UNCTAD 2001; WITS 2024).

To address cocoa productivity declines and land conversion away from cocoa and simultaneously respond to increased consumer demand for sustainably produced food products in high-income countries, VSS were introduced in the late 2000 s through buyer-driven certification schemes (FiBL, personal communication, 2023; Mithöfer et al. 2017). However, certification coverage remains limited. In 2020, certified cocoa—almost exclusively under RA or UTZ—only constituted eight percent of the total production volume in Indonesia (own calculations based on FiBL, personal communication, 2023; and on FAO 2025).

Methodology

Study area and data collection

This research focuses on three neighboring districts—Luwu, North Luwu, and East Luwu—on Sulawesi, the main cocoa-producing area in Indonesia (Fig. 2). These are coastal districts with inland highlands, and with similar socioeconomic characteristics. Cocoa producers in this area rely mostly only local cocoa varieties, such as MCC02, Sulawesi 1, Sulawesi 2, and BB01. Three multinational cocoa trading companies source

[1] Own calculations based on export data from UN COMTRADE (WITS 2024) and cocoa weight conversion factor from the International Cocoa Organization (UNCTAD 2001).

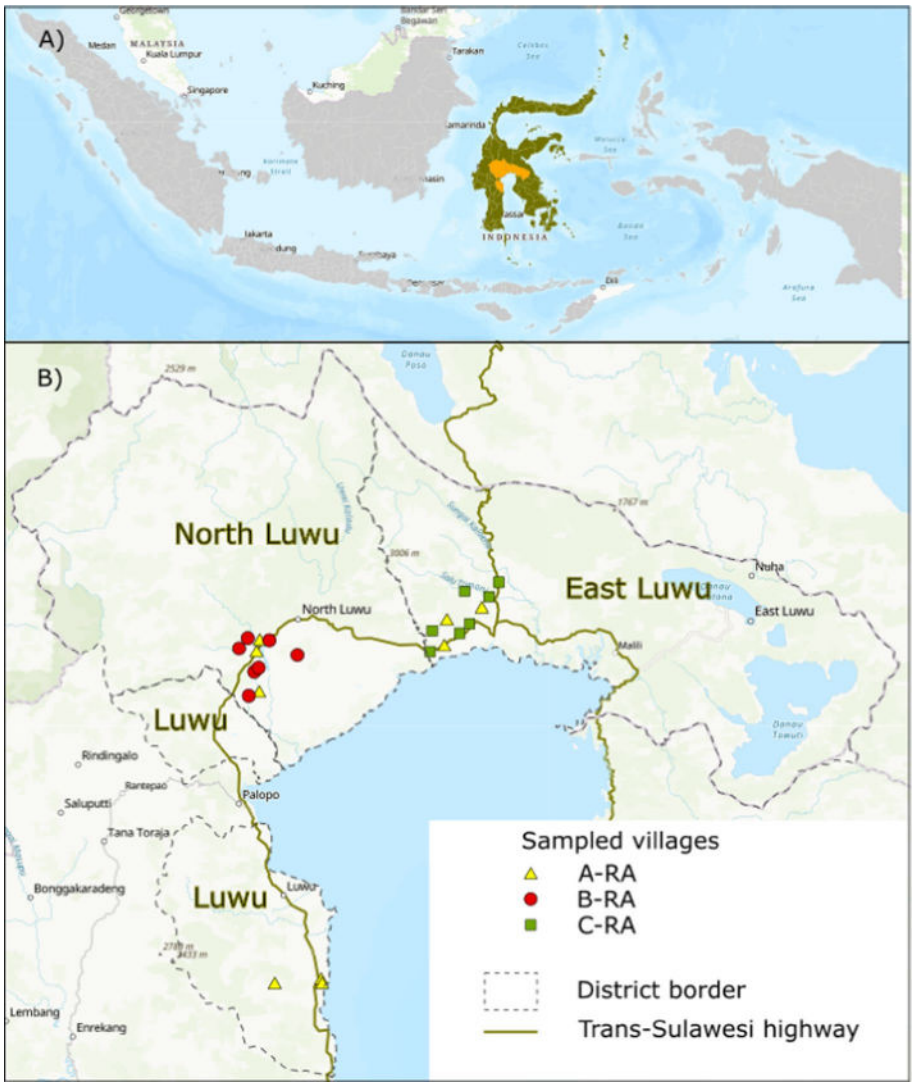

Fig. 2 **A** Indonesian map with Luwu, North Luwu, and East Luwu (orange) in Sulawesi (green). **B** Map of the research area, indicating sampled villages

form this area and operate RA group certificates that cover a large number of smallholder producers. While Mars implements RA certification in all three districts (A-RA hereafter), Cargill (B-RA hereafter), and Olam (C-RA hereafter) operate certificates in East Luwu and North Luwu, respectively. Although certification is organized in groups, producers can join on a rolling basis. Hence, not all producers in one certificate have joined at the same time.

To evaluate the impact of RA certification under different corporate-driven certification schemes and different VSS interventions, we rely on primary household survey data collected between October and December 2022 from 458 smallholder cocoa

Table 2 Summary of operationalization of RA certificates for the three companies

	A-RA	B-RA	C-RA
Geographical coverage	Luwu, North Luwu, East Luwu	East Luwu	North Luwu
Internal audit	External company	External company	Field staff
Premium type	In-kind, 100 USD/MT	Cash, 70 USD/MT	Cash, 70 USD/MT (in theory), in-kind (in practice)
Premium distribution	Field staff—> Procurement agent—> Producer	Bank transfers	Field staff—> Procurement agent—> Head farmer group—> Producer
Trainings per year	1 training; 4 coaching sessions	3 trainings (of which at least 2 mandatory); 1 coaching session	1 training; at least 2 coaching sessions
Training delivery	Field staff; peer-to-peer	External company	Field staff

producers, sampled through a two-stage stratified sampling strategy.[2] In the first stage, all known"certified"villages[3] were stratified by certification scheme and district before randomly selecting 23 villages from these strata: seven for the B-RA scheme in East Luwu, seven for the C-RA scheme in North Luwu, and nine for the A-RA scheme, three in each district. In the second stage, ten certified and ten noncertified cocoa producers were randomly selected in each village. Two certified households (under the B-RA and C-RA schemes) had to be excluded from the analysis as they did not sell any cocoa in the 12 months prior to the survey. We arrive at a sample of 458 producers, of which 228 are certified and 230 are not. Interviews were conducted in Bahasa Indonesia by trained local enumerators after receiving written consent from the participants. The questionnaire covered standard household and farm characteristics and income information and included a detailed section on certification and implementation of VSS interventions. Quantitative survey data were complemented with qualitative data gathered through over 40 semi-structured key-informant interviews, capturing most relevant stakeholders in the (local) cocoa sector, and three focus group discussions with certified producers, one for each of the different certification schemes. Key informants were identified through stakeholder mapping and snowball sampling, and included heads of farmer groups and cooperatives, local collectors, local government officials, staff from both the national and local RA office, higher management from the trading companies, as well as (partner) companies' local staff and field officers, certification bodies, partner NGOs and the Cocoa Sustainability Program (a national public–private forum for sustainable cocoa production).

These interviews revealed differences in the operationalization of RA certification across the three companies implementing the schemes as certificate holders, especially in terms of the modality of premium payments and the organization of training and internal audits (summarized in Table 2). In the A-RA certification scheme, in-kind premiums of 100 USD/metric ton (MT) are distributed for the sale of certified

[2] This research relies on a subsample of a larger data collection campaign covering 600 cocoa-producing households. Excluded producers were located in villages not covered by RA certification.

[3] Villages with RA-certified producers were identified through stakeholder interviews with district-level administration and local cocoa collectors and traders.

Table 3 Overview of outcome indicators

Variable name	Variable definition	Variable calculation
Cocoa area (ha)	Area under cocoa production	Total area of all cocoa plots
Tree density per ha	Number of cocoa trees per ha	Average number of cocoa trees per ha across cocoa plots
Cocoa yield (kg/ha)	Cocoa production per ha in dry bean weight	Total dry bean weight of cocoa produced, divided by total cocoa area
Cocoa price (1,000 IDR/kg)	Farmgate price for dry cocoa beans	Average farmgate price for one kg of cocoa in dry bean weight, including cash premiums received
Cocoa cost per ha (1,000 IDR/ha)	Total cost of cocoa production per hectare of cocoa	Sum of expenditure on variable inputs, rented-in or sharecropped-in land, and hired labor, divided by total cocoa area
Cocoa income (1,000 IDR)	Net income from cocoa production	Total cocoa sales revenue minus total cocoa cost
Cocoa income per ha (1,000 IDR/ha)	Net cocoa income per hectare of harvested cocoa	Total cocoa sales revenue minus total cocoa cost, divided by total harvested cocoa area
Cocoa income per day (1,000 IDR/day)	Net cocoa income per eight-hour day of household labor	Total cocoa sales revenue minus total cocoa costs, divided by total amount of household labor days in cocoa-related activities (calculated as total amount of household labor hours divided by eight)
Total household income (1,000 IDR)	Total household income	Net earnings from farming and non-farming activities and nonlabor income from private or public transfers
Per adult eq. household income (1,000 IDR/adult eq.)	Total household income per adult equivalent	Total household income divided by household size, weighted by the modified OECD adult-equivalence scale (first adult = 1, other adults = 0.5, children = 0.3) (OECD 2013)

All income, productivity, and cost indicators are log-transformed. Average IDR-USD exchange rate for 2022 is 1,000 IDR = 0.0673 USD

beans. Distribution happens by internal field staff over local traders or collectors to producers. A-RA organizes one producer training and four coaching sessions a year for which they rely on field staff and peer-to-peer learning structures. Internal audits are outsourced to a specialized company. In the B-RA scheme, cash premium payments of 70 USD/MT (as officially required by RA) are paid through bank transfers. Three trainings and one coaching session a year are organized through an external company, which is also responsible for performing yearly internal producer audits. In principle, the C-RA scheme pays the required RA premium of 70 USD/MT in cash. In practice, however, in-kind premium payments are often distributed by field staff through collectors to heads of farmer groups or directly to producers. C-RA organizes one training and at least two coaching sessions. These sessions, as well as a yearly internal audit, are implemented by internal field staff. It should be noted that all three companies source from both certified and noncertified producers.

Key indicators on certification outcomes and interventions

In line with the conceptual framework in Fig. 1, we evaluate the impact of VSS on economic performance indicators that relate to cocoa production and marketing (cocoa area, tree density, yield, price, and production cost), to cocoa productivity and income (cocoa income, cocoa income per ha, and cocoa income per household labor day), and to household income (total and per adult equivalent household income). An overview of all variable names, definitions, and calculations are provided in Table 3. All outcome indicators refer to the 12 months prior to the survey. In our analysis, all income, productivity, and cost indicators are log-transformed. We note that some producers sell unprocessed wet beans and report results in wet bean weights. For cocoa yield and price calculations, we convert these to dry bean measures using a conversion factor of 40% (100kg wet beans = 40 kg dry beans), which was obtained during fieldwork. The variable'Cocoa cost per ha'refers to cash expenditures for cocoa production and does not include opportunity costs of land and family labor. Beyond cocoa-specific income, we also study household income effects as these are ultimately important for producer welfare and cocoa-specific income effects are not necessarily transferred to household income effects—for example, due to displacement effects of land and labor away from other productive activities toward cocoa production, or because cocoa only constitutes a small part of total household income (Ruben 2017; Vellema et al. 2015).

We identify 13 binary indicators and two ordinal or frequency indicators to measure farm-level implementation of VSS compliance interventions identified in the conceptual framework (Table 1). Indicators for control interventions pertain to the frequency of audits, past occurrence of unannounced audits, receipt of an audit report, past receipt of a complaint, and past requests and verification of corrective actions after detection of noncompliance. For the first three indicators, we do not distinguish between internal and external (i.e., third-party) audits as producers are often unaware of who performs the audit. Indicators related to market-based incentives interventions are the receipt of a premium in the past 12 months, separately for cash and in-kind payments, and the main buyer being a procurement agent associated with one of the certificate-operating trading companies. Capacity-building intervention indicators include the frequency of training attendance (at least once, annual, more than annual), and binary indicators for having ever since certification received (non-premium-related) input and financial support, and guidance documents. We convert frequency indicators for training and audit implementation to three binary indicators for each variable (at least once, annual, and more than annual) to avoid splitting the sample of certified producers in subsamples by frequency of implementation that are too small for a meaningful comparative analysis. Four indicators identified in the framework, relating to complaints, corrective actions, and financial support, are not included in the analysis due to a lack of variation observed (Table 1).

Empirical approach

Propensity score matching

We evaluate certification effects by estimating the average treatment effect on the treated (ATT), using propensity score matching (PSM) to mitigate pretreatment differences between certified and noncertified producers. We first estimate propensity scores (PS), reflecting the probability of producers being certified based on covariates which

simultaneously affect selection into certification and the studied outcome variables and are not influenced by (the anticipation of) certification (Caliendo and Kopeinig 2008). Previous research has revealed that participation in certification schemes depends on producer preferences and characteristics (Gather and Wollni 2022; Jackson and Balema 2020) and is positively associated with crop-specific production potential (Dietz et al. 2019; Jackson and Balema 2020; Meemken 2021) and accessibility (Bray and Neilson 2017; Gather and Wollni 2022). Additionally, interviews also revealed that companies prefer not to source from producers closely located to the forest to avoid reputational damage of being associated with deforestation. Therefore, we include the following variable in our PS estimation: (measures of producer preferences and characteristics) household and labor force (aged > 15) size, household head age, dummy variables indicating gender and high school education of household head, (measures of cocoa production potential) current total farm area and 2009 cocoa area, years of experience in cocoa production of the household head, (measures of accessibility) elevation, distance of the homestead to the closest provincial town, distance of the main cocoa plot to the Trans-Sulawesi highway, district, and (measure of forest proximity) distance of the homestead to the forest border in 2014. Regarding the distance to the forest border, we follow the 2014 cutoff date set in the RA regulations after which deforestation on certified cocoa plots is not allowed. We consider the total size of all cocoa plots in 2009 to control for pretreatment cocoa production as the first certification program in the region was introduced in 2009. While producer organization is also an important determinant for participation in certification (Sellare et al. 2020b), we do not include membership to a farmer organization as a control variable as since the decision to join such organization might be influenced by producer's intention to become certified. We use a SuperLearner (SL) algorithm (SuperLearner package version 2.0–29 in R), including in the SL library logistic regression and stepwise regression with forward variable selection, both with and without covariate interactions, to estimate the PS (van der Laan et al. 2007).

Certified and noncertified producers are matched using the genetic matching method which combines traditional PSM and mahalanobis distance matching and applies machine learning algorithms to automatically check and optimize covariate balancing in an iterative process (Diamond and Sekhon 2013). We use the MatchIt package in R (version 4.5.5) (Ho et al. 2011) and perform genetic matching based on 2:1 nearest-neighbor matching with replacement. We discard 16 observations, four certified and 12 control households, with a PS outside the common support area (Caliendo and Kopeinig 2008). As a robustness check for the propensity score and matching method, we estimate propensity scores with a simple logistic regression and perform 4:1 nearest-neighbor matching with replacement (Table 7, Appendix).

We assess covariate balance through standardized mean differences (SMD) and variance ratios (Table 4). Covariate balancing is considered satisfactory for an SMD below 0.1 and a variance ratio between 0.5 and 2 (Stuart 2010; Zhang et al. 2019). The first four columns in Table 4 show that for all covariates first-order balance is achieved after genetic matching. Yet, we add a second matching approach to control for how producers sell cocoa, as wet or dry beans. Most producers exclusively sell dry cocoa beans which is, despite higher prices (± 27,000 IDR/kg versus ± 13,000 IDR/kg for wet beans), less profitable due to weight loss during drying. We repeat the genetic matching process and

Table 4 Standardized mean differences (SMDs) and variance ratios (VRs) of matching covariates estimated with the SL algorithm, for certified and noncertified producers in the unmatched sample and in the matched samples, without (Genetic matching) and with (Exact matching) exact matching on the main type of sales

	Unmatched		Genetic matching		Exact matching	
	SMD	VR	SMD	VR	SMD	VR
Location homestead						
Elevation (m.a.s.l.)	−0.131	0.376	0.046	1.182	0.058	1.130
Distance to closest provincial town (km)	0.064	0.995	0.013	1.026	0.010	1.055
Distance to 2014 forest border (km)	0.017	0.968	0.025	1.111	0.028	1.146
District East Luwu (0/1)	−0.001		0.072		0.032	
District Luwu (0/1)	0.003		0.013		0.079	
Distance main cocoa plot—highway (km)	0.101	0.862	0.008	0.894	0.063	0.898
Age household head (years)	0.020	0.884	0.051	1.239	0.072	1.136
Female household head (0/1)	−0.201		0.052		0.094	
High school education household head (0/1)	0.025		0.098		0.014	
Cocoa experience household head (years)	0.218	0.376	0.002	1.004	−0.015	1.076
Household size	−0.041	1.060	0.008	1.282	0.021	1.379
Workforce size household (age > 15)	0.043	0.953	−0.008	1.072	0.058	1.414
Total farm area (ha)	0.349	1.314	0.093	1.152	0.087	1.141
2009 cocoa area (ha)	0.295	1.594	0.034	1.227	−0.003	1.274
Wet bean sales (0/1)	0.150		−0.078		0.000	
N noncertified	230		169		167	
N certified	228		224		224	

additionally introduce an exact match on wet bean sales, ensuring that certified producers selling wet or dry beans are matched with noncertified producers selling the same type of beans. This"exact matching"results in covariate balancing (last two columns, Table 4) and allows us to better disentangle the effects of wet bean sales and certification.

Calculation ATT by G-computation

We estimate the ATT of certification on the outcome indicators using G-computation (with covariate inclusion) on the matched sample (Snowden et al. 2011). We prefer G-computation over the traditional calculation of treatment effects (as the difference between the average outcomes of the treated and control groups) because it increases estimate precision, reduces potential bias from remaining covariate imbalance, and has a doubly-robust nature (Nguyen et al. 2017; Vansteelandt and Keiding 2011). We first fit the following outcome model, f, on the matched sample for each outcome indicator:

$$Y_{ij} = VSS_{ij} + X_{ij} + VSS_{ij} \times X_{ij} + D_j \tag{1}$$

in which Y_{ij} represents the outcome variable of interest (defined in Sect. 3.2) for household i in district j, VSS_{ij} is a binary certification variable, X_{ij} represents the same vector of variables used in the matching procedure, and D_j is a vector of district dummies. We trim outcome variables at one percent extremes to reduce the influence of outliers. Fitted models are used to predict household-level outcomes with and without certification: $\widehat{Y}_{ij}(1) = \widehat{f}(Y|VSS_{ij} = 1, X_{ij}, D_j)$ and $\widehat{Y}_{ij}(0) = \widehat{f}(Y|VSS_{ij} = 0, X_{ij}, D_j)$. The difference between these predicted outcomes represents household-level predicted treatment

effects. The ATT is estimated by averaging these individual predicted treatment effects for the group of certified producers.

We additionally examine how certification effects vary across certification schemes and with VSS interventions. We extend the G-computation estimations of the ATT by introducing additional interaction terms between VSS certification and moderator variables of interest (Z_{ij}) in the outcome model. Z_{ij} is either a categorical variable for the three certification schemes or a dummy variable for specific VSS interventions:

$$Y_{ij} = VSS_{ij} + X_{ij} + VSS_{ij} \times X_{ij} + D_j + VSS_{ij} \times Z_{ij} \quad (2)$$

We estimate predicted individual treatment effects, $\widehat{Y}_{ij}(1) = \widehat{f}(Y|VSS_{ij} = 1, X_{ij}, D_j, Z_{ij})$ and $\widehat{Y}_{ij}(0) = \widehat{f}(Y|VSS_{ij} = 0, X_{ij}, D_j, Z_{ij})$, and calculate ATTs separately for each certification scheme by averaging individual predicted treatment effects within each scheme, or separately for groups of producers who did or did not receive a specific VSS intervention by averaging individual predicted treatment effects within these groups. For all estimations, we rely on the *avg_comparison* function in R (marginal effects package version 0.18.0) and estimate robust standard errors. We estimate the ATT for all outcome variables based on genetic matching, and additionally estimate ATT based on exact matching for those variables that are most influenced by wet versus dry bean sales (price, return to land, return to labor, and income indicators).

Results

Descriptive results

We observe significant differences in production and income indicators between certified and noncertified producers (Table 5). On average, certified producer's farm larger cocoa plantations with more dense cocoa tree planting and receive higher prices than noncertified producers, while cocoa yields and production costs per ha do not differ significantly between certified and noncertified producers. Compared to noncertified producers, tree density is only significantly larger amongst A-RA-certified producers, while cocoa yields and costs are lower for C-RA producers. Certified producers have a significantly higher average cocoa income than noncertified producers, and this difference is mainly driven by higher average cocoa incomes under the A-RA and B-RA certification schemes. The higher cocoa income translates into higher return to land and to household labor only under the A-RA scheme. On average, certified producers have a significantly larger total and per adult equivalent household income, which is driven by improved average household income of A-RA-certified producers.

In terms of the implementation of compliance interventions, considerable heterogeneity exists across certification schemes (Table 6) and reflects observations from the stakeholder interviews (Sect.'Study area and data collection'). In short, the B-RA scheme presents the strongest implementation of control and capacity-building interventions and operationalizes market-based incentives as cash premium payments. The A-RA certification scheme mostly relies on in-kind premium payments and the implementation of control and capacity-building interventions is lower compared to the B-RA scheme. The C-RA scheme has the weakest implementation of interventions in all three compliance mechanisms. Yet, implementation failure exists for all

Table 5 Summary statistics of the selected outcome variables for the full sample of producers, as well as by scheme-specific subsample

	Full sample ***N*** **= 458**	**Noncertified** ***N*** **= 230**	**Certified** ***N*** **= 228**	**A-RA** ***N*** **= 90**	**B-RA** ***N*** **= 69**	**C-RA** ***N*** **= 69**
Cocoa area (ha)	1.44 (1.12)	1.16 (0.90)	1.72*** (1.24)	1.83*** (1.30)	1.45** (0.91)	1.86*** (1.40)
Tree density (trees/ha)	628.44 (244.63)	605.93 (259.67)	651.14** (226.76)	687.17*** (222.02)	608.01 (221.61)	647.27 (233.24)
Cocoa yield (kg/ha)	500.20 (459.25)	506.17 (545.63)	494.18 (352.44)	598.93 (430.63)	521.80 (285.55)	329.94*** (218.49)
Cocoa price (1,000 IDR/kg)	30.24 (3.51)	29.44 (4.17)	31.04*** (2.44)	30.88*** (3.00)	31.28*** (2.14)	31.01*** (1.87)
Cocoa cost per ha (1,000 IDR/ha)	4,323.33 (5,544.22)	4,507.47 (6,361.97)	4,137.58 (4,580.69)	4,971.85 (4,718.86)	4,333.81 (5,483.13)	2,853.18** (2,863.92)
Cocoa income (1,000 IDR)	11,797.64 (13,506.12)	8,798.55 (11,066.65)	14,823.03*** (15,012.83)	18,374.95*** (16,253.83)	14,425.05*** (14,509.67)	10,588.08 (12,689.61)
Cocoa income per ha (1,000 IDR/ha)	10,168.42 (11,107.00)	9,409.23 (11,919.71)	10,934.27 (10,191.01)	13,294.04*** (11,466.19)	11.481.39 (10,366.80)	7,309.20 (6,792.92)
Cocoa income per HH labor day (1,000 IDR)	114.50 (157.26)	106.00 (164.29)	123.12 (149.66)	152.85** (172.71)	76.41 (87.54)	131.46 (157.28)
Total HH income (1,000 IDR)	43,905.63 (45,724.02)	40,304.64 (45,290.92)	47,538.22* (45,970.32)	58,761.77*** (60,076.86)	38,559.70 (30,358.19)	41,877.31 (33,587.05)
Per adult eq. HH income (1,000 IDR)	19,536.16 (18,265.76)	17,705.51 (17,763.25)	21,382.86** (18,615.88)	24,604.65*** (21,651.70)	19,428.38 (16,182.51)	19,135.00 (16,083.62)

HH = household. For cocoa income per HH labor day, the following sample sizes deviate: N(Full sample) = 457, N(certified) = 227, and N(A-RA) = 89. Standard deviations between parentheses. *'s indicate a significant difference in mean between certified producers in the related VSS scheme and noncertified producers. * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

interventions and in all schemes and might be attributed to heterogeneous intermediaries taking up a role in the implementation of interventions and non-adoption of interventions by producers.

More specifically, regarding control interventions, the implementation of an initial, more frequent, and unannounced audits is highest under the B-RA scheme, as well as the receipts of an audit report. While implementation rates of an initial audit and the receipt of an audit report are similar under the A-RA and the C-RA schemes, more frequent audits and unannounced audits are more common under the former certification scheme.

Regarding market-based incentives interventions, RA requires that producers receive a fixed cash premium payment of a value of 70 USD/MT on top of the cocoa market price for the sale of certified beans. Yet, only one-third of all certified producers received a cash premium payment in the 12 months prior to the survey. Notably, cash premium payments are prevalent under the B-RA scheme, while uncommon under the A-RA and C-RA. However, premium payments in kind are prevalent under the A-RA scheme, but more scantly distributed in the C-RA scheme and rare under the B-RA scheme. Most A-RA- and B-RA-certified producers sell mainly to a procurement agent of one of the cocoa companies operating RA certificates, while this

Table 6 Summary statistics of implementation of VSS interventions for the full sample of certified producers, as well as by scheme-specific subsample

	Certified ***N*** **= 228**	**A-RA** ***N*** **= 90**	**B-RA** ***N*** **= 69**		**C-RA** ***N*** **= 69**		
Control (0/1)							
At least one audit	0.77	0.68	0.96	***	0.70		xxx
Annual audit	0.60	0.54	0.94	***	0.32	***	xxx
More than annual audit	0.21	0.22	0.35	*	0.07	***	xxx
At least one unannounced audit	0.34	0.30	0.59	***	0.14	**	xxx
Report received after last audit	0.19	0.18	0.29	*	0.12		xx
Market-based incentives (0/1)							
Cash premium	0.32	0.03	0.96	***	0.07		xxx
In-kind premium	0.36	0.73	0.06	***	0.16	***	x
Company procurement agent as main buyer	0.78	0.87	0.94		0.57	***	xxx
Capacity-building (0/1)							
At least one training	0.80	0.87	0.90		0.62	***	xxx
Annual training	0.59	0.59	0.74	**	0.45	*	xxx
More than annual training	0.41	0.38	0.52	**	0.33		xx
Input support	0.30	0.38	0.01	***	0.49	***	xxx
Guidance document received	0.50	0.39	0.67	***	0.48		xx

*'s indicate a significant difference in mean between certified producers in the related VSS scheme and A-RA-certified producers. x's indicate a significant difference in mean between B-RA and C-RA-certified producers. * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

is less so for C-RA-certified producers. Only procurement agents can buy certified beans and record the certification status of sales to be used in calculating premium values. Hence, the lower rate of direct sales by C-RA-certified producers to company procurement agents compared to the other certification schemes, partly explains the low prevalence of premium payments among certified C-RA-certified producers.

Regarding capacity-building interventions, RA requires that producers receive at least one training a year organized by the certificate holder. Yet, we observe a significant gap in implementation 64% of producers participate yearly in training. The implementation of an initial training is stronger in the A-RA and B-RA schemes, compared to the C-RA scheme. More frequent training and the receipt of guidance documents are more common under the B-RA scheme compared to the other schemes. Significantly more C-RA-certified producers received input support, followed by A-RA-certified producers. Input support was almost absent for the B-RA scheme.

Pairwise correlations in the implementation of VSS intervention (Fig. 6, Appendix) show stronger correlations between interventions in the same compliance mechanism than for interventions across different mechanisms. We observe a moderate negative correlation between cash and in-kind premium payments and moderate positive correlations between cash premium payments and annual audits, and between in-kind premium payments and vertical integration. Correlations between interventions might bias estimations for intervention effects. As a robustness check, we perform additional G-computation estimations of ATT for each pair of interventions with an absolute correlation coefficient above 0.3. We expand the outcome equation (Eq. 2) to include two two-way interaction terms, one for each of the correlated interventions with VSS certification, and a three-way interaction term between both interventions and VSS

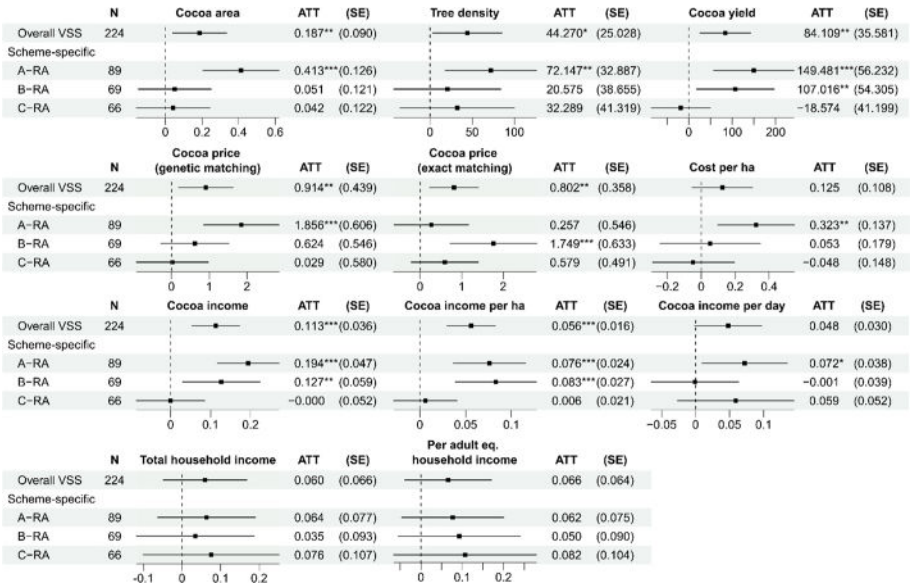

Fig. 3 ATT estimates of overall and scheme-specific certification on outcome indicators related to cocoa production and household income, based on genetic matching and for cocoa price, additionally on exact matching. Robust standard errors between parentheses

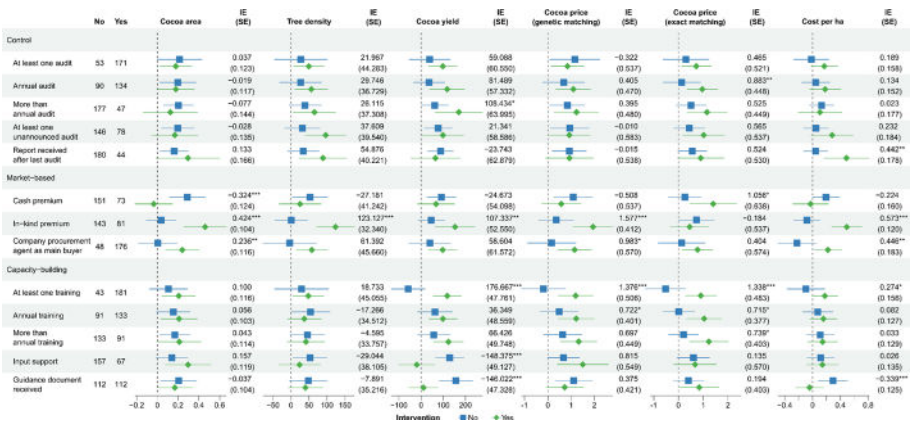

Fig. 4 ATT estimates of certification in groups with (blue square) and without (green diamond) implementation of specific compliance interventions on outcome indicators related to cocoa production, based on genetic matching, and for cocoa price, additionally on exact matching. Intervention effects (IEs) are calculated as the ATT difference between the groups. Robust standard errors between parentheses

certification. ATT are then calculated separately for each group of certified producers who did or did not receive one or both of the specific interventions. Results can be found in Tables 8, 9, 10, 11, 12, 13, 14, 15, and 16 in Appendix.

Estimation results

Figure 3 reports the overall and scheme-specific ATT of certification for all outcome indicators and Figs. 4 and 5 present ATT estimates across groups of producers who have and have not received specific compliance interventions, estimated based on genetic matching. For cocoa price, ATT estimates differ for genetic and exact matching and are both reported. For other outcome indicators, ATT estimates from exact

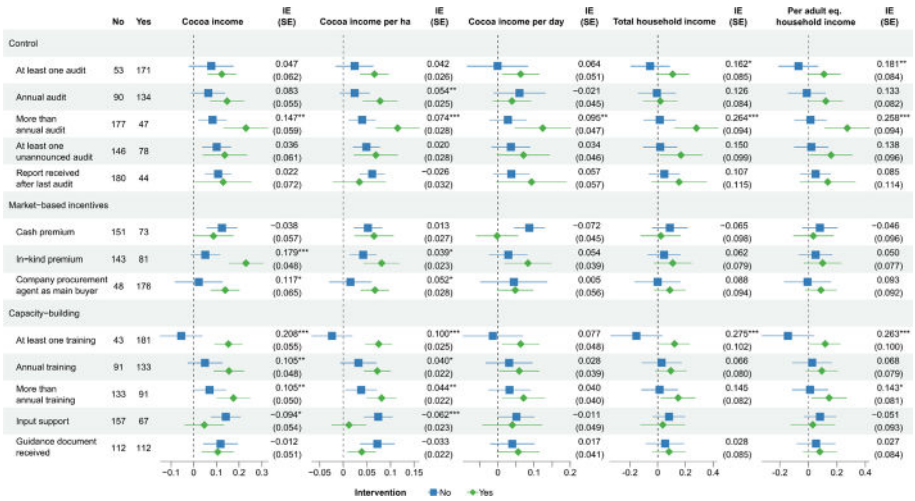

Fig. 5 ATT estimates of certification in groups with (blue square) and without (green diamond) implementation of specific compliance interventions on outcome indicators related to income, based on genetic matching. Intervention effects (IEs) are calculated as the ATT difference between the groups. Robust standard errors between parentheses

matching are similar to those from genetic matching and are reported in Figs. 7 and 8 in Appendix. Results in Fig. 3 indicate a positive effect of RA certification with cocoa area, tree density, yield, and price and no significant effect of certification on production costs per ha. ATT estimates show that RA certification improves cocoa income and return to land by 11.3% and 5.6%, respectively. However, we do not observe a significant effect on return to household labor, implying increased labor requirements under certification, nor on total or per adult equivalent household income.

Yet, heterogeneous effects across the different corporate-driven certification schemes exist. The A-RA certification scheme is associated with increased cocoa area, tree density, and yield, but also with increased production costs. Positive ATT estimates for A-RA certification on cocoa price are significant with genetic matching but not with exact matching, indicating that higher prices under this scheme mainly result from certification-induced increased sales of wet beans rather than from premium prices. We further find positive effects on cocoa income, return to land, and return to labor, also when controlling for type of sales (Fig. 7 in Appendix). This implies that increased return to land under A-RA holds after excluding wet bean price effects and is, hence, mostly driven by yield effects. The B-RA certification scheme is associated with higher cocoa yield, not induced by increased tree density. Here, we find a positive ATT for cocoa price with exact matching but not with genetic matching, suggesting that a positive price effect is generated directly through certification rather than indirectly through increased sales of wet beans. We also observe positive ATT estimates for B-RA certification on cocoa income and return to land but no significant effect on return to household labor, which implies higher household labor input among B-RA-certified producers. Despite positive effects on cocoa income, neither the A-RA nor the B-RA scheme leads to improvements in total or per adult equivalent household income. For the C-RA certification scheme, we do not find significant ATT estimates for any of the outcome indicators.

Results in Figs. 4 and 5 present for outcome variables related to cocoa production and income, respectively, the estimated ATT with (blue square) and without (green diamond) farm-level implementation of specific certification interventions. The presented intervention effect (IE) is calculated as the difference between these ATT. For control interventions, ATT estimates for all cocoa productivity and all income indicators are significantly higher for producers receiving audits more frequently than annually, compared to those who do not. In addition, annual audits result in higher ATT estimates for cocoa prices (with exact matching, controlling for wet bean sales) and for return to land. Receiving an audit report is associated with increased cocoa production costs. We do not find any significant intervention effects for unannounced audits.

For interventions related to market-based incentives, results show strong differences in the effects of cash and in-kind premiums. Cash premiums are associated with smaller ATT on cocoa area and larger ATT on cocoa price (with exact matching), while in-kind premiums are associated with increased ATT on cocoa area, tree density, yield, costs, and prices (with genetic matching) resulting from increased sales of wet beans. Despite increased cost effects, we find positive intervention effects of in-kind premiums on cocoa income and on return to land. Increased cocoa income effects even hold when controlling for wet bean sales (Fig. 8, Appendix). Similarly, selling directly to company procurement agents is associated with larger, positive ATT on cocoa area, costs, price, income, and return to land. However, ATT estimated in the robustness check, interacting the correlated interventions in-kind premium and selling directly to a company procurement agent (Table 15, Appendix), suggest that some significant intervention effects found for selling to a company procurement agent (on cocoa area, cocoa price with genetic matching, cost per ha, and cocoa income) might be driven by its correlation with receiving in-kind premiums. Selling to a company procurement agent without receiving an in-kind premium does not result in significant effects and in smaller ATT estimates than in the main analysis. None of the market-based incentive interventions significantly influences the ATT for total and per adult equivalent household income.

For capacity-building interventions, we find that receiving at least one training significantly increases the ATT on cocoa yield, price, costs, and all income indicators, except return to labor. More frequent training, annually or more, results in a larger ATT on price (with genetic and exact matching for annual training and with exact matching for more than annual training), cocoa income and return to land. Further, receiving guidance documents is associated with negative intervention effects on costs and yield, while input support is associated with negative intervention effects on yield, cocoa income, and return to land.

Discussion

Our results reveal that the intervention implementation of RA certification in the cocoa sector in South Sulawesi varies strongly across corporate-driven cocoa certification schemes, resulting in heterogeneous effects of certification on cocoa production and producer income. The certification scheme (C-RA) with the weakest implementation of farm-level compliance interventions does not create any significant effects on cocoa production or producer income. A second scheme (B-RA), performing strongest in the implementation of control and capacity-building interventions and relying on

cash premiums, improves cocoa income (with 12.7%) through improvements in land productivity (yields and income/ha) and premium prices for dry beans, but at the cost of increased household labor requirements. A third scheme (A-RA), with intermediate implementation of control and capacity-building interventions and relying on in-kind premiums, enhances cocoa income more substantially (with 19.4%) and improves land as well as labor productivity through a combination of cocoa expansion, intensification (tree density, yield, and costs), and more profitable wet bean sales. These findings resonate with heterogeneous effects for RA and UTZ[4] coffee and cocoa certification in the literature where some studies report insignificant welfare effects (Gather and Wollni 2022; Haggar et al. 2017) and others reveal positive farm production and income effects (Dietz and Grabs 2022; Fenger et al. 2017; Iddrisu et al. 2020; Mitiku et al. 2017; Vanderhaegen et al. 2018). The magnitudes of the ATT estimates on cocoa income in this study fall within the range of other estimates, for example, 15% for UTZ-RA cocoa certification in Ghana (Iddrisu et al. 2020) and 24% for triple RA-UTZ-4C coffee certification in Uganda (Vanderhaegen et al. 2018). Yet, they are far below the median crop income effect of 45% across different VSS reported in a recent meta-analysis of 205 quantitative studies (Meemken 2020).

In line with previous evidence for (combined) RA and UTZ certification (Barham and Weber 2012; Dietz and Grabs 2022; Estrella et al. 2022; Vanderhaegen et al. 2018), our findings suggest that positive price effects of certification only result in positive household income effects when combined with positive yield effects, while the latter can directly result in improved cocoa income. Aiming for improved economic outcomes through yield improvements may impede the adoption of certain, competing environmental practices such as restricting the use of agrochemical inputs or expanding cover crop planting (Dietz et al. 2021). Nevertheless, increased cocoa income under certification does not necessarily translate into improved household income. In the B-RA scheme, this might potentially be explained by increased labor requirements under certified production, which might prompt reallocation of household labor away from other productive activities toward cocoa production (Vellema et al. 2015). Further, while the relative importance of cocoa income in total income is higher among certified (31%) than noncertified households (22%)—without necessarily reflecting a causal relationship—reliance on cocoa remains relatively low, further explaining a lack of household income effects under certification. This corroborates the conclusion put forward in recent review studies (Dietz et al. 2022; Oya et al. 2018; Schleifer and Sun 2020) that VSS are more likely to lead to intermediate sustainability outcomes, while evidence for improvements in final outcomes is more contested.

The results highlight the importance and complementarity of frequent audits, premium payments, and training in certification schemes to improve farm production and income. Audits are associated with increased land productivity (yield and income/ha) and higher prices, which lead to increased cocoa income—contributing to improved outcomes under the B-RA scheme. Yet, we observe larger beneficial effects of certification when audits occur more frequently than annually, supporting qualitative evidence on

[4] RA and UTZ merged in 2018 and developed a new RA standard, operational from 2020 onwards, which consolidated requirements of both original (already similar) standards (Dietz & Grabs 2022; Rainforest Alliance, n.d.).

the importance of frequent auditing (Earnhart and Harrington 2021; LeBaron and Lister 2015). Estimated intervention effects of training are larger than those of audit interventions—contributing to improved outcomes under the A-RA and B-RA schemes—and seem additionally driven by increased costs, suggesting that training might be more effective in fostering the uptake of more (costly) GAP. This contradicts conclusions from the literature that stress the importance of monitoring and sanctioning interventions in fostering compliance with more costly practices (DeLeon and Rivera 2009; Rivera et al. 2006). Contrarily to audits, more frequent training does not further improve the impact of certification on production and income, stressing the importance of effective rather than frequent training (Grabs 2020).

Cash premiums improve cocoa prices without significant effects on income—contributing to improved outcomes under the B-RA scheme. In-kind premiums, on the other hand, are associated with larger cocoa income effects which are driven by expansion, intensification, and more profitable wet bean sales. This is in line with studies documenting that in-kind payments foster yield and income improvements in contract-farming—they stimulate productive investments and are especially important in settings with limited access to inputs (Mishra et al. 2016; Ruml and Qaim 2020; Zabel and Engel 2010). However, in-kind transfers are also criticized for being paternalistic instruments that limit beneficiary's autonomy in decision-making (Cunha 2014). Inadequate intervention implementation in the C-RA scheme can be potentially explained by a heavy reliance on field staff for the operationalization of the RA certificate which is reported to be understaffed and explains the lack of improved farm production and producer income effects in this scheme. In summary, all three compliance mechanisms in the conceptual framework—controlling compliance, providing market-based incentives, and capacity-building—contribute to improving the farm-level effects of certification. This partly contradicts findings from Boonaert et al. (2024) who indicate that positive revenue effects of VSS in Peru can mostly be attributed to market-based incentives in the form of price premia and improved market access, followed by capacity-building interventions, including training.

Some limitations of this study should be mentioned. Firstly, the applied matching approach does not address selection bias from unobserved heterogeneity. In addition, trading companies as certificate operators may favor producers who farm a large cocoa area and already adopt improved production practices to participate in certification schemes. By not controlling for production area and tree density at the time of certification, we might overestimate the magnitude of the effects of VSS. Since we are unable to fully address endogeneity issues, we interpret estimation results as associations rather than causal relationships. Secondly, a small sample size and the use of cross-sectional data limit the analysis. A larger sample and panel data would allow for the use of improved econometric approaches to better control for endogeneity (e.g., fixed effects model), the exploration of temporal dynamics of VSS interventions and outcomes (e.g., long-term versus short-term effects), or to estimate the relative effectiveness of interventions in improving farm production and producer income (e.g., multiple mediation model). Thirdly, we lack data to explore qualitative dimensions of VSS compliance interventions, such as the content of training or the stringency of audits, or to analyze the role of interventions on producer uptake of GAP and sustainable practices or on compliance to certification requirements, as undertaken in Boonaert et al. (2024) and Dietz et al. (2021).

Conclusions

Smallholder group certificates are often operated by downstream processing and distribution companies which are responsible for the organization of certification schemes in the field and the implementation of farm-level interventions for VSS compliance. This results in heterogeneity in how VSS are implemented in the field, even for a single VSS. This paper investigates this heterogeneity in VSS implementation across three corporate-driven RA certification schemes in the cocoa sectors in South Sulawesi, Indonesia. Using farm survey data and a propensity score matching approach, we analyze the effect of certification on cocoa production and producer income and examine how these are shaped by specific interventions in the certification schemes. Results reveal that RA certification is associated with improved cocoa yields, higher prices, and higher incomes from cocoa production but not with higher household income. Effects vary across the three certification schemes, with improved production and cocoa income effects only observed under certification schemes with stronger implementation of farm-level compliance interventions. Especially frequent audits, premium payments, and training are important interventions in promoting income gains from certification. Yet, these gains in cocoa income do not necessarily trickly down to improvements in overall household income. The potential of RA certification to improve the welfare of cocoa producers in Indonesia seems limited by both its lack of effect on total household income and its limited coverage.

By calling attention to the extent of implementation failure in VSS interventions which undermines the effectiveness of VSS on the ground, this article carries two main implications. First, VSS governance and implementation failure can be an important source of heterogeneity in VSS impacts and deserve more attention. To inform VSS-setting organizations, the role of VSS interventions in improving economic, environmental, and social sustainability merits further investigation. Second, our results highlight the responsibility of certificate operators, in many cases downstream value chain actors, in organizing effective implementation of compliance interventions to deliver improved sustainability outcomes through VSS, corroborating work from Grabs et al. (2024) and Grabs and Carodenuto (2021). For cash premiums, implementation failure might be particularly problematic as this erodes the incentive base for VSS adoption and compliance by producers. Trading companies, or other certificate operators, could enhance their VSS operationalization systems, for example, by investing in provision of recurrent internal audits which at the same time serve as individual training sessions or by setting up transparency and accountability systems to curb premium capture by intermediaries. Recent advances in blockchain or other technologies might help such transparency efforts but further require inclusive digitalization of smallholders (Abdulai et al. 2023; Radic and Gardeazabal 2024). VSS organizations, in turn, could improve systems for monitoring and enforcement of VSS operationalization by certificate holders to enhance accountability in certified value chains.

Appendix

See Figs. 6, 7, 8 and Tables 7, 8, 9, 10, 11, 12, 13, 14, 15, 16.

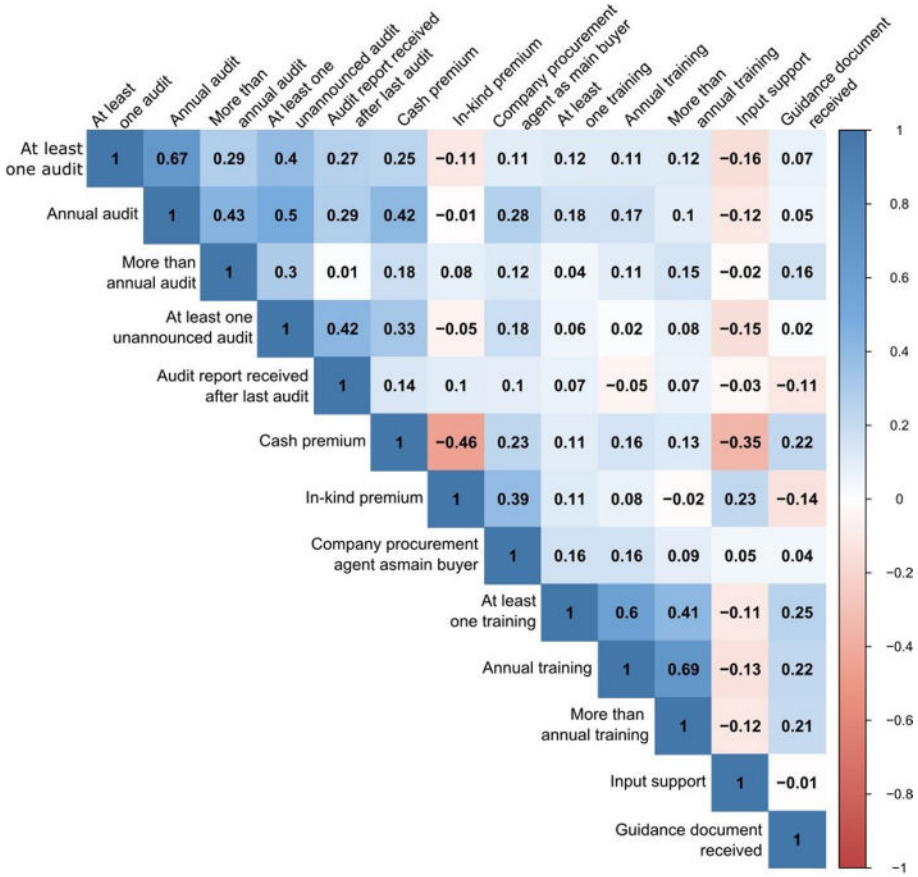

Fig. 6 Pairwise correlation plot for the variables measuring implementation of VSS compliance interventions

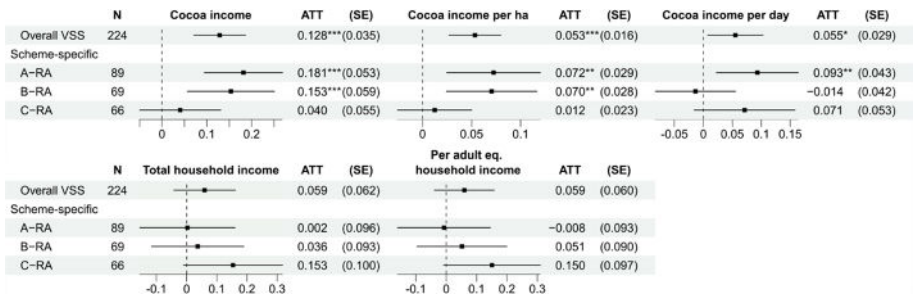

Fig. 7 ATT estimates of overall and scheme-specific certification on outcome indicators related to income, based on exact matching. Robust standard errors between parentheses

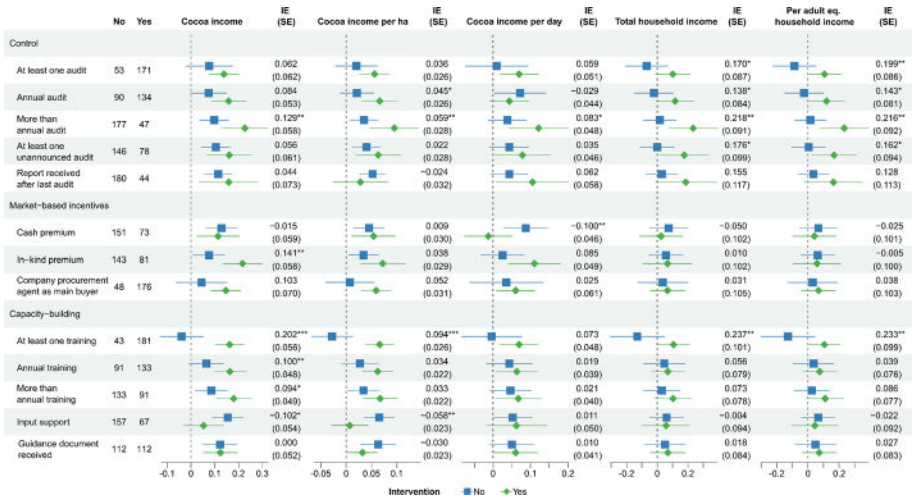

Fig. 8 ATT estimates of certification in groups with (blue square) and without (green diamond) implementation of specific compliance interventions on outcome indicators related to income, based on exact matching. Intervention effects (IEs) are calculated as the ATT difference between the groups. Robust standard errors between parentheses

Table 7 Robustness check: ATT estimates for all outcome indicators (in rows) using the (1) PS estimation with simple logistic regression (and genetic matching), and (2) 4:1 nearest-neighbor matching with replacement (and SL PS estimation)

	(1) Genetic—Logit				**(2) Nearest-neighbor 4:1—SL**			
	Overall *N* = 228	**A-RA *N* = 90**	**B-RA *N* = 69**	**C-RA *N* = 69**	**Overall *N* = 224**	**A-RA *N* = 89**	**B-RA *N* = 69**	**C-RA *N* = 66**
Cocoa area	0.219** (0.095)	0.428*** (0.133)	0.141 (0.111)	0.023 (0.139)	0.238** (0.098)	0.478*** (0.120)	0.124 (0.955)	0.032 (0.149)
Tree density	34.134 (26.031)	72.257** (34.411)	−16.196 (41.133)	34.177 (41.349)	20.987 (24.948)	55.043* (32.067)	−1.813 (39.980)	1.566 (36.780)
Cocoa yield	50.086 (39.470)	106.601* (60.375)	53.237 (60.451)	−27.364 (43.706)	54.661 (36.743)	91.776 (68.798)	74.105 (54.786)	−22.194 (39.672)
Cocoa price (genetic matching)	1.410*** (0.385)	2.271*** (0.533)	1.318** (0.520)	0.388 (0.549)	1.447*** (0.352)	2.305*** (0.521)	1.484*** (0.501)	0.228 (0.450)
Cocoa price (exact matching)	0.790** (0.396)	0.335 (0.558)	1.534*** (0.595)	0.641 (0.614)	0.947*** (0.332)	1.015* (0.569)	1.373** (0.537)	0.365 (0.507)
Cost per ha	0.051 (0.103)	0.265* (0.140)	−0.072 (0.162)	−0.110 (0.141)	0.034 (0.101)	0.238* (0.130)	−0.046 (0.154)	−0.143 (0.160)
Cocoa income	0.114*** (0.037)	0.188*** (0.049)	0.119* (0.061)	0.017 (0.054)	0.150*** (0.037)	0.204*** (0.053)	0.183*** (0.061)	0.036 (0.051)
Cocoa income per ha	0.049*** (0.017)	0.070*** (0.024)	0.064** (0.028)	0.008 (0.021)	0.059*** (0.017)	0.069*** (0.026)	0.081*** (0.027)	0.017 (0.021)
Cocoa income per day	0.036 (0.032)	0.059 (0.041)	−0.031 (0.045)	0.071 (0.055)	0.064** (0.029)	0.087** (0.038)	0.018 (0.042)	0.087* (0.051)
Total household income	0.053 (0.064)	0.077 (0.078)	−0.014 (0.095)	0.077 (0.103)	0.092 (0.056)	0.105 (0.073)	0.033 (0.088)	0.139 (0.094)
Per adult eq. household income	0.035 (0.065)	0.044 (0.082)	−0.012 (0.094)	0.063 (0.099)	0.077 (0.056)	0.082 (0.072)	0.029 (0.087)	0.126 (0.092)

Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 8 Robustness check on correlated intervention estimates of 'At least one audit' and 'At least one unannounced audit': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(At least one audit, At least one unannounced audit)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	***N*=53**	**NA**	***N*=97**	***N*=78**
Cocoa area	0.215 (0.131)		0.185* (0.107)	0.168 (0.135)
Tree density	26.301 (44.522)		34.947 (23.269)	69.5** (34.556)
Cocoa yield	38.164 (56.540)		99.121** (44.978)	98.173* (56.595)
Cocoa price (genetic matching)	1.131* (0.653)		0.833 (0.513)	0.914 (0.537)
Cocoa price (exact matching)	0.469 (0.562)		0.694* (0.386)	1.194** (0.514)
Cost per ha	−0.024 (0.153)		0.090 (0.118)	0.280 (0.184)
Cocoa income	0.076 (0.059)		0.114*** (0.042)	0.137** (0.059)
Cocoa income per ha	0.023 (0.024)		0.064*** (0.020)	0.069** (0.028)
Cocoa income per day	−0.001 (0.051)		0.057 (0.035)	0.070 (0.044)
Total household income	−0.063 (0.086)		0.053 (0.089)	0.158* (0.094)
Per adult eq. household income	−0.072 (0.085)		0.072 (0.087)	0.155* (0.090)

(Y, X) in title row indicates implementation of 'At least one audit' (Y) and 'At least one unannounced audit' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 9 Robustness check on correlated intervention estimates of 'Annual audit' and 'At least one unannounced audit': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(Annual audit, At least one unannounced audit)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	***N*=87**	***N*=5**	***N*=63**	***N*=73**
Cocoa area	0.210**	0.252	0.176	0.163
	(0.096)	(0.352)	(0.113)	(0.140)
Tree density	34.316	−137.321	25.614	86.891**
	(35.992)	(119.812)	(36.732)	(35.344)
Cocoa yield	46.956	−176.744	113.605*	123.844**
	(43.266)	(153.583)	(59.784)	(59.258)
Cocoa price (genetic matching)	0.621	1.219	1.355**	0.921*
	(0.541)	(2.129)	(0.591)	(0.542)
Cocoa price (exact matching)	0.236	1.371	1.089**	1.229**
	(0.447)	(1.944)	(0.443)	(0.504)
Cost per ha	0.028	0.238	0.072	0.291
	(0.126)	(0.276)	(0.140)	(0.199)
Cocoa income	0.076*	−0.153	0.130**	0.164***
	(0.045)	(0.168)	(0.052)	(0.062)
Cocoa income per ha	0.029	−0.079	0.073***	0.084***
	(0.019)	(0.070)	(0.026)	(0.030)
Cocoa income per day	0.067	−0.126	−0.004	0.083*
	(0.043)	(0.138)	(0.037)	(0.046)
Total household income	−0.012	−0.084	0.034	0.186*
	(0.083)	(0.221)	(0.095)	(0.099)
Per adult eq. household income	−0.010	−0.105	0.052	0.185*
	(0.082)	(0.213)	(0.092)	(0.096)

(Y, X) in title row indicates implementation of 'Annua audit' (Y) and 'At least one unannounced audit' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 10 Robustness check on correlated intervention estimates of 'More than annual audit' and 'At least one unannounced audit': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(More than annual audit, At least one unannounced audit)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	N **= 131**	***N*** **= 48**	***N*** **= 19**	***N*** **= 30**
Cocoa area	0.201**	0.208	0.163	0.104
	(0.090)	(0.147)	(0.293)	(0.177)
Tree density	38.387	40.820	−17.330	114.438***
	(30.828)	(41.634)	(61.508)	(39.585)
Cocoa yield	53.214	84.373	251.721**	126.120*
	(39.007)	(65.337)	(115.200)	(71.389)
Cocoa price (genetic matching)	0.780	0.982	2.138**	0.818
	(0.503)	(0.578)	(0.906)	(0.644)
Cocoa price (exact matching)	0.474	1.254**	1.657**	1.118*
	(0.382)	(0.554)	(0.773)	(0.614)
Cost per ha	0.010	0.454**	0.325	0.0183
	(0.111)	(0.198)	(0.248)	(0.234)
Cocoa income	0.079**	0.093	0.267***	0.209***
	(0.039)	(0.070)	(0.091)	(0.074)
Cocoa income per ha	0.038**	0.047	0.132***	0.106***
	(0.017)	(0.033)	(0.045)	(0.034)
Cocoa income per day	0.030	0.025	0.086	0.144**
	(0.034)	(0.051)	(0.074)	(0.058)
Total household income	−0.018	0.077	0.235*	0.298**
	(0.076)	(0.110)	(0.137)	(0.120)
Per adult eq. household income	−0.006	0.067	0.217	0.306**
	(0.074)	(0.106)	(0.138)	(0.119)

(Y, X) in title row indicates implementation of 'More than annual audit' (Y) and 'At least one unannounced audit' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 11 Robustness check on correlated intervention estimates of 'Audit report received after last audit' and 'At least one unannounced audit': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(Report received after last audit, At least one unannounced audit)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	***N*=139**	***N*=45**	***N*=11**	***N*=33**
Cocoa area	0,174*	0.127	0.440	0.236
	(0.089)	(0.133)	(0.400)	(0.195)
Tree density	27.334	54.811	82.552	92.535*
	(30.186)	(38.210)	(60.270)	(49.229)
Cocoa yield	83.309**	102.111*	11.579	89.047
	(38.924)	(59.270)	(103.713)	(79.941)
Cocoa price (genetic matching)	0.862	1.090*	1.946*	0.682
	(0.493)	(0.557)	(1.079)	(0.688)
Cocoa price (exact matching)	0.547	1.324**	1.502	1.025
	(0.373)	(0.552)	(0.996)	(0.625)
Cost per ha	0.038	0.060	0.049	0.663***
	(0.111)	(0.190)	(0.274)	(0.237)
Cocoa income	0.092**	0.155**	0.226*	0.097
	(0.038)	(0.061)	(0.122)	(0.090)
Cocoa income per ha	0.050***	0.091***	0.053	0.032
	(0.017)	(0.028)	(0.051)	(0.042)
Cocoa income per day	0.023	0.079	0.208*	0.055
	(0.032)	(0.048)	(0.122)	(0.063)
Total household income	−0.012	0.195**	0.327*	0.100
	(0.074)	(0.096)	(0.183)	(0.144)
Per adult eq. household income	0.000	0.197**	0.301*	0.092
	(0.073)	(0.094)	(0.177)	(0.140)

(Y, X) in title row indicates implementation of 'Audit report received after last audit' (Y) and 'At least one unannounced audit' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 12 Robustness check on correlated intervention estimates of 'Annual audit' and 'Cash premium': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(Annual audit, Cash premium)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	***N*=84**	***N*=8**	***N*=70**	***N*=66**
Cocoa area	0.249**	−0.115	0.334**	−0.017
	(0.108)	(0.286)	(0.146)	(0.117)
Tree density	33.336	3.813	73.594*	31.638
	(36.663)	(105.779)	(35.462)	(36.421)
Cocoa yield	53.990	−119.597	132.785**	94.610*
	(44.566)	(123.169)	(59.837)	(54.413)
Cocoa price (genetic matching)	0.739	−0.138	1.456***	0.714
	(0.576)	(1.131)	(0.540)	(0.533)
Cocoa price (exact matching)	0.191	1.004	0.695	1.709***
	(0.465)	(1.362)	(0.467)	(0.569)
Cost per ha	0.082	−0.035	0.316*	−0.006
	(0.129)	(0.264)	(0.162)	(0.172)
Cocoa income	0.071	0.023	0.186***	0.101*
	(0.046)	(0.155)	(0.055)	(0.057)
Cocoa income per ha	0.027	−0.017	0.079***	0.078***
	(0.020)	(0.063)	(0.026)	(0.027)
Cocoa income per day	0.075*	−0.048	0.067	0.001
	(0.045)	(0.101)	(0.043)	(0.038)
Total household income	−0.012	0.113	0.182*	0.019
	(0.086)	(0.211)	(0.094)	(0.094)
Per adult eq. household income	−0.006	0.055	0.173*	0.046
	(0.085)	(0.204)	(0.090)	(0.091)

(Y, X) in title row indicates implementation of 'Annua audit' (Y) and 'Cash premium' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 13 Robustness check on correlated intervention estimates of 'At least one unannounced audit' and 'Cash premium': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(At least one unannounced audit, Cash premium)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	***N*=118**	***N*=32**	***N*=36**	***N*=42**
Cocoa area	0.289***	−0.090	0.294	0.010
	(0.105)	(0.153)	(0.200)	(0.137)
Tree density	39.986	11.113	87.026*	44.226
	(33.459)	(51.463)	(45.922)	(41.620)
Cocoa yield	92.817**	29.961	87.530	100.359
	(44.548)	(56.172)	(66.470)	(71.769)
Cocoa price (genetic matching)	0.931*	0.942	1.471**	0.448
	(0.555)	(0.697)	(0.649)	(0.618)
Cocoa price (exact matching)	0.204	1.914***	1.102*	1.443**
	(0.428)	(0.696)	(0.592)	(0.680)
Cost per ha	0.131	−0.192	0.380*	0.135
	(0.120)	(0.174)	(0.230)	(0.217)
Cocoa income	0.101**	0.107*	0.197***	0.080
	(0.044)	(0.058)	(0.067)	(0.081)
Cocoa income per ha	0.047**	0.057**	0.065**	0.075*
	(0.020)	(0.027)	(0.030)	(0.039)
Cocoa income per day	0.058	−0.028	0.107*	0.024
	(0.040)	(0.039)	(0.058)	(0.054)
Total household income	0.018	0.003	0.259**	0.047
	(0.086)	(0.106)	(0.111)	(0.123)
Per adult eq. household income	0.027	0.014	0.230**	0.069
	(0.084)	(0.103)	(0.107)	(0.122)

(Y, X) in title row indicates implementation of 'At least one unannounced audit' (Y) and 'Cash premium' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 14 Robustness check on correlated intervention estimates of 'In-kind premium' and 'Cash premium': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(In-kind premium, Cash premium)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	***N*=76**	***N*=71**	***N*=78**	***N*=3**
Cocoa area	0.080 (0.116)	−0.012 (0.113)	0.479*** (0.128)	−0.042 (0.223)
Tree density	−22.706 (37.819)	27.380 (36.188)	118.890*** (32.485)	237.539*** (75.006)
Cocoa yield	8.257 (44.877)	86.523* (51.037)	164.572*** (53.915)	−181.490 (112.320)
Cocoa price (genetic matching)	0.105 (0.583)	0.671 (0.515)	1.976*** (0.530)	0.496 (1.126)
Cocoa price (exact matching)	0.211 (0.491)	1.659*** (0.582)	0.638 (0.490)	0.826 (0.992)
Cost per ha	−0.187 (0.141)	0.033 (0.157)	0.529*** (0.131)	−0.530 (0.387)
Cocoa income	0.002 (0.050)	0.106** (0.053)	0.240*** (0.046)	−0.046 (0.136)
Cocoa income per ha	0.015 (0.020)	0.072*** (0.026)	0.083*** (0.023)	0.003 (0.057)
Cocoa income per day	0.056 (0.049)	−0.004 (0.036)	0.084** (0.040)	0.053 (0.173)
Total household income	0.036 (0.096)	0.039 (0.088)	0.120 (0.083)	−0.448** (0.217)
Per adult eq. household income	0.038 (0.095)	0.057 (0.086)	0.117 (0.080)	0.406 (0.256)

(Y, X) in title row indicates implementation of 'In-kind premium' (Y) and 'Cash premium' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 15 Robustness check on correlated intervention estimates of 'In-kind premium' and 'Company procurement agent as main buyer': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(In-kind premium, Company procurement agent as main buyer)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	N **= 50**	***N*** **= 97**	**NA**	***N*** **= 81**
Cocoa area	0.009 (0.112)	0.052 (0.102)		0.460*** (0.124)
Tree density	−1.553 (44.999)	1.550 (34.906)		123.697*** (31.821)
Cocoa yield	40.039 (56.954)	49.219 (41.248)		153.238*** (53.996)
Cocoa price (genetic matching)	0.166 (0.648)	0.472 (0.487)		1.935*** (0.514)
Cocoa price (exact matching)	0.311 (0.580)	1.219** (0.506)		0.639 (0.472)
Cost per ha	−0.218 (0.167)	−0.011 (0.141)		0.493*** (0.131)
Cocoa income	0.024 (0.063)	0.065 (0.045)		0.230*** (0.046)
Cocoa income per ha	0.016 (0.027)	0.055*** (0.020)		0.081*** (0.023)
Cocoa income per day	0.043 (0.056)	0.020 (0.034)		0.083** (0.039)
Total household income	−0.007 (0.100)	0.063 (0.081)		0.101 (0.082)
Per adult eq. household income	−0.006 (0.099)	0.077 (0.079)		0.099 (0.080)

(Y, X) in title row indicates implementation of 'In-kind premium' (Y) and 'Company procurement agent as main buyer' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

Table 16 Robustness check on correlated intervention estimates of 'Input support and 'Cash premium': ATT estimates of certification in groups of producers, classified by implementation of the correlated interventions

	(Input support, Cash premium)			
	(0,0)	**(0,1)**	**(1,0)**	**(1,1)**
	***N*=90**	***N*=69**	***N*=64**	***N*=5**
Cocoa area	0.258**	−0.037	0.337**	−0.015
	(0.111)	(0.122)	(0.140)	(0.229)
Tree density	67.721*	29.034	30.177	−13.297
	(36.526)	(37.394)	(36.426)	(104.780)
Cocoa yield	158.577***	84.165	−8.316	−94.385
	(49.019)	(49.552)	(47.320)	(238.751)
Cocoa price (genetic matching)	0.836*	0.487	1.484**	1.234
	(0.482)	(0.525)	(0.680)	(1.323)
Cocoa price (exact matching)	0.234	1.611***	0.753	1.094
	(0.421)	(0.613)	(0.541)	(1.165)
Cost per ha	0.202	−0.021	0.180	−0.107
	(0.142)	(0.166)	(0.139)	(0.387)
Cocoa income	0.164***	0.109*	0.064	−0.133
	(0.047)	(0.056)	(0.054)	(0.108)
Cocoa income per ha	0.076***	0.073***	0.014	−0.008
	(0.021)	(0.026)	(0.022)	(0.100)
Cocoa income per day	0.080**	0.007	0.055	−0.091
	(0.041)	(0.037)	(0.052)	(0.083)
Total household income	0.094	0.034	0.057	−0.205
	(0.086)	(0.093)	(0.100)	(0.245)
Per adult eq. household income	0.094	0.051	0.055	−0.165
	(0.084)	(0.091)	(0.098)	(0.250)

Company procurement agent as main buyer

(Y, X) in title row indicates implementation of 'Input support' (Y) and 'Cash premium' (X). Robust standard error between parentheses. Significant coefficients indicated with * $p \leq 0.10$; ** $p \leq 0.05$, and *** $p \leq 0.01$

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Author contributions
Janne Bemelmans performed conceptualization, design, methodology, data acquisition and analysis, interpretation of data and results, writing—original draft, and visualization. Miet Maertens presented conceptualization, design, data acquisition, interpretation of data and results, writing—review & editing, supervision, project administration, and funding acquisition.

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Data availability
The data generated and analyzed during this study are available from the corresponding author on reasonable request. All analysis presented in the paper are performed in R version 4.2.3.

Declarations

Ethics approval and consent to participate
Ethical approval for the data collection and analysis for this study was obtained from the KU Leuven Social and Societal Ethics Committee [Approval Number: G-2022-5681-R2(MIN) (v.1.3)]. The research was additionally approved by the National Research and Innovation Agency (BRIN) of the Indonesian government (Research Permit No 195A/SIP/IV/FR/10/2022).

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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