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Can cooperative membership foster compliance with New European Union regulations on deforestation-free production? Evidence from cocoa farmers in Western Côte d'Ivoire

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ABSTRACT

Cocoa cultivation (*Theobroma cacao*) in Côte d'Ivoire faces significant challenges, including deforestation, poverty, and child labour. Like other countries involved in the production and export of palm oil, cattle, soy, coffee, cocoa, timber, and rubber, Côte d'Ivoire now faces the challenge of meeting new European Union regulations on deforestation-free production (EUDR) by June 2025, posing multiple questions and challenges on implementation. While agricultural cooperatives play a vital role in disseminating information, building skills, and enhancing farming practices, their impact on EUDR awareness is underexplored. This study examines the effect of cooperative membership on awareness of the new EUDR among cocoa farmers. We applied a mixed-methods approach combining Propensity Score Matching (PSM) and Inverse Probability Weighting with Regression Adjustment Estimator based on a 2024 household survey ($N = 218$ households) and 12 focus group discussions ($N = 144$) involving cooperative and non-cooperative cocoa farmers in the central-west and western regions of Côte d'Ivoire. Descriptive statistics reveal significant differences between the two groups of farmers in terms of demographic and socioeconomic characteristics. Cooperative members are predominantly male, older, and more educated compared to non-cooperative members, with larger households and bigger farms. They also have better access to credit, extension services, and training resources, leading to higher cocoa yields. PSM analysis reveals that cooperative members exhibited higher awareness of EUDR requirements, with results consistent across different matching methods and robust to potential hidden biases, suggesting a possible association between membership and access to EUDR-related information. While the findings indicate a strong association between cooperative membership and EUDR awareness, further research is needed to examine whether this awareness translates into actual changes in compliance behavior. These findings underscore the important role cooperatives can play in enhancing awareness of sustainability regulations like the EUDR and inform policy initiatives aimed at strengthening cooperative participation.

1. Introduction

Development initiatives, policy reforms, and supply chain interventions aim to improve smallholder farmers' living standards in developing countries by enhancing market access, addressing technical knowledge gaps, and improving infrastructure (Molenaar and Short,

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2018). Agriculture is central to rural households in Sub-Saharan Africa (SSA), particularly in Côte d'Ivoire. The cocoa (*Theobroma cacao*) sector alone directly employs over 2 million households, with indirect support for an additional 5 million people in West Africa (Steffany et al., 2022). Including household dependents, the cocoa economy supports over 20 million West Africans (Paschall and Seville, 2012). Côte d'Ivoire is the most important player in the global cocoa industry, accounting for roughly 43 % of the world's cocoa production. The cocoa sector is vital to the Ivorian economy, making up about 40 % of agricultural exports, contributing around 40 % to export income, and accounting for about 15 % of the gross domestic product (GDP) (Kouassi et al., 2023). In Côte d'Ivoire, unlike in many other countries, cocoa export involves a comprehensive chain of activities from production to supply (Renier et al., 2023). Cocoa trade represents over a third of Côte d'Ivoire's total export revenue, with an annual freight-on-board value exceeding $5.44 billion (OEC, 2021). Furthermore, Cocoa is the primary livelihood source for over 843,798 smallholder rural households (Kouassi et al., 2023), employing over 18 % of the country's population (Ariza-Salamanca et al., 2023).

Despite its crucial role, the cocoa sector faces significant challenges. Many farmers live in poverty, with poor working conditions that fail to meet fair standards (Coral et al., 2024). The industry also contributes to deforestation and unsustainable practices, posing environmental risks. Cocoa farming is a significant driver of deforestation in tropical regions, often requiring clearing forest land for new plantations (Goldman et al., 2020). Research on transparency, traceability, and deforestation within the Ivorian cocoa supply chain indicates that from 2000 to 2019, cocoa-related activities led to deforestation and degradation of over 2.4 million hectares, averaging 125,000 hectares annually and accounting for 45 % of the country's total deforestation and forest degradation (Renier et al., 2023). Additionally, the reduction in national forest cover, from 12 million hectares in 1960 to only 3 million hectares in 2017 (Facility, 2017), is concerning given the overlap of cocoa-producing regions with the Guinean Forest ecoregion, a recognised biodiversity hotspot (Mittermeier et al., 1998). One study examining the impact of cocoa production on primate populations within protected areas shows a significant correlation between cocoa farming and the extinction of primate species in national parks and forest reserves (Bitty et al., 2015). Additionally, only 43.6 % of cocoa exports can be traced to specific cooperatives or regions, with over 55 % remaining untraceable due to indirect sourcing (Renier et al., 2023).

In response to these challenges, multiple efforts seek to improve sustainability in cocoa production (Kouassi et al., 2023). Although implementing strategies like Voluntary Sustainability Standards (VSS), core issues remain unaddressed. This prompted the European Union (EU) to take more stringent action through its new European Union Deforestation Regulation (EUDR/Regulation 2023/1115), which enforces stricter due diligence requirements on cocoa imports. Under EUDR, EU importers must prove that their cocoa does not come from deforested areas. Each cocoa shipment must provide a list of contributing producers and GPS coordinates of their plots. In case of a compliance check, satellite images will be used to verify that no deforestation occurred after 2020, thus putting pressure on Côte d'Ivoire to enhance its sustainability practices (EC, 2021).

However, despite its imminent deadline, many of its provisions are still being clarified or delayed due to technical, logistical, and institutional challenges along the cocoa supply chain (Dijk, 2024). Since approximately 75 % of Ivorian cocoa beans are exported to the EU (OEC, 2021), compliance is crucial for companies seeking to maintain market access. Non-compliance with the EUDR could have severe repercussions, including the EU rejecting cocoa shipments, thus devastating the Ivorian cocoa sector in its current form. Additionally, non-compliance might classify Côte d'Ivoire as a high-risk country, leading to further checks, delays, and bottlenecks in the cocoa supply chain, exacerbating trade and export difficulties (Aboa, 2023). Thus far, progress has been slow toward meeting EUDR requirements despite efforts like the Cocoa and Forest Initiative (CFI) and Côte d'Ivoire's national sustainable cocoa strategy (SNCD) (Aboa, 2023). One major obstacle is the complexity and high cost of compliance, estimated at $692 million, which poses significant financial and logistical challenges for the cocoa sector and individual farmers (Dijk, 2024). As the EUDR is not yet fully operational and many aspects are still evolving, understanding how farmers prepare for it—particularly their level of awareness—is a critical first step. Given this early stage, the study focuses specifically on farmers' awareness and intention to comply, rather than on actual adoption or compliance behaviour.

While cooperatives play a critical role in information dissemination and farmer organization, compliance strategies may also involve government-led sustainability programs and private-sector certification schemes such as Fairtrade and Rainforest Alliance. Understanding and complying with the new EU regulations is a significant challenge for cocoa sector stakeholders, especially smallholder cocoa farmers in Côte d'Ivoire. There are concerns that these farmers cannot meet EUDR requirements independently due to limited access to information, training, and traceability tools. Importantly, this study does not assess actual compliance behaviour. Instead, it focuses on farmers' awareness of the regulation and its key components, such as traceability, transparency, and deforestation-free sourcing. These elements represent the foundational knowledge necessary for eventual compliance. Research indicates that cooperatives can play a critical role in improving agricultural outcomes by facilitating knowledge transfer, input access, and institutional support For instance, Verhofstadt and Maertens (2015) find that cooperative membership positively affects smallholder performance in Rwanda, while Zhang et al. (2020) show that cooperatives in China contribute to promoting environmental sustainability. Similarly, Kehinde and Ogundeji (2022) demonstrate that cooperative membership increases cocoa productivity and access to extension services in Nigeria. These studies highlight the potential of cooperatives in enhancing productivity, environmental outcomes, and market access.

However, few studies examine how cooperative structures specifically influence farmers' awareness of international regulatory frameworks such as the EUDR, or their ability to prepare for and comply with such regulations. While recent work has investigated the impact of EU regulations on income and fertilizer use in the cocoa sector (CAC/RCP 72-2013) (Akande et al., 2023), the role of cooperatives in enabling farmers to navigate compliance pathways — especially in the context of due diligence and traceability — remains underexplored. This study addresses that gap by examining how cooperative membership influences the awareness of cocoa farmers of the EUDR/Regulation 2023/1115. It compares the preparedness and challenges faced by cooperative and non-cooperative farmers and explores the mechanisms through which cooperatives support information dissemination. In doing so, it provides new insights into how farmer organizations can help smallholders engage with evolving sustainability requirements. The findings contribute to the literature on sustainable agriculture and offer actionable guidance for policymakers, value chain actors, and researchers working to support smallholder compliance in global commodity markets.

2. The role of cooperatives in agricultural technology adoption

Farmer cooperatives play a crucial role in implementing marketing strategies, negotiating prices, gaining access to the market, and promoting sustainable agricultural practices. These efforts help enhance agricultural farmers' living conditions (Calkins and Ngo, 2010; Olagunju et al., 2021). Cooperatives provide access to resources and information needed for the adoption of technology, thus serving as a platform for promoting sustainable practices in the agricultural sector. They encourage cooperation and solidarity among producers by facilitating the exchange of knowledge and experiences. Overall, cooperatives are a driving force behind positive outcomes in technology adoption and household welfare in agricultural communities. Furthermore, farmers

who are members of cooperatives tend to achieve significantly higher productivity than those who are not (Kehinde and Ogundeji, 2022; Verhofstadt and Maertens, 2014). Many studies explore how agricultural cooperatives enhance the adoption of improved agricultural technologies, land management practices, and economic performance and welfare of smallholder farmers (Wossen et al., 2017). Evidence includes the impact of cooperatives on agricultural technology adoption in Ethiopia (Abebaw and Haile, 2013) and China (Zhang et al., 2020), the impacts of extension access and cooperative membership on technology adoption and household welfare in Nigeria (Wossen et al., 2017), the impact of agricultural cooperative membership on the wellbeing of smallholder farmers in Ethiopia (Ahmed and Mesfin, 2017), and the simultaneous impact of access to credit and cooperative services on cocoa productivity in southwestern Nigeria (Kehinde and Ogundeji, 2022). Additionally, cooperatives often negotiate better prices for inputs and outputs on behalf of their members, further contributing to improved economic outcomes. For example, research shows that the technical efficiency levels for maize (*Zea mays*) of non-cooperative members are consistently lower than those of cooperative members (Olagunju et al., 2021). Jaza Folefack et al. (2021), conducting a comparative cost-benefit analysis between fairtrade certified and non-certified cocoa production in southwest Cameroon, show that the profitability of cocoa agroforests is highest when the farmer was a member of a cooperative.

By pooling resources and leveraging collective bargaining power, cooperatives negotiate better prices for inputs and secure higher prices for their products. By fostering a culture of cooperation and mutual assistance, cooperatives help farmers navigate challenges and capitalize on opportunities in the agricultural industry. Other studies establish a link between the adoption of cocoa certification and cooperative membership: the adoption rate of cocoa certification by cocoa farmers is higher if the producer is a cooperative member, especially since certification agencies encourage the producers to become a cooperative member to benefit from the complete certification package (Jaza Folefack et al., 2021; René et al., 2023; Teague, 2022). This enables farmers to operate more efficiently and competitively in the market, ultimately leading to a more resilient and prosperous agricultural sector. Additionally, cooperatives can serve as a platform for knowledge sharing and innovation, allowing farmers to learn from each other and adopt best practices that can further enhance their productivity and sustainability. Overall, cooperatives are crucial in empowering smallholder farmers and improving their livelihoods. By fostering collaboration and providing access to essential resources, cooperatives help farmers overcome challenges, thus achieving greater success.

3. Materials and methods

3.1. Presentation of study area

Data was collected in Biankouma and Issia Prefectures in western Côte d'Ivoire (Fig. 1). Although the region was initially considered as unsuitable for cocoa cultivation, it now plays a key role in cocoa production (Barima et al., 2020). The region experienced substantial migration flows from the southwest during the 2000s, driven by the socio-political crisis at that time, which led to a 720 % expansion in agricultural areas between 2002 and 2019 (Barima et al., 2020; Ruf et al., 2020). With the agricultural landscape being reshaped, understanding the implications of these changes on cocoa production and

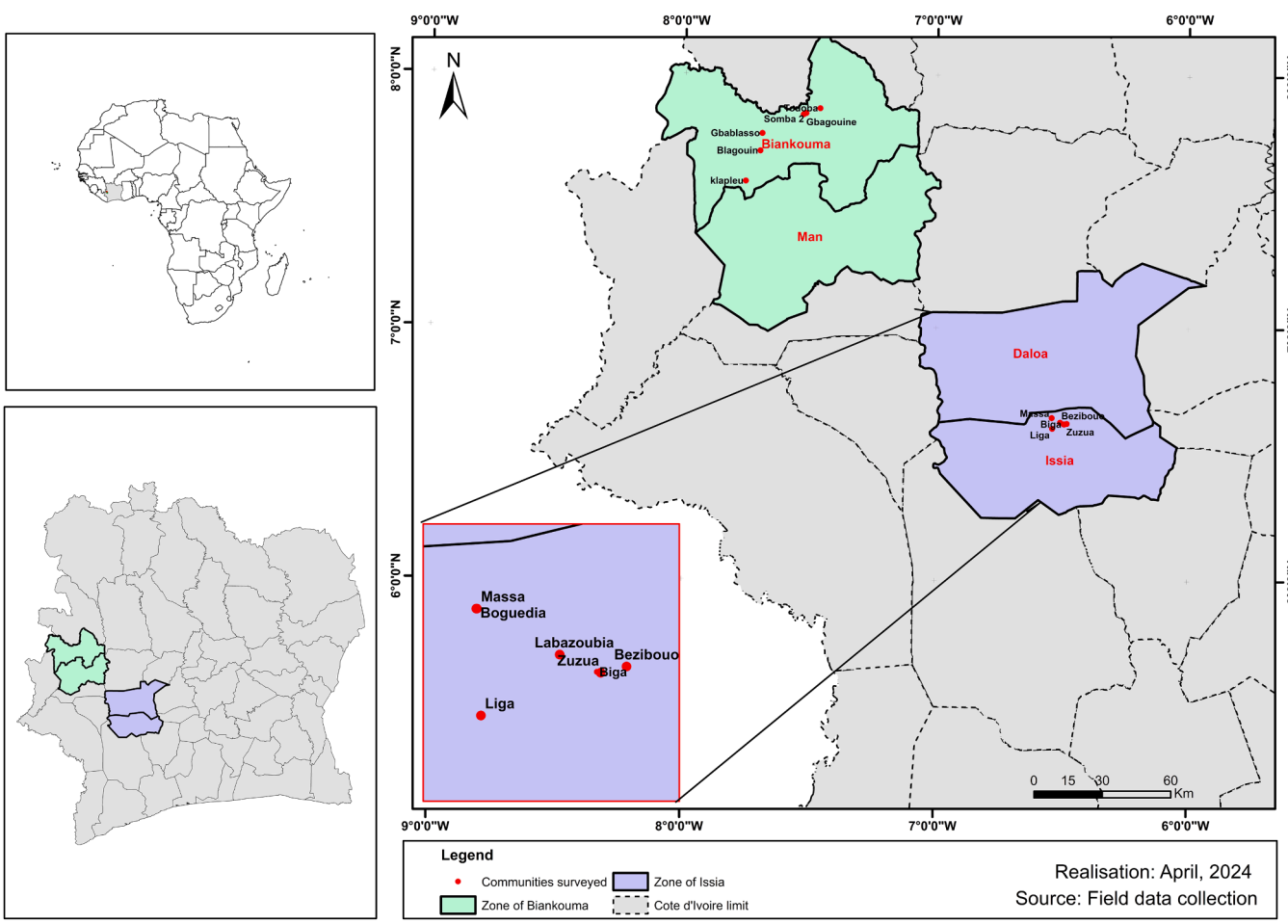

Fig. 1. Location of the study areas.

regulatory compliance is critical.

The district of Issia is located in the Haut Sassandra region, specifically in the center-west of Côte d'Ivoire, 368 km from Abidjan. The climate is suitable for growing cocoa, coffee, rubber, rice, and vegetables. The population has grown rapidly: from 195,663 in 1988 to 372,638 in 2011 and 410,628 in 2021 (RGPH, 2021). This rapid growth is explained by migration due to the agricultural potentiality of the region, which requires a large workforce. Like the country as a whole, this population is young. In fact, more than half of the total population is under the age of twenty-five (RGPH, 2021).

The district of Biankouma is located in the Tonkpi region: 46 km from Man, the regional capital, and approximately 700 km northwest of Abidjan. The department of Biankouma comprises seven sub-prefectures or communes: Biankouma, Blapleu, Gbangbeguiene, Gbonne, Gouine, Kpata, and Santa-Biankouma, with a total of 48,027 households (RGPH, 2021). The primary economic activity of the Biankouma people is agriculture, with the main crops being rice, yams, coffee, and, more recently, cocoa. Thus, both regions are well-suited for examining the complexities and opportunities related to compliance with the EUDR requirements within the cocoa sector (Barima et al., 2020).

3.2. Theoretical framework for cooperative membership

The present study is built on a random utility framework. A random utility framework is essential for analyzing a household's decision to be a cooperative member (Fischer and Qaim, 2012; Wollni and Zeller, 2007). The central assumption underlying the utility framework is that each cocoa farmer's actual utility level of cooperative membership is unknown. However, the farmer chooses to be a member of a cooperative if the utility gained from membership (U_i^m) is larger than the utility from non-cooperative membership (U_i^n) (Abebaw and Haile, 2013; Mojo et al., 2017).The utility gain (U_i^m- U_i^n) of cooperative membership is expressed as a function of observed characteristics or covariates (Z) in the latent variable model:

$$C_i^* = \beta Z_i + \varepsilon_i \quad (1)$$

where C_i^* is an indicator of the latent cooperative membership, and ε_i is the disturbance term. In turn, the observed dependent variable, which depicts cooperative membership status (C_i), where C_i=1 for members of a cooperative and C_i=0 for non-members of a cooperative, is related to C_i^* as follows:

$$C_i = \begin{cases} 1 \ if \ C_i^* > 0 \\ 0 \ otherwise. \end{cases}$$

Previous empirical research on cooperative membership investigates the determinants of farmers' decision to join cooperatives (Abebaw and Haile, 2013; Kehinde and Ogundeji, 2022; Mojo et al., 2017; Olagunju et al., 2021). The selection of explanatory variables incorporated into Z is based on the identification of variables potentially related to joining cooperatives. These variables presented in Table 1 include personal and household characteristics, asset ownership, access to road and geographic location, access to information, and access to training.

Regarding the personal characteristics of the household head, previous studies find that participation in a cooperative is positively associated with the household head's age and educational status (Olagunju et al., 2021). These studies also report that male-headed households are more likely to participate in cooperatives than female-headed households. We expect similar influences of these variables on the likelihood of cooperative participation in this study. Additionally, we include a proxy variable for the cocoa production experience of the household head in the village. Controlling for other characteristics, we expect that this variable improves the probability of cooperative participation by easing access to relevant information about cooperatives. We also control for the household head's marital status.

Table 1
Definition and description of variables.

Variables	Description	Nature of the variable
Treatment variable		
Cooperative membership	1 = if the farmer is a member of cooperation, 0= otherwise	Dummy
Outcome variable		
Awareness EU regulation	1 = aware,0 = otherwise: Indicates whether the farmer is aware of the EUDR, including key elements such as traceability, transparency, and deforestation-free sourcing.	Dummy
Explanatory variables		
Age	Age of the farmer	Continuous
Gender	1= if the farmer is male, 0= otherwise	Dummy
Educational status	1= if the farmer is educated, 0= otherwise	Dummy
Marital status	1= if the farmer is married, 0= otherwise	Dummy
Residence status	1= if the farmer is native, 0= otherwise	Dummy
Extension services	1= if the farmer has access to extension services, 0= otherwise	Dummy
Access to credit	1= if the farmer has access to credit, 0= otherwise	Dummy
Participation in training	1= if the farmer receives the training on cocoa production, 0= otherwise	Dummy
External labor	1= if the farmer hires external labor, 0= otherwise	Dummy
Household size	The total number of people in a household	Continuous
Household farm size	The total landholding by the household (hectare)	Continuous
Cocoa production	The quantity of cocoa produced in the previous year in ton /hectare	Continuous
Experience in cocoa production	Number of years in cocoa production	Continuous

Household size can also influence cooperative membership. Empirical findings are mixed. For instance, Kehinde (2021); Kehinde and Ogundeji (2022) discover that larger households are more likely to be cooperative members. In contrast, Olagunju et al. (2021) find no statistically significant association between these variables. Thus, we include household size, measured in adult equivalent units, as an explanatory variable without assigning any specific sign expectation. In terms of physical assets, studies indicate that the size of landholding, ownership of oxen, and possession of other physical assets, such as farm equipment and consumption assets, are directly related to the likelihood of cooperative membership (Olagunju et al., 2021). We expect these variables also positively impact cooperative membership.

We anticipate that access to information and distance to markets can influence cooperative participation, as shown in Fischer and Qaim (2012). In line with this, this study predicts a similar connection between the likelihood of cooperative membership and the distance to the nearest all-weather road. We expect cooperative membership to be positively associated with awareness of EU regulations as membership can facilitate access to relevant information and training. This is because access to these services enhances the acquisition of pertinent information about the advantages of cooperative membership. Lastly, a set of district dummy variables address unobserved agro-climatic, institutional, market access, and socio-economic differences across the sample districts.

3.3. Sampling procedure and sample size

A stratified sampling method was employed to effectively capture the diverse perspectives on EUDR and cocoa production of cocoa farmers, considering both cooperative and non-cooperative members. By including both, we sought to capture varying perspectives and experiences, particularly regarding the potential of cooperative membership to ensure smooth compliance with EU regulations. Stratified sampling was chosen because it provides more reliable information from

the same sample size (Song and Kawai, 2023) by ensuring that comparisons between the two groups (members and non-members of agricultural cooperatives) are accurate and meaningful. A multi-stage stratified sampling technique drew an appropriate sample for this study. In the first stage, two districts, Biankouma and Issia, were selected based on their prominence in cocoa production. Secondly, villages within these districts were randomly selected proportional to the size of farm households. Subsequently, household heads in each district were categorized into agricultural cooperative members and non-members with the assistance of village leaders and local guides, as formal lists of producers were not available.

The final sample comprised 218 household heads, including 57 cooperative members and 161 non-members (Table 2). This distribution reflects the fact that, according to the Conseil Café Cacao (CCC), approximately 50 % of cocoa farmers are cooperative members, though other sources report a lower figure of about 20 % (Bymolt et al., 2018). The more significant number of non-member farmers in the sample aligns with these estimates and ensures a comprehensive range of perspectives and experiences. This overrepresentation of non-members was intentional, thus ensuring a comprehensive range of perspectives and experiences. The smaller sample size of cooperative farmers reflects their proportionate representation in the local farming community. We aim to investigate and compare the experiences, practices, and challenges facing both groups. Data was collected using quantitative household surveys and included information about farmers' motivation to adopt different practices, access to information and resources, and awareness of EU regulations.

The sampling process began with selecting seven villages in each of the two cocoa-producing zones, Biankouma and Issia, based on the intensity of cocoa production, cooperative membership, the size of the producers, and accessibility. Village leaders and local guides assisted in identifying cocoa farmers within these villages. The study targeted individuals with at least one cocoa plot. The number of respondents per village was proportional to the number of cocoa farmers registered in the village, ensuring representation across the study area.

Overall, the sample included 135 farmers from Biankouma and 83 from Issia (Table 2). The larger sample from Biankouma reflects its prominence and higher number of cocoa farmers than Issia. A stratified purposive sampling approach was used, targeting farmers with at least one cocoa plot and ensuring representation across key districts. This approach enabled the inclusion of both cooperative members and non-members, thereby facilitating a thorough investigation of the research questions.

While the sample size ($N = 218$) does not aim for national representativeness, it was designed to capture meaningful variation between cooperative and non-cooperative farmers in key cocoa-producing regions. Given the underrepresentation of non-member farmers in previous studies, this study adopts an exploratory approach to generate insights into this often-overlooked group. Although the sample size limits statistical power, it still allows for the identification of important trends that warrant further investigation in larger-scale studies.

3.4. Model and data analysis

The survey data collected from non-cooperative and cooperative cocoa farmers is analyzed using descriptive statistics, propensity score matching, and inverse probability weighting with regression adjustment (IPWRA) estimator. We perform content analysis to analyze the qualitative data from the FGDs.

Table 2
Distribution of the sample size by locality and cooperative membership.

Districts	Non-members	Members	Total
Biankouma	102	33	135
Issia	59	24	83
Total	161	57	218

3.4.1. Descriptive statistics

The first step of data analysis is determining the profile of farming activities and the socio-economic characteristics of non-cooperative and cooperative cocoa farmers. We compute basic descriptive statistics to provide summary statistics of the data. Frequency distributions and percentages are used for categorical variables. Mean, minimum, maximum, and standard deviation are used for continuous variables. Due to the differences in sample sizes, Welch's *t*-test is used to compare the means of individual and cooperative cocoa farmers (Sakai, 2016). Matavel et al. (2022) use such a test to compare the means of two study sites in Mozambique.

3.4.2. Specification of the econometric model

With agricultural cooperatives increasingly recognized as an effective strategy for improving farmers' socio-economic conditions and enhancing the yields and quality of cocoa, this study assesses the impact of cooperatives on the awareness of the EU regulation in Côte d'Ivoire. Additionally, the aforementioned studies have not explicitly focused on how cooperatives affect farmers' awareness of the EUDR, nor have they used propensity score matching (PSM) or similar estimation techniques. While relevant studies often apply methods such as random assignment, regression discontinuity, and/or difference-in-differences to analyze the impact of cooperatives on technology adoption, our study employs PSM followed by Inverse Probability Weighting with Regression Adjustment (IPWRA) to address selection bias and control for unobserved characteristics.Compared to others, these approaches are based on the observed and unobserved characteristics of both treated and untreated groups, thus helping avoid attrition and contamination problems related to using a pre-experimental sample. The combined use of PSM and IPWRA further minimizes unobservable bias, a common source of endogeneity.

3.4.2.1. Propensity score matching. We aim to answer the question: "What would be the level of awareness of new EU regulations among cocoa farmers in case households had not been cooperative members?" We answer this question using the counterfactual causality approach (Heckman et al., 1997). In a randomized experiment, the mean impact of a treatment on the treated can be measured by computing the difference between mean values of the outcome variable of interest for the treatment and control groups. However, this method is not applicable in the current scenario as cooperative membership is non-random in our sample (Abebaw and Haile, 2013).

An impact evaluation is carried out using a suitable non-experimental method for a setting like this. Therefore, before proceeding to future counterfactuals, initial comparability must be established to avoid initial selection bias (Caliendo and Kopeinig, 2008). Choosing a non-experimental method depends on data type, availability, and program design (Smith and Todd, 2005).

To address this problem, we apply a PSM method to quantify the impact of cooperative membership on the information gap experienced by the farmer using cross-sectional data (Rosenbaum and Rubin, 1983). The idea is to identify non-members who are similar to members in their observable characteristics. The idea behind PSM is identifying non-members of a cooperative with similar observable characteristics to members, allowing for the adjustment of initial differences between the member and non-member groups by matching each member unit to a non-member unit based on these resemblances, effectively summarizing the conditional probability of membership given pre-treatment characteristics. The first step in applying PSM is to estimate the predicted probability that a household is a cooperative member, also known as the propensity score, using a logit model. The mathematical formulation of the logit model is:

$$P_i = \frac{e^{zi}}{1 + e^{zi}} \tag{2}$$

where P_i is the probability of joining agricultural cooperatives, e represents the base of natural logarithms, and Zi is a function of n-explanatory variables.

The propensity score can also be estimated:

$$P(Z_i) = Prob(C_i = 1|Z_i) \tag{3}$$

where the propensity score, P(Zi) is estimated by a logit model (Eq. (2)), which regresses cooperative membership (1= members and 0 = non-members or individual) on observed personal, household, farm, and location characteristics.

After predicting the propensity scores, a matching estimator is chosen. The literature suggests several alternative indicators. An excellent matching estimator does not eliminate too many of the original observations from the final analysis while it should, at the same time, yield statistically equal covariate means for households in the treatment and control groups (Caliendo and Kopeinig, 2008). We use three estimators: a kernel-matching estimator to pair cooperative members with similar non-members using the estimated propensity scores and two alternative matching estimators – nearest neighbor matching and radius matching – to check the robustness of our results.

Following Becker and Ichino (2002), the average treatment effect on the treated (ATT), which in our case is the average impact of cooperative membership on awareness of the EU regulations by members, is estimated as:

$$ATET = E\{Y_{1i}^k - Y_{0i}^k | C_i = 1\} = E[E\{Y_{1i}^k - Y_{0i}^k | C_i = 1, P(Z_i)\}] \tag{4}$$

$$= E[E\{Y_{1i}^k | C_i = 1, P(Z_i)\} - E\{Y_{1i}^k | C_i = 0, P(Z_i)\} | C_i = 1] \tag{5}$$

where Y_1 and Y_0 are, respectively, values of the outcome variables of interest for cooperative members and non-members; i refers to households; k refers to the level of awareness of compliance with EU regulation being analyzed. The statistical significance of ATET is tested using bootstrapped standard errors, which consider the variation caused as a result of the matching process.

As stated above, the main assumption behind matching is selection on observables, also known as conditional independence assumption (CIA) (Heckman et al., 1997) . However, if unobserved variables affect participation in cooperatives and the level of awareness of EU regulation (outcome variable of interest), a hidden bias might arise, making matching estimators unreliable (Rosenbaum, 2002). Specifically, hidden bias leads to both positive and negative unobserved selection. Positive unobserved selection occurs if households who become cooperative members are also more likely to be aware of EU regulations. Thus, the treatment effect would be overestimated. In contrast, the treatment effect would be underestimated if negative unobserved selection exists. Unfortunately, the CIA cannot be tested directly with non-experimental data.

To address this matter, we are taking several measures. First, following (Abebaw and Haile, 2013), we included several covariates in the logit model specification to reduce bias due to omitted variables. Secondly, we use the bounding approach (Rosenbaum, 2002) to examine the sensitivity of the estimated results to hidden bias. Although we considered conducting a placebo regression as an additional robustness check, we could not proceed with this due to the lack of an unrelated outcome variable, such as the age of the household head's spouse.

Finally, we test whether the levels of awareness of EU regulations of cooperative membership are the same among member households. For this, we use ordinary least squares (OLS) regression of estimated household-level impacts on household characteristics and location factors. The data used for this estimation is obtained from cooperative members in the matched sample.

Most importantly, we also implement the IPWRA estimator and placebo regression to check the consistency of the PSM result to control for selection bias and for robustness check. Applying these models also helps to check whether the level of awareness of EU regulations is consistent among households within the cooperative.

3.4.2.2. Inverse probability weighting with regression adjustment estimator. To ensure the robustness of our findings regarding the impact of agricultural cooperative membership on cocoa farmers' awareness of the EU's new regulation, we apply the Inverse Probability Weighting with Regression Adjustment (IPWRA) estimator. This method was chosen for its double-robust property, which provides a valuable relaxation of the strong assumptions required by PSM (Ma et al., 2024). IPWRA has the particularity that it guarantees consistent and unbiased treatment effect estimates as long as either the treatment model (propensity score model) or the outcome model is correctly specified, even if one of these models is mis-specified (Kumanayake et al., 2023; Ma et al., 2024).

In our analysis, we first estimate the propensity scores for cooperative membership using logit regression to predict membership based on observed covariates. These propensity scores are used to compute weights that adjust for covariate imbalances between cooperative members and non-members. We apply these weights in a regression model that adjusts covariates to estimate the impact of cooperative membership on farmers' awareness of EU regulations. This approach is intended to address potential confounding and covariate imbalances. By comparing the treatment effects obtained from IPWRA with those from PSM with Radius Matching, we aim to assess the robustness and reliability of our findings. This dual approach helps us determine the consistency of our estimates and provides additional validation for the identified causal relationships.

The IPWRA estimator specifies the treatment and outcome models as follows:

$$\text{Treatment model}: \ P(A_i = 1) = g(X_i, \alpha) + \varepsilon_i \tag{6}$$

$$\text{Outcome model}: \ Y_i = f(X_i, \beta) + v_i \tag{7}$$

where $P(A_i = 1)$ refers to the probability that a household adopts cooperative membership. Y_i is the outcome variable representing the level of cocoa farmers' awareness of the EU's new regulation; X_i denotes the vector of covariates that influence both the treatment assignment (cooperative membership) and the outcome variable (farmers' awareness). Specifically, α and β are the parameters in the models; $g(X_i, \alpha)$ represents the regression specification for the determinants of cooperative membership, while $f(X_i, \beta)$ describes the regression specification for the determinants of the outcome variable; ε_i and $v_i$denotes the random error terms in these models, capturing unobserved factors that affect both the treatment and the outcome.

Under the analytical framework of potential outcome, we estimate the average treatment effects (ATE) of cooperative membership on cocoa farmers' awareness of the EU's new regulation as:

$$\text{ATE} = E[\text{Y}_{i1} - \text{Y}_{i0}] \tag{8}$$

The IPWRA estimator calculates the predicted outcomes, contrasting their means to obtain the ATE using the inverse of estimated treatment probability weights.

While PSM and IPWRA allow us to control for observable differences between cooperative and non-cooperative farmers, we acknowledge that unobserved confounding factors may still bias our estimates. These unobserved factors may include farmers' intrinsic motivation to comply with regulations, prior exposure to sustainability initiatives, or their underlying attitudes toward environmental standards — variables that are not captured in our dataset. The use of instrumental variables (IV) is one strategy to address endogeneity and establish stronger causal inference (Euler et al., 2024) . Instead, we rely on PSM estimates and reinforce our findings through additional robustness checks, including a

placebo regression.

3.4.2.3. Placebo regression. In addition to the IPWRA estimator, which serves as a doubly robust method to estimate treatment effects, we also implement a placebo regression as a falsification test to assess the robustness of the PSM estimates. The placebo regression involves randomly assigning the treatment variable to a subset of the sample and re-estimating the ATT using the same set of covariates. Since the treatment is assigned at random in this case, any significant effect would suggest that the original findings might be driven by model misspecification or unobserved confounding. This approach is grounded in the principle that if a treatment effect is detected under a random or unrelated assignment, it may signal hidden bias or model misspecification (Rosenbaum, 2002). By comparing the placebo ATT with the actual treatment effect, we can verify whether the estimated impact of cooperative membership on the outcome is genuine or spurious. This robustness check complements the IPWRA estimates and strengthens the credibility of our causal inference.

3.4.3. Qualitative data analysis

To gather data on the contextual variables affecting cocoa farmers' efforts to comply with the new EU regulations and to further investigate cooperatives' role in enhancing compliance, we conducted twelve focus group discussions (FGDs), each comprising 12 participants. This aligns with recommendations in the literature for optimal FGD group size (Nyumba et al., 2018). Participants were selected from various villages in the study regions, ensuring the inclusion of both cooperative members and non-members. The primary criterion for participation was ownership of at least one cocoa plot, to ensure relevance to the discussion topics. During the FGDs, we explored themes such as challenges related to sustainable farming practices, the implications of EU regulations, and the influence of cooperative membership on farmers' awareness and preparedness.

All FGDs were voice-recorded and supplemented with handwritten notes. Recordings were transcribed and translated into English when necessary to facilitate digital analysis. We performed content analysis using MAXQDA software to examine the qualitative data. A mixed coding approach, incorporating deductive and inductive methods, was employed to systematically identify, categorize, and code key themes and subthemes related to sustainability requirements (Table 3). The content analysis was conducted in two stages: first, we gained a holistic understanding by reviewing the transcripts within MAXQDA; next, we extracted and organized recurring themes and patterns using the software's coding features. Specific codes were formulated based on research questions, facilitating a structured data organization into major themes. An overview of the codes and thematic categories is provided in Table A3 (Supplementary materials)

Table 3
Key themes and sub-themes identified for the FGD analysis.

Themes	Sub-themes
Awareness and Understanding of EU Regulations	Awareness of EU Regulations Identified EU Regulations Requirements
Access to Information and Resources	Information Sources Mechanisms of Information Sharing Access to Resources
Limitations of Adoption and Compliance with EU Regulations	Access to Information Limitations Resource Accessibility Limitations Financial Limitations Traceability Limitations Institutional Support Limitations
Facilitators of Adoption and Compliance with EU regulations	Cooperative Membership

The coding was conducted manually by the first two authors, who developed the codebook based on theoretical constructs and emerging insights from the data. Codes were assigned directly within MAXQDA and then grouped into thematic and subthemes relevant to the research objectives. Analytic rigour was ensured through collaborative review and multiple rounds of cross-checking codes against the original transcripts to maintain consistency and validity.

This method ensured a thorough and systematic analysis, enabling efficient information retrieval (Krippendorff, 2018). Additionally, MAXQDA's qualitative analysis tools enabled the exploration of relationships and contrasts among identified themes, allowing us to capture the diversity of perspectives expressed by participants. This approach aligns with contemporary standards of qualitative research and ensures analytical rigour (Guetterman and James, 2023).

4. Results

4.1. Descriptive statistics

The data show significant differences in several variables between cooperative and non-cooperative members (Table 4). For instance, the gender composition of cooperative members is significantly more male-dominated compared to non-members. Cooperative cocoa farmers are also more likely to be educated and married. Additionally, household size and landholding are, on average, larger among cooperative members. Non-cooperative cocoa farmers are more likely to be native to the study area compared to cooperative members. The descriptive statistics show that the average age of household heads among cocoa farmers is 45 years. Cooperative members tend to be older than non-cooperative members. Cooperative cocoa farmers also have larger farm sizes and better credit access. Furthermore, cooperative members are more likely to receive extension services, participate in training, and employ external labor than non-members. Regarding cocoa production, cooperative members have significantly higher average yields, likely due to better resources and support. Finally, members have on average more experience in cocoa production than non-cooperative members.

4.2. Estimation of propensity scores

The empirical analysis proceeds with the estimation of propensity scores using a logit model to predict cooperative membership (Table 5). The dependent variable is binary, coded as 1 for cooperative members and 0 for non-members. Following the estimation, the propensity scores are used to match cooperative members with non-members based on similar covariate characteristics. This matching process aims to reduce selection bias and to establish a control group comparable to the treatment group. The subsequent steps involve evaluating the quality of the matches through balance diagnostics, ensuring that the covariates are balanced between the treated and control groups post-matching. Finally, the treatment effects of cooperative membership on the various outcome variables are estimated and analyzed. The estimated model is statistically significant at the 1 % level. The logit model also correctly predicts 86.70 % of the sample observations. The estimated propensity scores for the whole sample range between 0.000021 and 0.99995, with a mean score of 0.2639 (SD= 0.297). With a mean score of 0.144 (SD= 0.180), the propensity scores for non-members vary between 0.000021 and 0.82951. In contrast, the propensity scores for members vary between 0.01862 and 0.99995 with a mean score of 0.6023 (SD= 0.3043). Thus, the region of common support for distribution of estimated propensity scores of members and non-members would range between 0.01862 and 0.99995. Observations whose propensity scores lie outside this range are dropped from the sample.

Most explanatory variables in the logit model have the expected sign. The estimation results indicate that cooperative participation is strongly associated with the household's socioeconomic and demographic characteristics. The analysis reveals several factors that are statistically and

Table 4
Descriptive statistics of sample cocoa farmers by cooperative membership status.

Variables	Cooperative member (57)		Non-cooperative members (n =161)		Combine (n = 218)		Difference in means
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev	p-Value
Awareness EU regulation	0.964	0.185	0.366	0.483	0.522	0.500	0.000
Age	54.228	13.440	46.068	10.403	48.201	11.803	0.000
Gender	0.947	0.225	0.838	0.369	0.866	0.340	0.037
Educational status	0.736	0.444	0.546	0.499	0.596	0.491	0.011
Marital status	0.719	0.453	0.527	0.500	0.577	0.495	0.0118
Residence status	0.649	0.481	0.770	0.422	0.738	0.440	0.074
Extension services	0.684	0.468	0.422	0.495	0.490	0.501	0.0006
Credit access	0.526	0.503	0.372	0.485	0.412	0.493	0.0431
Participation in training	0.631	0.486	0.260	0.440	0.357	0.480	0.000
External labor	0.614	0.491	0.465	0.500	0.504	0.501	0.0548
Household size (number of person)	9.280	2.304	7.149	3.356	7.706	3.249	0.000
Household farm size (Ha)	4.728	3.546	3.144	2.212	3.558	2.709	0.0001
Cocoa production (ton/ha/Household)	1627.702	1849.605	814.118	865.116	1026.844	1250.236	0.000
Experience in cocoa farming (Year)	25.315	17.040	20.149	15.224	21.5	15.843	0.0340

Table 5
Logit model results of factors determining cooperative membership.

Variables	Odds ratio	Robust standard error	z-value
Age	1.0806	0.0219	3.81***
Gender	3.571	2.264	2.01**
Educational status	2.9305	1.4781	2.13**
Marital status	1.7813	0.7422	1.39
Residence status	0.5411	0.2796	-1.19
Extension services	2.5135	1.0716	2.16**
Credit access	2.6588	1.1986	2.17**
Participation in training	4.2678	1.9946	3.10***
External labor	2.5092	1.0701	2.16**
Household size	1.2804	0.0867	3.65***
Household farm size	1.1907	0.1304	1.59
Total Cocoa production	1.0003	0.0001	1.98**
Experience in cocoa production	1.0183	0.0141	1.31
Observations = 218			
Wald chi2 (13)= 58.93			
Prob > chi^2 = 0.0000			
Pseudo R2= 0.420			
% predicted correctly= 86.70			

* Significant at 10 %, **significant at 5 % and ***significant at 1 %.

positively associated with cocoa cooperative membership. Gender shows a significant association, indicating that being male is associated with a higher likelihood of joining, suggesting that gender bias exists in membership and resource accessibility. Age is highly significant, suggesting that older farmers are more likely to be members. Educational status also has a significant positive relationship, implying that educated farmers tend to participate in cooperatives. Access to extension services, credit access, and training participation are all significantly associated with cooperative membership, highlighting that those with more support and resources are more inclined to join. Use of external labor is another significant factor, suggesting that farmers with external labor are more likely to be cooperative members. Additionally, household size is highly significant: larger households are more likely to be part of a cooperative. Finally, total cocoa production is significantly associated with cooperative membership. This suggests that demographic, educational, and resource access factors play a crucial role in determining cooperative membership among cocoa farmers.

4.2.1. *Average treatment effect on the treated (ATET)*

We employed PSM to estimate the association between cooperative membership and EU regulation awareness. The difference in awareness of EU regulations between the members of the cooperative and non-members is estimated using nearest-neighbor matching, radius matching, and kernel-based matching. We use the nnmatch command combined with the bias adjustment option in Stata (Abadie et al., 2004) to obtain the ATET estimates of nearest-neighbor matching. To obtain the ATET estimates of radius matching and kernel-based matching techniques, we use the psmatch2 command (Leuven and Sianesi, 2018) to ensure robustness in our analysis (Table 6). As Table 6 shows, all the matching estimators provide consistent results, demonstrating that cooperative membership is positively and significantly associated with awareness of EU regulations. Specifically, awareness is 50–70 percentage units less in a situation where cocoa farmers do not join a cooperative. The impact of cooperative membership on the likelihood of awareness of EU regulations is statistically significant and aligns with expectations.

In evaluating the reliability of these estimates, we carried out several tests to check if the balancing requirements of PSM are satisfied in our data. We conducted a balancing test using kernel matching with a bandwidth of 0.01; the results are in Table 7. As shown in Table 7, members and non-members have statistically similar characteristics after matching in contrast to the unmatched sample (Table 4). Specifically, the test for equality of the two-group means shows no statistically significant difference between members and non-members after matching. Moreover, the standardized differences (% bias) for the mean values of the majority of covariates between members and non-members are below 10 %. This reassures that the balancing requirement is adequately satisfied. The distributions of the estimated propensity scores for members and non-members are presented in Fig. 2 for visual inspection: as expected, the two groups substantially overlap.

4.2.2. *Robustness of results to hidden bias*

As stated earlier, the reliability of impact estimates using PSM depends on selection based on observables. However, it is essential to check the robustness of the estimates against the selection of

Table 6
Estimation of the effect of cooperative membership on awareness of EU regulations.

Matching estimators	ATET for cooperative membership	Standard error	Estimated rosenbaum bounds
Nearest neighbor Matching	0.540***	0.0963	[3.71–4.6]
Radius matching (caliper=0.05)	0.597***	0.0985	[11.8–12.7]
Kernel-based matching (bandwidth= 0.01)	0.683***	0.1069	[6.4–7.3]

For nearest neighbor matching, the standard errors are bias-adjusted standard errors and bootstrapped standard errors for kernel and radius matching estimators. With the kernel and radius matching estimators, a common support condition is imposed. The matched sample includes 57 members and 161 non-members of cooperatives.
* Significant at 10 %, **significant at 5 % and ***significant at 1 %.

Table 7
Test of matching quality.

Variables	Mean		% bias	% Reduction | bias|	p-value for equality means
	Member	Non-member			
Gender	0.9302	0.9422	6.3	82.3	0.82
Age	51.51	48.13	-2.3	96.6	0.16
Marital status	0.651	0.7148	19.4	51.6	0.531
Residence status	0.7209	O,6419	7.3	72.7	0.438
Educational status	0.6976	0.6133	28.7	28.7	0.416
Extension services	0.6279	0.7248	-9.6	82.4	0.343
Credit access	0.5348	0.5836	-9.1	70.8	0.654
Participation in training	0.5581	0.4497	8.1	89.8	0.320
External labor	0.5814	0.5873	1.3	95.6	0.956
Household size	9.069	0.985	-4.3	94.1	0.283
Household farm size	3.953	4.257	-15.1	71.8	0.605
Total cocoa production	1337.2	1161.8	8.1	85.7	0.425
Experience in cocoa production	22.698	22.751	-31.9	0.2	0.988

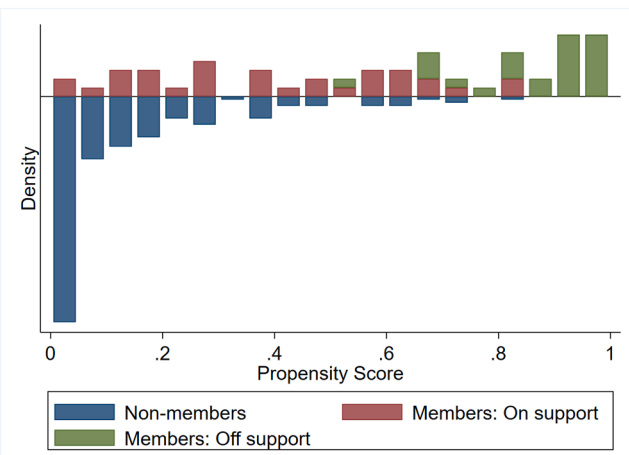

Fig. 2. Distribution of propensity scores.

unobservables. For this, we took two approaches. First, we computed the Rosenbaum bounds as recommended by Becker and Caliendo (2007); the Mantel–Haenszel (MH) test statistics are reported in Table 6. We performed a sensitivity analysis focused on our estimate of EU regulation awareness, as evaluating insignificant results would not provide meaningful insights (Abebaw and Haile, 2013). We searched for evidence of an overestimation of the ATET for awareness of EU regulation due to the presence of unobserved confounders. In our sensitivity analysis using Rosenbaum bounds, we assessed the robustness of our estimated Average Treatment Effect on the Treated to potential hidden biases. We tested gamma values (Γ) ranging from 1 to 15 in increments of 0.09

For Nearest Neighbor Matching, the bounds under the assumption of positive hidden bias reach a significance level at Γ= 3.7 to 4.6. This suggests that the treatment effect remains robust to hidden biases that could increase the odds of treatment by up to 460 %. For Kernel-based Matching, the gamma range was Γ= 6.4 to 7.3, showing robustness against hidden biases, increasing the odds of treatment by up to 630 %. Lastly, for Radius Matching, the gamma range was Γ= 11.8 to 12.7, indicating exceptional robustness as the treatment effect withstands hidden biases that could inflate the odds of treatment by up to 1170 %.

These results affirm the reliability and validity of our findings, with the treatment effect consistently remaining significant across different matching methods, indicating strong resistance to potential unobserved confounders.

4.3. Robustness check and treatment effect analysis of propensity score matching (PSM) model

To ensure the reliability and robustness of the estimated treatment effects, we complement the PSM analysis with two additional approaches: the IPWRA and a placebo regression. These serve as robustness checks for hidden bias and specification errors that may affect the credibility of causal inferences from observational data.

4.3.1. Inverse probability weighted regression adjustment

First, we estimated the Average Treatment Effect (ATE) using IPWRA to evaluate the robustness of our treatment effect estimates. This method allows us to account for potential imbalances and validate our results by weighting the sample according to the estimated propensity scores, making it suitable for analyzing cooperative membership and awareness of EU regulations. Following this, we compared the ATE derived from IPWRA (Table 8) with the ATE obtained from PSM using Radius Matching, one of our three matching methods.

Our IPWRA estimate yielded an ATE of 0.596, which is closely aligned with the ATE of 0.597 obtained from the PSM with the Radius Matching approach (Table 5). This striking similarity in the treatment effect estimates across these methods is noteworthy. Despite using three different matching techniques, the close agreement between the IPWRA and Radius Matching results suggest that our treatment effect estimates are robust and reliable.

This observed consistency reinforces the validity of our findings, indicating that the treatment effects are stable across different methodological approaches. Thus, the conclusion that the treatment effects are not sensitive to the specific method used for confounding adjustment is supported. Given the strong alignment of results across these approaches, we conclude that the Radius Matching method provides a solid basis for our treatment effect estimates. The similarity in outcomes enhances our confidence in the robustness of the observed association.

In evaluating the reliability of the IPWRA estimates, we conducted several tests to ensure model validity. We performed a diagnostic check to assess whether our data meets the balancing requirements of IPWRA. Specifically, we examined the covariate balance between treated and control groups after applying the weights generated by IPWRA. The results, detailed in Table A1 and Table A2 (Supplementary materials), show that, following the application of IPWRA, members and non-members exhibit statistically similar characteristics, contrasting with the pre-adjustment sample (Table 2). The balance tests indicate no statistically significant differences between members and non-members post-weighting. Furthermore, the standardized differences (% bias) for the mean values of most covariates between members and non-members are below 10 %, affirming that the balancing condition is adequately satisfied. This validation confirms the robustness of our IPWRA model in adjusting for confounding factors and ensuring reliable estimates.

4.3.2. Placebo regressions

As a falsification test to further assess the robustness of the estimated treatment effects and detect potential hidden bias, we conducted placebo regressions by randomly assigning the treatment variable and re-

Table 8
Impact of agricultural cooperative membership on cocoa farmers' awareness of new EU regulations.

Outcome	ATE	Percentage change
Awareness of EU regulations	0.596 (0.0518)***	10.37

estimating the ATT using the same set of covariates. Following the approach discussed in Rosenbaum (2002) and Imbens and Rubin (2015), the placebo treatment was applied across all three matching methods: nearest neighbor, kernel, and radius matching. Since the assignment is random, any significant effect would indicate potential bias or model misspecification in the original analysis. The results of this placebo analysis are presented in Table 9

The results presented in Table 9 show that the placebo ATT estimates are not statistically significant across all three matching methods. This implies that when treatment is randomly assigned, no significant differences in the outcome are observed between the placebo-treated and control groups. These findings provide additional support for the validity of our main PSM results, suggesting that the treatment effect estimated using the actual treatment variable (cooperative membership) is unlikely to be the result of model misspecification or random chance.

4.4. Focus group discussion results

This section presents qualitative insights derived from the FGDs conducted to investigate the role of cooperative membership in enhancing compliance with the EUDR. The discussions explore the awareness and understanding of the EUDR, information-sharing mechanisms, the role of cooperative membership, and the challenges farmers face in complying with the new regulations.

4.4.1. Level of awareness and understanding of the EUDR among cocoa farmers

The FGDs results reveal varying levels of awareness among cocoa farmers regarding the EUDR. Generally, cooperative farmers are more familiar with EUDR requirements than non-members. Across Biankouma and Issia, the FGDs results reveal that farmers mentioned several aspects of the EUDR, with deforestation and sustainable practices being the most recognized topics. In addition, child labor and traceability requirements were also frequently discussed during the sessions in Issia. Traceability was discussed:

> We used to sell the product directly to buyers, but now our product will no longer be sold in the same way. Now an International Organization has taught us a new method. What does this mean? They issue us cards on which the weight of the cocoa you deliver is recorded. After selling the cocoa, you take the card and go to the bank to withdraw your money. This is the new method we have learned. At the moment, that's what we know. Additionally, people are going around the villages to issue these cards to the producers. (FGD in Issia, March 3, 2024. Participant 3, cooperative farmer).

To help them comply with policy requirements, cooperative member participants also reported being regularly informed about new methods and techniques through training sessions provided by visiting agents. One cooperative farmer in Biankouma highlighted this difference:

> Those of us in cooperatives are often more informed about methods and techniques because extension agents frequently come to train us in agricultural practices. Simultaneously, they provide us with information, and we also attend training sessions. In comparison to non-members – they lack this training. The information we receive from the EU is not accessible to non-cooperative members. They can use their children for work however they please. Nonetheless, when we receive this information and attempt to implement it, we recognize the importance of child welfare. There is profit, so all these aspects make the cooperative—and the information we receive as an organized group—very important to us (FGD in Biankouma, February 24, 2024. Participant 3, cooperative farmer).

In summary, the FGDs indicate that cooperative members generally understand the EUDR better, particularly in areas such as sustainable practices, child labor, and traceability. However, in both groups, cooperative and non-cooperative, some farmers still reported having no information about the EUDR, underscoring the need for improved outreach and education efforts.

4.4.2. Information sharing mechanisms

The FGDs results reveal various information-sharing strategies among cocoa farmers. Media outlets, especially radio and television, disseminate information. For cooperative members, cooperative meetings are a principal mechanism for accessing information, particularly in Biankouma. Surprisingly, some non-cooperative farmers also reported attending these meetings to gather information. One non-cooperative farmer in Biankouma shared:

> I am not a cooperative member, but when cooperatives provide information, I visit, gather the information, and use it in my cocoa production as instructed by the cooperative. (FGD in Biankouma, February 23, 2024, Participant 7, non-cooperative farmer).

However, for most non-cooperative farmers, informal peer sharing—exchanging information with neighbors and family members—is the primary means of staying informed. Additionally, extension services from government and NGOs are significant sources of information for both cooperative and non-cooperative farmers.

Community meetings and gatherings with village leaders were highlighted as critical information-sharing venues. One participant noted:

> When people come to provide information, we gather at the village chief's place to learn about cocoa sorting, proper fermentation, and sorting. The advice is given here at the village chief's place; they do not have separate advice. It is at the village chief's place where everyone gets informed. (FGD in Biankouma, February 23, 2024, Participant 2, non-cooperative farmer).

In Issia, cooperative farmers emphasized the importance of cooperative meetings and training sessions as primary information sources. Informal peer sharing remains the primary method of obtaining information for non-members. Media sources, including radio, television, and the internet, were also relevant for both groups. A non-member in Issia explains:

> Information often comes from television, radio, or the internet. Currently, this is the norm here. Phones are everywhere and our network is reliable, so accessing information is very efficient. To stay informed, one must listen to the radio news, watch TV, and use the internet (FGD in Issia, March 1, 2024, Participant 2, non-cooperative farmer).

For non-cooperative farmers, meetings with community leaders are also vital for receiving information, while cooperative farmers more often mentioned community meetings as key information-sharing venues. Additionally, non-members benefit from informal peer sharing that spreads information from cooperatives or governmental extension services.

Table 9
Placebo average treatment effects on the treated (ATT) across matching methods.

Matching estimators	ATT for cooperative membership	Standard error	T-stat
Nearest neighbor Matching	0.513	0.0935	0.72
Radius matching (caliper = 0.05)	0.513	0.0514	0.44
Kernel-based matching (bandwidth= 0.01)	0.509	0.0791	1.19

The matched sample includes 57 members and 161 non-members of cooperatives.
* significant at 10 %, **significant at 5 % and ***significant at 1 %.

4.4.3. The role of cooperative membership

The FGDs conducted in the study area indicate that cooperative membership significantly enhances cocoa farmers' preparedness for EUDR compliance. Both cooperative and non-cooperative farmers recognize the benefits of cooperative membership, particularly regarding technical assistance, economic advantages, and social benefits. Technical assistance, including training, information dissemination, and field monitoring, was consistently identified as a primary advantage of cooperative membership. For example, a non-cooperative farmer in Biankouma highlighted the economic benefits associated with cooperative membership:

> The advantages of being a cooperative member include receiving bonuses. I once attended a meeting with a cooperative that had decided the previous year to distribute bonuses in envelopes to each of its members. These are the benefits that cooperative members can enjoy, which those who are not members cannot. (FGD in Biankouma, February 23, 2024, Participant 1, non-cooperative farmer).

In addition to economic benefits, participants ocassionally mentioned social advantages, such as improvements in village infrastructure. For instance, a cooperative farmer in Issia emphasized the role of cooperatives in addressing community needs:

> If there's no school in that village, we can bring a school. If there's no canteen at the school, we can build one. (FGD in Issia, March 3 2024March, 3 2024, Participant 1, cooperative farmer).

Despite these recognized benefits, several barriers prevent non-cooperative farmers from joining cooperatives. These include limited access to resources, insufficient financial support, inadequate institutional policies to address illegal deforestation, and issues of mistrust and credibility regarding cooperatives. Another significant constraint identified by cooperative farmers relates to the geographical location of cocoa farms. Specifically, farms near protected forest areas are often ineligible for cooperative membership. A cooperative farmer in Biankouma described this limitation:

> You cannot join the cooperative if your farm is 200 meters away from the protected forest. It is not that they do not want to join, but it's because of where their farm is located (FGD in Biankouma, February 28, 2024, Participant 1, cooperative farmer).

These qualitative insights underscore the importance of cooperative membership in enhancing farmers' preparedness for EUDR compliance while highlighting those limitations that prevent non-cooperative farmers from joining.

4.5. Limitations of adoption and compliance with the EUDR

The FGDs revealed several challenges cooperative and non-cooperative farmers face in complying with the EUDR. These challenges are grouped into (i) information access limitations; (ii) resource constraints; (iii) market challenges; and (iv) institutional support limitations. Participants from both Biankouma and Issia identified similar issues.

4.5.1. Access to information limitations

A recurring theme from the FGDs was the lack of access to clear and sufficient information regarding the EUDR. Non-cooperative farmers, in particular, expressed frustration about the lack of technical information on sustainable practices, such as agroforestry and pest management. This information gap was more pronounced among non-cooperative farmers who had not participated in any formal training sessions:

> Those who are not members receive news from various sources to learn about cocoa prices or upcoming meetings. Since they are not members of cooperatives, they may not always be aware of important information. (FGD in Issia, March 6, 2024. Participant 1, cooperative farmer).

In Biankouma, there was a perceived lack of reliable information and mistrust due to previous unfulfilled promises by external actors. One non-cooperative farmer noted:

> Each year, people visit four or five times about cocoa matters. They call people, people sit down, they give their information, saying they will return on a certain day, but they never actually return. There are many, we cannot count. (FGD in Biankouma, February 27, 2024. Participant 6, non-cooperative farmer).

4.5.2. Access to resource limitations

Resource limitations are another major challenge identified during the FGDs. Farmers report difficulties accessing high-quality inputs essential for maintaining sustainable cocoa production. In particular, non-members in Biankouma struggled to afford fertilizers, while cooperative farmers in Issia expressed dissatisfaction with the limited resources provided by their cooperatives:

> The cooperative can give us fertilizer, maybe two or three sacks. That's not enough for the field; you have to pay for additional fertilizer, and fertilizer is expensive. (FGD in Issia, March 1, 2024. Participant 2, cooperative farmer).

4.5.3. Market limitations

Market-related challenges also emerged as significant obstacles. Although compliance with the EUDR is not yet mandatory, non-cooperative farmers in Biankouma already face difficulties selling their cocoa in traced markets that are preparing for or anticipating EUDR requirements. Exclusion from premium markets means lower payments. Cooperative farmers, on the other hand, faced payment delays, leading them to sell their cocoa through non-traced markets to obtain quicker cash:

> When the cooperative takes the cocoa, the producer has problems. He needs money, and the cooperative says, 'Wait a week, I will give you your money. The producer is not patient; he has problems and avoids all of that. He prefers to give his cocoa to another buyer two to three days after drying." (FGD in Issia, March 3, 2024. Participant 1, cooperative farmer).

4.5.4. Institutional support limitations

Institutional support was perceived as lacking, particularly regarding extension services and public policies. Cooperative farmers in Biankouma reported limited field visits from trainers, while non-cooperative farmers in Issia emphasized the need for more robust institutional frameworks to protect their land-use rights. Corruption, especially in the mismanagement of subsidies, was also mentioned as a significant issue in Issia:

> When the trainers come, it is all theory: they do not even visit the field. It has been a long time since one visited a field. (FGD in Biankouma, February 23, 2024. Participant 2, non-cooperative farmer).

4.5.5. Environmental limitations

Environmental factors, such as high cocoa plant mortality, deforestation, and climate change, further constrained farmers' ability to comply with the EUDR. In Biankouma, cooperative farmers cited cocoa mortality and deforestation as significant challenges, while non-cooperative farmers struggled with resource competition and land management costs. Climate change and pest-related issues are also prevalent concerns across both regions:

Deforestation is a big problem. We need better protection for our forests, but we also need more support to deal with pests and diseases. (FGD in Issia, March 5, 2024. Participant 3, non-cooperative farmer).

5. Discussions

In this discussion, we analyze our results with an emphasis on the association between cooperative membership and cocoa farmers' awareness of EU regulations, particularly in the context of cocoa farmers in Western Cote d'Ivoire. This study investigates the role of agricultural cooperatives in enhancing regulatory awareness and compliance among cocoa farmers, highlighting how cooperative membership bridges information gaps and fosters better adaptation to regulatory changes. By examining the results through the lens of cooperative involvement, we emphasize how cooperatives contribute to improving farmers' awareness and understanding of regulations while identifying opportunities to further strengthen cooperative support systems. Our discussion also integrates existing research, observations, and the challenges encountered in ensuring effective information dissemination and regulatory compliance within cooperative frameworks.

Our results reveal that cooperative members are significantly more likely to be male, older, and more educated than non-members. This aligns with previous studies suggesting that cooperative membership often correlates with higher levels of education and resource access (Abebaw and Haile, 2013; Zhang et al., 2020). However, contrary to our findings, Zhou et al. (2024) find that younger farmers are more likely to join cooperatives, indicating potential regional or contextual differences in cooperative membership dynamics. The larger household and farm sizes among cooperative members may reflect the enhanced economic stability and support provided by cooperatives, which is consistent with the findings of Olagunju et al. (2021): cooperatives can lead to better access to resources and improved yields. Additionally, larger families contribute to labor endowments, allowing farmers to engage more actively in agricultural cooperatives, as Zhou et al. (2024) notes. Access to extension, credit services, and training are significantly associated with cooperative membership, highlighting the importance of support and resources, aligning with findings of (Lei et al., 2024; Zhang et al., 2023) that cooperatives enhance access to agricultural services and inputs.

Furthermore, the results show that cooperative membership is also significantly linked to greater regulatory awareness, particularly regarding regulations governing sustainable commodity supply chains, such as Corporate Sustainability Due Diligence (CSDD). The analysis of propensity scores and the matching methods used (nearest-neighbor, radius, and kernel-based) confirm that cooperative membership is positively associated with awareness of EU regulations. This aligns with Rosenbaum and Rubin (2022), who demonstrate that matching methods can effectively estimate treatment effects in observational studies. The consistent results across different matching estimators suggest that cooperative membership significantly improves awareness of EU regulations, a finding that is crucial given the increasing importance of compliance with international standards. Our robustness checks, including the Rosenbaum bounds sensitivity analysis, indicate that the treatment effects are robust to potential hidden biases. This is supported by similar research, like Becker and Caliendo (2007), that emphasizes the importance of testing for hidden biases in propensity score matching. Despite potential unobserved confounders, the significant treatment effects across different matching methods reinforce our findings' reliability. These results resonate with the conclusions of Becker and Caliendo (2007), who highlight the robustness of propensity score methods in the presence of hidden biases.

Our findings contribute to the literature on cooperative membership and its influence on regulatory awareness. By employing robust statistical methods and addressing potential biases, this study confirms that cooperative membership significantly enhances awareness of EU regulations among cocoa farmers. However, it is crucial to recognize that relying solely on cooperative membership is not sufficient. There is considerable room for improvement, including better and more equal access to information and resources for both members and non-members of cooperatives. While the government of Côte d'Ivoire has been proactive in responding to the EUDR, continued collaboration with other stakeholders, such as NGOs and private sector actors, is essential to ensure widespread compliance and support for both member and non-member farmers. This comprehensive approach can create a more inclusive and supportive environment for all farmers, regardless of their cooperative membership status. These results highlight the importance of cooperatives in supporting farmers' compliance with international standards and provide a valuable reference for policymakers and researchers interested in the role of cooperatives in agricultural development.

The importance of cooperative membership in enhancing farmers awareness and preparedness for EU regulatory compliance becomes even more relevant in light of the EU Directive on CSDD. This directive introduces mandatory obligations for companies related to compliance with human rights and environmental impacts, presenting both challenges and opportunities for the cocoa sector. While the EUDR focuses on environmental standards, the CSDD complements it by emphasizing corporate responsibility and transparency. Given our findings on the role of cooperatives in improving traceability and regulatory awareness, it is clear that cooperatives can play a crucial role in supporting structures that help companies implement sophisticated traceability systems together with farmers in meeting these new requirements, particularly in improving traceability systems. This reinforces the need for stronger cooperative support, enhanced public policies, and stakeholder involvement to ensure that cocoa farmers can continue to access international markets and comply with evolving regulations.

Moreover, while most studies explore those factors that facilitate smallholder compliance with sustainability standards, such as the role of cooperatives, there is still restricted in-depth information addressing the context of the EUDR requirements (Cesar de Oliveira et al., 2024). In the case of non-compliance with the EUDR, the new regulatory framework introduces the risk of rejecting cocoa shipments and banning their entry into the EU markets (EC, 2023). This scenario could severely impact cocoa-producing countries, such as Côte d'Ivoire, where smallholder farmers rely heavily on exports to the EU (Renier et al., 2023). Notably, implementing the EUDR could amplify existing vulnerabilities in the cocoa value chain, where smallholder farmers may already face challenges aligning with sustainability standards due to limited access to information, resources, and training. This scenario calls for comprehensive support mechanisms that focus on technical assistance and financial support to facilitate smallholder farmers' compliance with the EUDR to minimize the risks of market exclusion and economic decline.

Nevertheless, the literature suggests that, as deforestation rates increase, smallholder farmers might encounter more significant compliance challenges associated with the costs of implementing and monitoring deforestation prevention measures (Cesar de Oliveira et al., 2024). These costs may arise from the need to implement traceability systems, collect and process information on the legality of farmers, and ultimately halt deforestation. The burden of compliance can vary depending on factors such as farm size, institutional organization, and the extent to which producers are linked to native vegetation conversion or adhere to voluntary sustainability standards. Börner et al. (2015) find that smallholder farmers are more likely to adopt sustainability commitments if compliance costs are reasonable. If compliance costs are burdensome, particularly in regions with extensive deforestation, it may become more appealing for smallholder farmers to divert their exports to less stringent markets (Cesar de Oliveira et al., 2024). This effect is known as "leakage," which refers to the unintentional environmental impacts in one place caused by actions taken in another. This is recognized as a major problem for the overall effectiveness of environmental

policies (Meyfroidt and Lambin, 2009).

In this sense, some studies propose that the inability to meet the stringent requirements of the EUDR might drive farmers to export to other major commodity-consuming countries, such as China, which have less stringent environmental standards (Brandt et al., 2022; Köthke et al., 2023; Vasconcelos et al., 2024). This could undermine the global sustainability goals of the EUDR and encourage the redirection of commodities to markets with lower regulatory pressures. These risks underscore the necessity of global collaboration and the creation of more comprehensive policies to assist small-scale farmers in meeting environmental regulations, ensuring the prevention of market fragmentation due to varying levels of regulatory pressure.

Our study highlights the pressing need for improved traceability in the cocoa supply chain to meet the new EU regulations. The EUDR's requirements for detailed traceability to farm level, including GPS coordinates, pose a substantial challenge, given that over 55 % of cocoa exports remain untraced (Renier et al., 2023). The findings of significant deforestation associated with cocoa production in Côte d'Ivoire further underscore the urgency for implementing robust traceability systems. The approval of the CSDD and the imminent enforcement of the new EUDR call for collaborative efforts at multiple levels, including company- and state-led traceability systems, landscape-level interventions, and more robust regulatory policies. These measures are essential to preserve the remaining stretches of forests in West Africa and ensure the sustainability of the cocoa sector.

Moreover, complementary compliance mechanisms such as voluntary sustainability standards (e.g., Rainforest Alliance, Fairtrade) and national initiatives like the African Regional Standard for Sustainable Cocoa (ARS-1000) overlap significantly with EUDR requirements. Many of these standards are implemented through cooperatives, giving certified cooperatives a comparative advantage in promoting EUDR awareness and readiness. Producers already participating in certification schemes tend to have greater exposure to traceability systems, sustainability training, and documentation protocols (Fairtrade, 2024). These cooperatives can leverage their existing knowledge and infrastructure to support farmers and companies in adapting to the EUDR. In contrast, non-certified cooperatives and independent farmers may face more significant challenges as they must build these systems from the ground up. This highlights the importance of integrating cooperative-led certification efforts with broader public and private compliance strategies.

While this study provides valuable insights into cocoa farmers' awareness of EU regulations, we acknowledge limitations in external validity. While purposefully stratified to include cooperative and non-cooperative farmers, the sample does not claim to be statistically representative of the entire cocoa-farming population in Côte d'Ivoire. Our primary aim was to better understand non-member farmers, a group often underrepresented in empirical research. Stakeholder consultations and existing studies (Löhr et al., 2020) indicate that private sustainability interventions in Côte d'Ivoire predominantly target cooperative members, who constitute only 20–50 % of cocoa producers. As a result, non-member perspectives remain limited in the literature. This study addresses that gap and can inform future research with broader national coverage.

Our study underscores the importance of cooperatives in enhancing awareness and preparedness for new EU regulations among cocoa farmers in Côte d'Ivoire. To further strengthen these findings, future research should focus on tracking changes in awareness and compliance over time to assess the long-term impact of cooperative membership, expanding the study to include other cocoa-producing regions in West Africa to compare the effectiveness of cooperatives across different contexts, and evaluating specific interventions within cooperatives that are most effective in promoting regulatory compliance. Additionally, it is important to investigate whether cooperative membership has heterogeneous effects across different farmer groups—for example, between small-scale and large-scale farmers, men and women, or those with and without prior exposure to sustainability programs. Understanding these differences can help design more targeted and inclusive strategies. In conclusion, this study highlights the critical role of cooperatives in supporting cocoa farmers to meet the new EU regulations, ensuring sustainability, and securing market access. By fostering cooperative membership and enhancing information dissemination, policymakers and stakeholders can better equip farmers to navigate the regulatory landscape and sustain the vital cocoa economy of Côte d'Ivoire.

6. Conclusion

This study examines the association between cooperative membership and awareness of EU regulations on sustainable cocoa production among cocoa farmers in Côte d'Ivoire. We analyze data using PSM and IPWRA models. The study reveals that cooperative membership is positively associated with higher awareness of EU regulations among cocoa farmers in Côte d'Ivoire. Cooperative members, who are more educated and have better resource access, are more likely to comply with international standards. The PSM and IPWRA analysis confirms the robustness of these findings, indicating that the positive impact of cooperative membership is resilient to potential hidden biases. The results emphasize the importance of cooperatives in bridging information gaps and providing essential support to cocoa farmers. As the EU implements stricter regulations through the CSDD, the role of cooperatives in facilitating compliance becomes even more critical. Enhanced traceability and sustainable practices are essential for the cocoa sector to meet new regulatory requirements and maintain market access. While cooperatives significantly improve awareness of EUDR, future research should explore how they complement other compliance mechanisms, such as government training programs and private certification schemes. This study highlights the need for policymakers and stakeholders to foster cooperative membership and enhance information dissemination to better equip cocoa farmers for regulatory compliance. More specifically, we recommend targeted technical and financial support for uncertified cooperatives to help them meet EUDR requirements, develop digital traceability tools that non-member farmers can access, and promote coordinated partnerships between government agencies and NGOs to deliver inclusive sustainability training. Future research should track changes in awareness and compliance over time, comparing the effectiveness of cooperatives across different regions and evaluating specific interventions within cooperatives that promote regulatory compliance. By strengthening cooperative support systems and expanding access to reliable compliance information, the cocoa sector in Côte d'Ivoire can better align with evolving sustainability frameworks while preserving market access.

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Ethics statement and consent to participate

The research followed the ethical standards as laid down in the Declaration of Helsinki and the protocol was approved by the Biosciences Training and Research Unit at the University of Félix Houphouët-Boigny in Abidjan, Côte d'Ivoire. Informed consent was obtained from all participants, with a written consent form provided within the Kobo Collect survey. The consent form was read aloud to participants, and their voluntary agreement to participate was documented before data collection commenced.

Consent for publication

A verbal consent for publishing was obtained and no identifying

details of the participants is published

CRediT authorship contribution statement

Hamza Moluh Njoya: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sofía Cristóbal Reyes:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Koumbo Alberic Hien:** Writing – review & editing, Investigation. **Franziska Ollendorf:** Writing – review & editing. **Bonna Antoinette Tokou:** Writing – review & editing. **Constant Yves Adou Yao:** Writing – review & editing, Supervision. **Stefan Sieber:** Writing – review & editing, Supervision. **Katharina Löhr:** Writing – review & editing, Supervision, 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:

Katharina Loehr reports financial support was provided by The German Cocoa and Chocolate Industry. If there are other authors, they 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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Supplementary materials

Supplementary materials associated with this article can be found, in the online version, at doi:10.1016/j.tfp.2025.100897.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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