frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 19 February 2025
DOI 10.3389/fsufs.2025.1524997

OPEN ACCESS

EDITED BY
Teshome Emana Soboka,
Addis Ababa University, Ethiopia

REVIEWED BY
Athina Koutouleas,
The University of Copenhagen, Denmark
Ingrid Fromm,
Bern University of Applied Sciences, Switzerland

*CORRESPONDENCE
Katharina Löhr
✉ Katharina.Loehr@zalf.de

RECEIVED 08 November 2024
ACCEPTED 24 January 2025
PUBLISHED 19 February 2025

CITATION
Tokou BA, Coral C, Montiel FI, Adou Yao CY, Sieber S and Löhr K (2025) Diversification strategies to improve cocoa farmers' household income: the case of Côte d'Ivoire. *Front. Sustain. Food Syst.* 9:1524997. doi: 10.3389/fsufs.2025.1524997

Diversification strategies to improve cocoa farmers' household income: the case of Côte d'Ivoire

Bonna Antoinette Tokou[1,2], Claudia Coral[1,3], Flora Isabella Montiel[1,4], Constant Yves Adou Yao[2,5], Stefan Sieber[1,4] and Katharina Löhr[1,6]*

[1]Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany, [2]UFR Biosciences, University Félix Houphouët-Boigny, Abidjan, Côte d'Ivoire, [3]Department of Agricultural Economics, Agrifood Chain Management, Humboldt Universität zu Berlin, Berlin, Germany, [4]Resource Economics, Humboldt Universität zu Berlin, Berlin, Germany, [5]Switzer Centre of Scientific Research (CSRS), Abidjan, Côte d'Ivoire, [6]Urban Plant Ecophysiology, Humboldt-Universität zu Berlin, Berlin, Germany

Diversification is a strategy adopted by farming households to meet several challenges. However, there is a lack of empirical evidence to support these positions. We contribute to filling this research gap by providing quantitative evidence of the impact of diversification on the additional income of cocoa-producing households. This study aims to analyze income from the diversification strategies of cocoa producers by building the typology of the most common systems and assessing their impacts on household income. A survey of 303 households across five Côte d'Ivoire regions reveals that cocoa producers have four distinct types of production systems, namely: (1) simple cocoa production systems; (2) cocoa production systems with crops in association; (3) cocoa production systems combined with income generating diversification on the additional plot; and (4) cocoa production systems, and food cropland. Of the four systems, type 3 is the most widely adopted by cocoa producers, generating higher income per household than the other types due to the large part of perennial income that requires a larger area. Furthermore, type 2 presents the best cocoa yield. We also assessed differences per population group. Thus, the results show that women adopt type 2 and type 4 systems with less surface area and are more devoted to the production of subsistence crops. Non-Ivorian producers have systems with higher cocoa yields and income from diversification than Ivorian producers. However, only 7% of producers have access to financing enabling them to invest in diversification crops. The findings demonstrate that crop diversification strategies can successfully improve households' living income and ensure the sustainability of cocoa production.

KEYWORDS

diversification, production, system, cocoa, livelihood, income, households

1 Introduction

West Africa's leading role in global cocoa production dates back to the chocolate boom in the twentieth century (Staritz et al., 2023). In 2020, global cocoa production was estimated to be more than 5 million tons, with 2.2 million tons coming from Côte d'Ivoire, representing 45 percent of total global production (Bermudez et al., 2022; ICCO, 2021).

The cocoa sector employs two-thirds of the country's active population, comprising at least 843,798 (95%) smallholder farmers, while supporting 6 million people directly or indirectly (Kouassi et al., 2021). Ivorian cocoa producers are characterized as smallholders with a farm size ranging from 2 to 5 hectares (Kouassi et al., 2021). Despite the importance of cocoa to the national economy, it is estimated that only 7% of Ivorian cocoa farmers earn a Living Income (LI), meaning a sufficient income to afford a decent standard of living for all household members (Rusman et al., 2018). The LI has been widely adopted for agrifood commodities as a concept and a poverty benchmark that goes beyond economic income to recognize the need to fulfill human rights to food, shelter, housing, healthcare, education, transport, clothing, and provision for unexpected events (Living Income Community of Practice, 2024). Additionally, most cocoa farmers still have a very low standard of living due to income strongly linked to the effects of climate change, cocoa diseases, and the fluctuation of cocoa prices (Amfo and Ali, 2020). This can ultimately result in reduced yields, negatively affecting both farmers and the environment (Jagoret et al., 2017; Tondoha et al., 2015). Acknowledging the devastating environmental and social effects of dominant models of cocoa production and the need for more sustainable natural resource management and poverty reduction (Wessel and Quist-Wessel, 2015; Losch, 2001), in 2010, the Ivorian government started promoting diversification strategies, particularly agroforestry (Hatløy et al., 2012; Kouadio, 2021). Indeed, following the agreement between the United Nations Environment Program (UNEP) and the Rainforest Alliance for a sustainable change in cocoa production practices, the Ivorian government, like other program countries, received support for sustainable cocoa production, including efforts to improve the living conditions of farming families (Reinecke et al., 2012). Moreover, most existing private and public-private initiatives supporting cocoa farmers have adopted the narrative that diversifying income is key to combat poverty to the extent that, in 2022, it was even reported as the cocoa sector's second strategy after increasing cocoa productivity (Fountain and Huetz-Adams, 2022). The idea is that low cocoa income due to low and unstable farm gate prices as well as low productivity levels must be complemented by the diversification of farm revenues to reduce cocoa income dependency (Bymolt et al., 2018; Laven et al., 2017; Waarts and Kiewisch, 2021). In this way, farming systems have been pushed toward diversification to overcome households' dependence on cocoa income and ensure their sustainability (Bymolt et al., 2018; Ruf and Schroth, 2015; Gyau et al., 2014). Indeed, crop diversification is a known practice, but not yet very efficient. Furthermore, following the adoption of the 2010 Ivorian policy on agroforestry, crop diversification, and capacity building, several strategies have been developed including capacity building and training in good agricultural practices that enable producers to diversify their production systems and their income (Komla et al., 2022; Kouadio et al., 2021; Kraft et al., 2021; Gyau et al., 2014; Reinecke et al., 2012). Although promoting agroforestry and crop diversification are considered important steps for sustainable cocoa production, the success of such efforts requires considering the various factors that influence farmers' choice of crop systems (Adou Yao et al., 2016; Gockowski and Sonwa, 2011; Owusu and Frimpong, 2014). In addition to these different approaches and diversification programs promoted by policies, there is a lack of sufficient financial or technical incentives to encourage cocoa producers to diversify their crops. This suggests the need to rethink the prevailing policy, which focuses narrowly on increasing productivity and commercializing cash crops as the main way to improve household incomes the ability of a household to diversify is shown to depend not just on economic characteristics but also on its demographic, physical, and social contexts (Johny et al., 2017). Diversification efforts require important investment from cocoa farmers, resulting in risky decisions made by already resource-limited households (Fountain and Huetz-Adams, 2022; Waarts and Kiewisch, 2021). Additionally, often it remains unclear if there are sufficient market opportunities for certain crops at the scale necessary to benefit cocoa farmers (Fountain and Huetz-Adams, 2022).

Currently, few studies have assessed diversification products and the resulting income of cocoa producers at the scale of their production systems, taking into account the different factors that influence household decision-making (Kouadio et al., 2021; Folefack et al., 2015; Cerda et al., 2014). To develop effective diversification strategies for sustainable cocoa production, this study aims to contribute to an enhanced understanding of smallholder cocoa farmers' decision-making regarding diversification and related income effects, thus informing future decision-making and policy advice. In this context, this study identifies different types of production systems, assesses their income potential, and discusses various diversification strategies.

1.1 Contextual background

Cocoa farming is facing economic (price instability, lack of agricultural credit), social (decline in cultivable land, lack of labor), and ecological (variation in climatic parameters, crop diseases, soil poverty) challenges that have a considerable impact on household income (Amfo and Ali, 2020; Barima et al., 2020). Agricultural diversification is identified as one of the mechanisms for managing household food security and reducing poverty, as it spreads risk across multiple production systems or plots and provides a range of food products to households (Djokoto et al., 2017; Nandi et al., 2024; He et al., 2019; Asante et al., 2018). Three general types of diversification are identified (Johny et al., 2017; Alobo Loison, 2015): (i) farm diversification is observed when the producers diversify their income through agricultural products; (ii) value-added diversification when the producers diversify their income through processing agricultural products; and (iii) service diversification when the producers diversify their income through agricultural products service delivery for on-farm or off-farm engagement (informal or formal work). Farm diversification integrates a diversity of crops and varieties into smallholder systems (He et al., 2019). McCorda et al. (2015) suggest that the production systems of smallholders present greater spatial and temporal complexity, such as polycultures, monoculture, and intercropping systems. Of these farm diversification strategies, Manlosa et al. (2019) identify that smallholder farm households, to increase their well-being, choose to commercialize crops or raise them for domestic needs. The diversification strategies rely on a mix of subsistence and cash crops to generate income, enabling households to achieve sustainable food and financial security (Manlosa et al., 2019; Basantaray et al., 2024). The decisions to diversify and which crops to grow are impacted by different drivers, including the aim of making the most of limited areas, seeking income stability, particularly via agronomic risk mitigation, and responding to consumer demand for marketing channels (Johny et al., 2017; Alobo Loison, 2015; Adetoye et

al., 2018). Moreover, factors such as market access, the perceived risk of crop failure or a market price crash, different labor demands for each crop, climate, and soil conditions, as well as crop seasonality might play important roles in the diversification strategies selected by the farmers (Bymolt et al., 2018). Although cash crops illustrate higher economic benefits, in certain regions, this strategy does not provide the means to ensure food security and a living income. For example, the production of cotton in Zimbabwe and Ghana and palm oil in Indonesia provided potential economic benefits to households (Manlosa et al., 2019), but did not enable households to ensure their food and financial security. Koffi and Oura (2019) identified diversification crops in the Côte d'Ivoire cotton-growing zone. They show that producers were more interested in cash crops with a more commercial objective than subsistence crops. At a parallel point, studies show that diversification is still very low among cocoa farmers in households that rely heavily on cocoa as their main source of income (Bymolt et al., 2018; Balineau et al., 2016). Thus, few studies investigate diversification strategies according to their spatial and temporary distribution in production systems and their income in cocoa-producing areas. In this study, in addition to identifying the diversification strategies, the type of production system and the income derived from diversification by type of system are evaluated. In the Ivorian agricultural context, the majority of local practices remain unstable and inefficient, keeping household incomes low and risks high (Rusman et al., 2018; Balineau et al., 2016; Michler and Josephson, 2016). Thus, it is important to note that the impact of local practices on household incomes and risks varies according to the specific context and locality. Nevertheless, efforts to promote more stable, efficient local practices are necessary to help to improve people's living conditions. In-depth analyses are needed to understand local dynamics in the context of diversification strategies (McCorda et al., 2015). Indeed, in this study, we focus on farm diversification, including perennial crops, subsistence crops, vegetables, fruit, and livestock on farms (Waarts and Kiewisch, 2021; Johny et al., 2017; Stilmant et al., 2019).

In our study, we examine farmers' diversification strategies, based on acreage management and each crop's income potential, and identify the socioeconomic factors influencing these strategies.

2 Materials and methods

2.1 Study area

The study was conducted in five regions of Côte d'Ivoire: Abengourou, Aboisso, Agboville, Divo, and Yamoussoukro (Figure 1). These are five out of the 13 regional divisions of the Ivorian Coffee-Cocoa Council (Gbongué et al., 2021). The council is the national regulator of the coffee-cocoa sector and its role is to ensure the management, control, and implementation of all activities relating to the Coffee-Cocoa Sector in Côte d'Ivoire these regions belong to the three main cocoa growing areas corresponding to the successive "loops" of cocoa production in Côte d'Ivoire (Adji et al., 2020). The so-called cocoa loops define the epicenter and shifts in cocoa growing areas. The East and South-East (Abengourou and Aboisso, Agboville) are characterized by a senescent orchard and a strong dynamic of

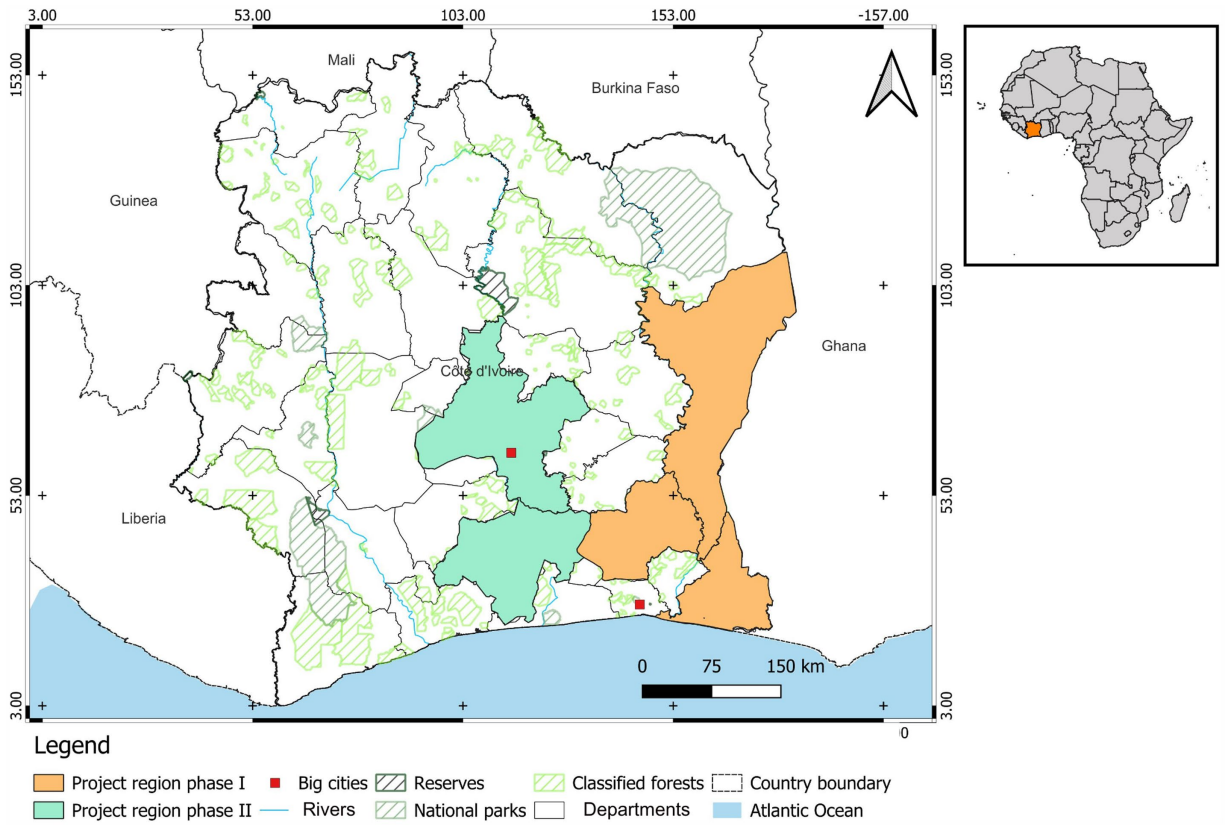

FIGURE 1
Project region, phases I and II.

diversification toward other perennial crops (loop 1), the Center zone (Yamoussoukro) is marked by the cessation of cocoa expansion, the aging of the orchard and a decline in soil fertility (loop 2), and the South-West zone (Divo) is characterized by expansion development of cocoa farming (loop 3). The study areas were chosen according to the three cocoa loops and their heterogeneous characteristics and where the diversification dynamic is increasingly strong. Diversification is a response to structural environmental degradation and also to the dynamics of production systems (Schroth and Ruf, 2014).

2.2 Data collection

To assess cocoa farmers' diversification models and related decision-making factors, a household survey of cocoa smallholders was conducted in June and July 2022. The survey focused on questions relating to good agricultural practices on farms, on-farm income, production costs, and training received. Data was also collected on farmers' management practices, associated crops, livestock, yields, and selling prices. Farmers were all members of cooperatives participating in the PRO-PLANTEURS project. The project aims to enable cocoa-producing families in selected areas of Côte d'Ivoire to improve their socio-economic living conditions and contribute to conserving natural resources through good agricultural training and technical support. The project is active in two different regions, whereby in one (project region A) activities started in 2015 and region B in 2020 with a total of 30,000 farmers linked to 46 cooperatives. For this study, a total of 303 households were randomly sampled from the baseline database of the PRO-PLANTEURS project (2020) for the first regions (Abengourou, Aboisso, and Agboville) with 13 cooperatives and 158 households – hereby region A – and from the list of cooperatives targeted by the second phase of the project in two new regions (Divo and Yamoussoukro) with 9 cooperatives and 144 households surveyed – hereby region B (Table 1).

In region A, we selected randomly four to six cooperatives depending on the number of available cases (Farmers interviewed in 2020) per cooperative. We randomly selected 20 households per cooperative, including a gender filter, if available, to include at least 6 women per cooperative. For some cooperatives, fewer than 20 farmers were represented in the baseline, so here only a smaller number of respondents could be selected. In the second region, cooperatives were sampled randomly based on the list of new cooperatives targeted by the project. Each cooperative was asked to gather about 15 farmers for interviews, including a range of young and older farmers, as well as men and women. The survey was conducted using the Kobo Toolbox, a free and open-source data collection tool, and performed in French by an international team of researchers that was supported by local research assistants who eased the introduction to the respective villages and provided translation to local languages as needed. Interviews averaged 45 min. Interviewees were informed about the purpose of the study and participated voluntarily.

2.3 Data analysis

Descriptive analyses of variables and statistical tests of regression are performed for this study. The production systems were further categorized and characterized into four categories guided by agronomic information related to land use and the distribution of plots for cocoa and other diversification products.

TABLE 1 Sampling procedure in the regions.

PRO-PLANTEURS regions	Number of cooperatives selected	*N* = 303
Agboville	5	*N* = 51 Men = 39 Women = 12
Aboisso	5	*N* = 60 Male = 55 Women = 05
Abengourou	3	*N* = 47 Men = 38 Women = 09
Divo	5	*N* = 75 Men = 63 Women = 12
Yamoussoukro	4	*N* = 69 Men = 61 Women = 8

2.3.1 Indicators of economic profitability

The economic analysis of diversification products took into account all agricultural products in the household production system (Kouadio et al., 2021; Assiri et al., 2012; Kpenavoun et al., 2018).

2.3.1.1 Mean annual yield of cocoa MAYC

The mean annual yield of cocoa trees corresponds to the ratio between the total cocoa production and the total area in hectares (kg an^{-1} ha^{-1}). It is given by the following Equation 1:

$$\text{MAYC}\left(\text{kg ha}^{-1}\,\text{an}^{-1}\right) = \text{Total cocoa production} / \text{Total area} \quad (1)$$

2.3.1.2 Production cost of cocoa

Although fixed costs are important, the production costs taken into account in this study are variable costs to avoid estimation bias (Impact Institute, 2022; Tyszler and Ríos, 2020). Variables costs represent expenditure on chemical inputs (insecticides, herbicides, fungicides), remuneration of occasional labor, and other expenses (harvesting, denting, transportation) in the 2021–2022 season. It is calculated following Equation 2:

$$\text{PC} = \sum \text{CV} \quad (2)$$

Where CV represents the variable costs related to expenses. It takes into account labor, inputs, application fees, and. Most producers remember monetary expenses but have difficulty estimating services. Thus, we monetized non-cash costs when producers reported having purchased food for an activity with a support group.

2.3.1.3 Mean gross income from cocoa production MGICP

This is the product of the total cocoa production and the mean purchase price per kilogram during the 2021–2022 season. It is given by the following Equation 3:

$$MGICP = \text{Total cocoa production}^{*} \text{ Purchase price} \quad (3)$$

Gross cocoa margin (GCM): The total gross margin (GCM) corresponding to the annual profit from cocoa production was determined from the annual cocoa income and the cost of production. It is given by the following Equation 4:

$$GCM = MGICP - CP \quad (4)$$

2.3.1.4 Gross income from other crops

The gross average income from products derived from the production system. For each product including livestock, the number and the quantity of product harvested per individual were reported. The prices attributed to the different sale units (bag, diet, bunch…) on the local market were applied to the quantities harvested by the farmers.

2.3.1.5 Mean total gross income of the farm MTGIF

Total gross mean income (MTGIF). This was determined from the mean gross income from cocoa production, the amount of prime cocoa received, and the other crops on the farm. It was calculated using the following Equation 5:

$$MTGIF = MFICP + GIOC + \text{Prime cocoa} \quad (5)$$

2.3.2 Statistical analysis

The measured and calculated parameters were subjected to descriptive analyses of the different variables. To better assess possible variations between the income from each product, the type of production system, and the region, variance analysis tests (ANOVA) were applied. The Tukey's multiple comparison test was then applied to identify the differences. For data without normality or homogeneity, the Kruskal–Wallis test was applied instead. The 5% significance level ($p = 0.05$) was chosen for all these analyses. The multivariate regression analysis between the socio-economic characteristics of the producer cocoa yield and income from diversification was applied. We used SPSS 25, XLSTAT 2014, and R 4.2.1. software programs.

The limitations of this study must be acknowledged, as the data was based on what farmers recalled about their experiences and practices. This reliance on memory introduces the possibility of recall bias, which can result in inaccurate or incomplete information. Specifically, farmers' recall of yields, prices received, components of past training, diversification revenues, and field sizes may be impacted by a variety of factors, including the amount of time that has passed since the events occurred. While the study provides valuable insights into farmers' practices, the results must be interpreted with caution and the limitations of relying on recall data should be taken into account.

3 Results

We analyzed diversification strategies adopted by the producers based on producer and farm characteristics: farm, household size, gender, type of production systems, and the diversity of crops from diversification. Results are presented in four sub-sections. First, in 3.1, we present characteristics of producers and production systems; subsequently, in 3.2, we analyze the diversification product managed by the producers; in 3.3, we assess income from diversification products, and, finally, we analyze household income from cocoa in 3.4.

3.1 Characteristics of the surveyed producers and their farms in the 5 regions of the study

3.1.1 Profile of the respondents

Table 2 presents an overview of the socio-demographic factors of the producers. Of the 303 producer interviewees, 25.1% were from Divo and the majority (85.1%) were male-headed households. Further, 62.5% of the producers are between 40–60 years old and 77.9% are Ivorian. The majority of producers are married (56.2%) while a small proportion is divorced (1.3%). Most – 34.6% – producers have at least a secondary education level and only 3.7% have Koranic education. In terms of labor used by the producers, 74.3% employ salaried workers versus 24.7% who use family labor. The mean household size is 8 people per household.

3.1.2 Structure of the farms

Producers have an average of two cocoa plots with an average of 4.3 ha. In addition to the cocoa area, most producers also have 2 plots for other crops with an average of 3.44 ha. Regarding land acquisition, seven types of land acquisition have been identified, of which acquisition by inheritance dominates (58.8%), against rental (0.4). Producers were asked whether their cocoa was certified, with 81.5% reporting certification, compared with 18.5% who were not. When we asked producers about the use of input and pesticides, 50% replied input in their cocoa system. Chemical fertilizer was applied by 45.53%, biofertilizers such as organic manure applied by 6.61%, and compost applied by 14.40%. Table 3 shows that 42.80% used fungicides, 91.05% insecticides, and 9.73 herbicides. As regards the cocoa cultivars, the majority of farmers surveyed have a mixture of different cocoa varieties, with All varieties (including the different types of cocoa cultivars on the farm whose names are unknown to the producers), Mercedes-All varieties, and Amelonado-All varieties being the most common (Table 3).

To analyze the diversity of agricultural products and management, four types of systems are classified according to the number of plots and the income from diversified products (Table 3):

- Type 1: Simple production systems where producers only produce cocoa with few shade trees, and no income from diversification (4% of producers).
- Type 2: Production systems in association with cocoa. These are systems where producers have a single cocoa plot but associate other crops and shade trees in the same cocoa plot either following intercropping strategies, as temporary shade plants, or on the edge of cocoa trees (25% of producers).
- Type 3: Production systems with crop extension generating income. These are systems where producers have cocoa plots and other plots for diversification (66% of producers).
- Type 4: Production systems with crop extension for household consumption. These are systems where producers have cocoa

10.3389/fsufs.2025.1524997

TABLE 2 Producers characteristics.

Variables		Region A	Region B	Total
Region	Abengourou	29.6	0	15.5
	Aboisso	38.4	0	20.1
	Agboville	32.1	0	16.8
	Divo	0	52.8	25.1
	Yamoussoukro	0	47.2	22.4
Gender	Men	83.6	86.8	85.1
	Women	16.4	13.2	14.9
Education	Secondary	34.4	34.7	34.6
	None	30.6	34.7	32.6
	Primary	22.9	27.1	24.9
	High school	6.4	2.1	4.3
	Koranic school	5.7	1.4	3.7
Producer age	20–40	12	24.5	17.9
	40–60	65.2	59.4	62.5
	60–80	21.5	16.1	18.9
	>80	1.3	0	0.7
Resident status	Ivorian	78.6	77.1	77.9
	No-Ivorian	21.4	22.9	22.1
Marital status	Married	45.2	47.2	56.2
	Concubinage	44.6	41	42.9
	Single	3.8	6.3	5
	Widowed	6.4	2.8	4.7
	Divorced	0	2.8	1.3
Labor	Family labor	15.1	35.5	24.7
	Salaried workers	84.9	64.5	75.3
Household size (Means±SD)		8.33 ± 4.81	6.74 ± 4.7	7.58 ± 4.82

**SD: standard deviance.

TABLE 3 Farms characteristics.

Variables		Region A	Region B	Total
Land acquisition	Inheritance	70.3	43.8	58.8
	Purchase	8.2	31.4	18.3
	Donation	13.3	16.5	14.7
	Work sharing	5.7	4.1	5
	First occupant	1.9	2.5	2.2
	Others	0.6	0.8	0.7
	Rental	0	0.8	0.4
Production systems $N = 301$	Type 1	4.4	4.23	4.32
	Type 2	21.38	28.17	24.58
	Type 3	69.81	62.68	66.45
	Type 4	4.4	4.93	4.65
Input $N = 257$		91.8	93.3	92.4
Chemical fertilizer		47.59	43.24	45.53
Biological fertilizer		6.21	7.21	6.61
Compost		11.03	18.92	14.4
Insecticides		91.72	90.99	91.05
Fungicides		48.97	35.14	42.8
Herbicides		5.52	15.32	9.73
Cocoa variety	All varieties	61.4	57.6	59.8
	Mercedes-all varieties	11.8	16.9	14.0
	Amelonado-all varieties	7.2	14.4	10.3
	Amelonado	9.2	3.4	6.6
	Mercedes	7.8	6.8	7.4
	Amelonado-Mercedes	2.6	0.8	1.8
Cacao plot number	Means±SD	1.65 ± 0.94	1.38 ± 0.71	1.52 ± 0.85
Cocoa area		4.84 ± 4.35	3.67 ± 2.82	4.3 ± 3.76
Others crops plot		1.6 ± 1.49	1 ± 1.05	1.31 ± 1.33
Others crops area		3.93 ± 3.82	2.58 ± 2.17	3.44 ± 3.36

**SD: standard deviance.

plots and other plots for diversification. The producer does not earn income from these plots but grows for household consumption only (5% of producers).

Farmers were asked to list the types of crops diversified in their systems. According to the four system types, type 1 systems are dominated by fruit trees acting as shade trees in a few densities. Type 3 is dominated by the adoption of perennial crops and livestock, while system 2 is dominated by shade and subsistence fruit trees (Figure 2). In addition to cocoa, the producers surveyed cultivate other crops for sale and/or domestic consumption, depending on gender (Figure 3). Perennial crops, such as rubber and palm oil, are the most produced and most adopted by men. Income from perennial crops is mainly (89%) managed by men (Figure 4). Vegetable and food crops are associated with cocoa in its young development cycle to allow the young cocoa tree to resist the effects of the sun and, at the same time, to protect the soil. As far as subsistence crops are concerned (Figure 3), cassava (92%) and maize (78%) are adopted more frequently by women than men; men tend to raise bananas (91%) and rice (43%). Most household heads (44%) manage income from subsistence crops. Vegetable crops, like tomatoes, peppers, and eggplant, are often produced on small separate areas of fields or in association with yams on new land for cocoa. Of the vegetable crops, eggplants are the most adopted by women (Figure 3). These crops are mainly managed and sold by the wife of household heads (Figure 4). Fruit trees are also a type of agricultural production for households. Fruit trees are mainly located within cocoa plots as part of an agroforestry system and are consumed by farm household members and/or sold locally. Of the fruit trees, orange and avocado are the most common in the production systems (Figure 3). In the majority of households (50%), the head's wife is responsible for selling the fruit and managing the income (Figure 4). Cocoa producer households also raise livestock for their consumption and occasionally for sale. This practice is more

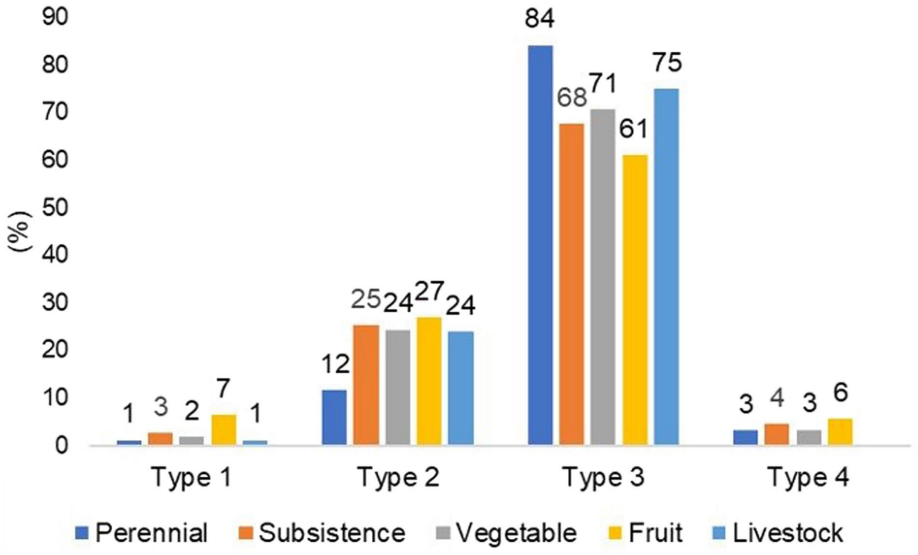

FIGURE 2
Diversification products adopted by production systems.

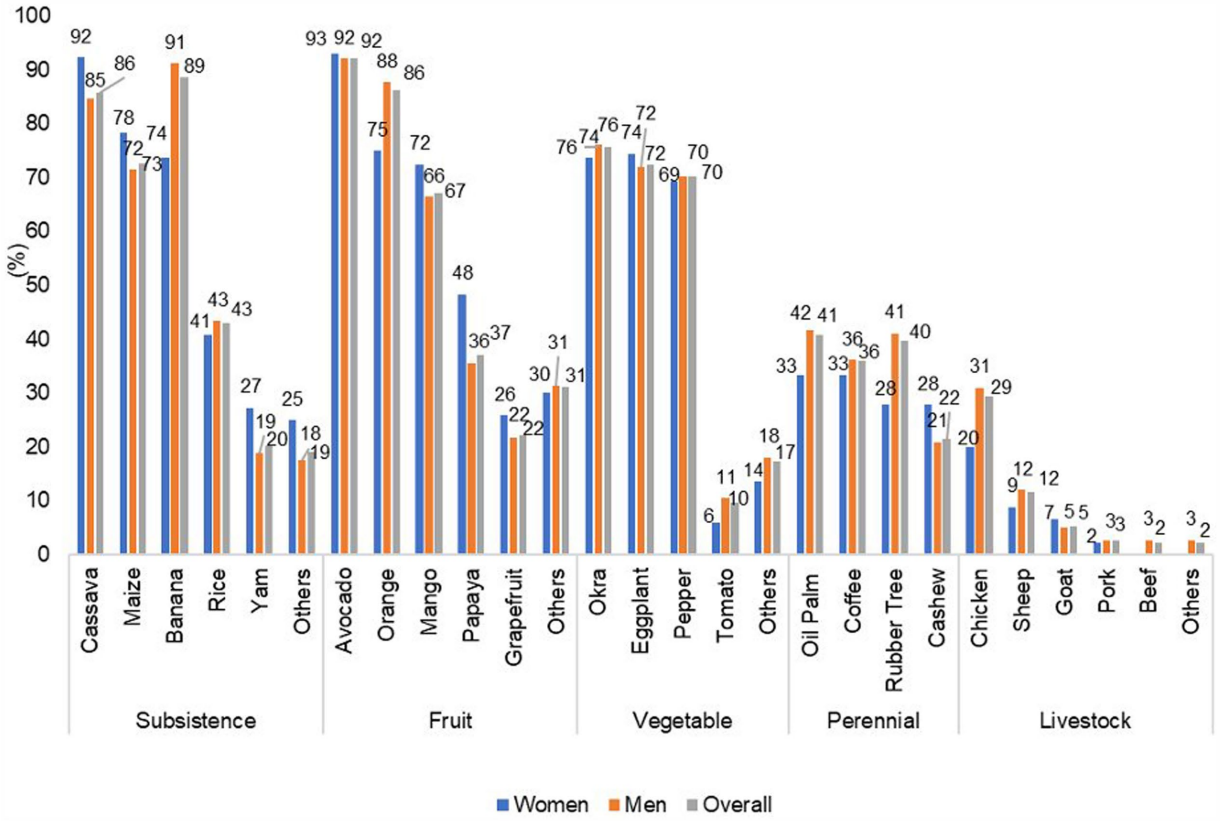

FIGURE 3
Overview of diversification products adopted by producers according the gender.

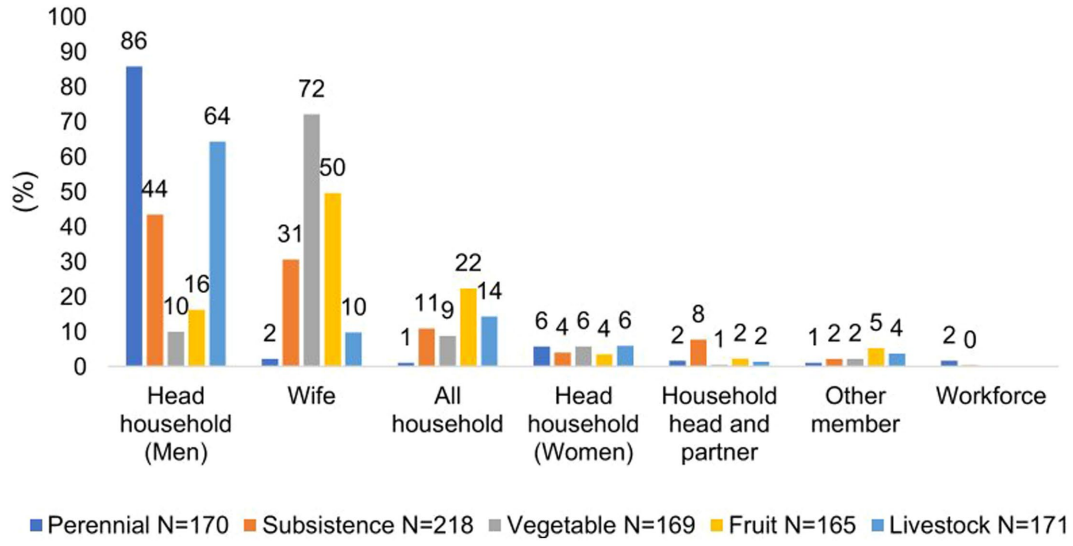

FIGURE 4
Income management of diversification products by household members.

adopted by men; except among the goats, where women are more dominant. In terms of livestock income management, male household heads (64%) are the main managers (Figure 4).

3.1.3 Distribution of diversification products in the production system

Diversification products adopted by production systems shown in Figure 2

3.1.4 Distribution of diversification products by gender

Overview of diversification products adopted by producers according the gender shown in Figure 3.

3.1.5 Share of household self-consumption and commercialization

Self-consumption applies mainly to subsistence crops, vegetables, fruit, and some livestock products. Although most crops are produced for self-consumption, in addition to perennial crops, subsistence crops are also produced for commercialization purposes (Table 4).

3.2 Diversification products managed by the producers

3.2.1 Certification and access to finance

Farmers were invited to answer a series of questions about cocoa certification and access to finance (Table 5). Most cocoa farmers (94%) depend on agricultural activities for their income, of which 79.86% are directly dependent on cocoa production, versus 14.13% of producers who depend on income from other crops (Table 5). In region B, 84.92% of producers depend on cocoa income. On the other hand, 17.20% of producers in region A depend on income from other crops. In parallel to the income generated by household farming systems, producers were asked about access to formal and informal financial credit (Table 5). The results show that only 38% of producers use financial credit, with a significantly higher proportion in region A (46.3%). For the source of financial credit, 62% of farmers take out loans from their cooperatives, compared with 7% from formal financial institutions (Table 5). The largest share of these financial loans is allocated to children's schooling (56.8%) and agricultural inputs (13.1%).

3.2.2 Management of diversification products by household members

Producers were asked to determine responsibility according to the type of diversification products and the family members involved. The head of the household mostly takes decisions on diversification products. However, family members contribute to the production and financial management of these diversification products.

3.3 Income from diversification products

Farmers were implicated in their gross income from agricultural products other than cocoa and, due to incomplete data or imprecise responses, only products for which respondents provided information are considered in this section. The results allow us to gain knowledge about the range of gross incomes that can be earned by cocoa producers with different crops, based on the quantities sold excluding production costs. Table 6 highlights the household income from diversification products in US$ according to the production system, gender, and producer origin. Regarding the production systems, Type 3 generates more income from diversification products, with significant differences between systems except for income from fruit. Similarly, for gender, men generate more income from diversification, with significant differences between systems, except income from fruit.

In terms of income from diversification products by producer origin, we observe that, except for fruit, non-Ivorians generate more income than nationals, with significant differences in perennials, subsistence, and livestock (Table 6).

10.3389/fsufs.2025.1524997

TABLE 4 Household self-consumption and commercialization by agricultural products (frequency of citation).

Agricultural products		Consumption %	Commercialization %
Perennial $N = 121$	Palm oil	34	85
Subsistence $N = 202$	Rice	100	17
	Cassava	94	40
	Banana	93	40
	Maize	91	34
	Other	94	11
Vegetable $N = 105$	Eggplant	100	23
	Pepper	100	22
	Cabbage	100	0
	Okra	97	28
	Other	95	1
Fruit $N = 108$	Orange	100	24
	Mango	100	0
	Avocado	99	21
	Papaya	97	0
	Other	98	1
	Grapefruit	0	0
Livestock $N = 156$	Chicken	33	22
	Sheep	14	15
	Guinea fowl	0	0
	Pork	0	0
	Beef	0	0

3.3.1 Household income from diversification products by production system and region

Of the four types of production systems identified in this study (Figure 5), the production system of type 3 generated the highest income (US$1869 per household), while the production system of type 2 generated the lowest income (US$716 per household). According to the average area, the producers of the production system of type 3 have a large area of non-cocoa crops (4 ha), while the producers of production systems of type 4 show a smaller area (3 ha). In terms of household size, production system type 3 has a larger average household size (8 members per household) than production system type 1 and type 2 (6 members per household). According to the estimated income from diversification products following the region and the production system, the producers of region A generate more income from type 3 (US$2261 per household) than the producers of region B, where type 2 generates the greatest income (US$844 per household).

3.3.2 Results of multivariate regression analysis of diversification and socio-economic characteristics

It is hypothesized that income from diversification products varies according to producer characteristics. The multivariate regression analysis aims to identify those factors that explain and drive production performance income for each crop (Table 7). The regression analysis between area and perennial crop income and livestock shows a significant positive relationship, which means that as area increases, so does perennial crop income ($p = 0{,}0001$) and so does livestock income ($p = 0.004$). The adjusted R-squared of 0.42 indicates a moderate relationship and that approximately 42% of the variation in the income of perennial is explained by the producers and the farm characteristics listed, while 58% of the variation in the income of perennial is explained by other factors, such as price. However, only 10% of the variables explain the income of livestock variation. The significant positive relationship with total diversification income could be explained by the large share of perennial crop income in diversification income and only 47% of the variables listed explain the income of diversification variation.

As for income from subsistence crops, a positive relationship was observed with access to credit ($p = 0.03$) and region ($p = 0.02$). This explains that farmers with access to credit according to agroecological region have more income from subsistence crops and invest more in subsistence crop production. However, only 13% of the factors listed explain this relationship, the remaining 87% of this variation is due to other factors (Table 7). Additionally, the type of labor and income from perennial crops show a positive relationship ($p = 0.05$), which means that households in this study with a workforce have more income from perennial crops (Table 7). Concerning gender, we noted a positive relation with income from total diversification ($p = 0.01$). This result suggests that the men in this study have more income from diversification. This can also be explained by the significant contribution of income from perennial crops to total diversification income, of which men are the main producers (Figure 4).

10.3389/fsufs.2025.1524997

TABLE 5 Certification and access to finance.

Variables		Region A	Region B	Total
Cocoa certification	No	11.6	27.6	18.5
	Yes	88.4	72.4	81.5
Access credit	No	53.7	70.3	62.1
	Yes	46.3	29.7	37.9
Principal source of revenue $N = 283$	Cocoa	75.8	84.92	79.86
	Others agricultural products	17.2	10.32	14.13
	Commercial and artisanal activities	3.82	3.17	3.53
	Money transaction	0.64	0	0.35
	Others	2.55	1.59	2.12
Credit source $N = 100$	Bank institution	10	2.5	7
	Cooperative	66.7	55	62
	Family	18.3	30	23
	Other	5	12.5	8
Credit purpose $N = 99$	Education	47.7	76.3	58.6
	Health	24.6	13.2	20.2
	Agricultural input product	14.8	10.5	13.1
	Other	13.1		8.1

3.4 Cocoa production

3.4.1 Cocoa yield and costs

From cocoa production to the commercialization of cocoa beans, producers invest to obtain a high cocoa yield. The average cocoa yield in our study area is 519.1 ± 338.11 kg ha − 1. The highest level of productivity recorded was 1727 kg/ha and the lowest reported productivity was 62.5 kg ha − 1. Productivity is overall higher in the A regions, with 524.63 kg ha − 1, compared with 511.46 kg ha − 1 in the B regions. According to the production system, type 2 yields more cocoa (553.34 ± 362.67 kg ha^{-1}) while type 4 (434.13 ± 141.25 kg ha^{-1}) yields less cocoa. Regarding the origin of producers, non-Ivorians have greater cocoa yields than Ivorian producers (586.53 ± 384.62 kg ha − 1). In terms of distribution, 38.21% of growers have yields between 500 and 750 kg ha − 1/ha, and only 7.72% have yields between 250 and 500 kg ha − 1 (Table 8).

Concerning the cost of cocoa production for the 2021–2022 season, the costs related to production from cleaning to the point of sale are presented in Table 9. These include costs of packaging, fertilizer, crop protection products, herbicides, pruning, cleaning and harvesting equipment, labor, and other miscellaneous costs. The production costs of cocoa plantations averaged US$150.23 ha^{-1} with most attributable to labor costs (US$ 120.44 ha^{-1}); packaging and pruning are the least expensive component (US$11.39 ha^{-1}).

TABLE 6 Estimated income from diversification products (US$) according to production systems, gender, and origin of the producer.

Variables	Perennial		Subsistence crop		Vegetable		Fruits		Livestock		Total diversification	
	Mean	*p*-value	Mean	*p*-value	Mean	*p*-value	Mean	*p*-value	Mean	*p*-value	Mean	*p*-value
Type 1	0	< 0,0001	0	< 0,0001	0	0.0010	0	0.0008	0	< 0,0001	0	< 0,0001
Type 2	32.03 ± 133.40		207.29 ± 22,536		54.60 ± 135.76		25.25 ± 52.71		396.76 ± 1503.8		715.93 ± 1541.23	
Type 3	857.7 ± 2115.32		374.94 ± 624.49		190.9 ± 794.86		22.59 ± 52.9		422.73 ± 1013.7		1868.85 ± 2984.11	
Type 4	0		0		0		0		0		0	
Men	677.92 ± 1900.72	< 0,0001	317.78 V561.4	0.266	149.51 ± 702.51	0.769902	24.24 ± 54.30	0.0028	426.05 ± 1195.97	0.005	1595.5 ± 2803.74	< 0,0001
Women	8.04 ± 30.64		199.47 V323.38		87.68 ± 246.1		4.014 ± 11.5		107.53 ± 344.95		406.73 ± 644.17	
Ivorian	526.04 ± 1852.78	< 0,0001	264.36 ± 494.7	0.351	119.22 ± 510.5	0.583	21.96 ± 52.64	0.915	300.35 ± 1049.75	< 0,0001	1231.92 ± 2458.71	0.000
No Ivorian	762 ± 1426.811		427.33 ± 642.95		215.2 ± 1016.8		18.56 ± 43.74		656.45 ± 1297.7		2079.52 ± 3101.55	

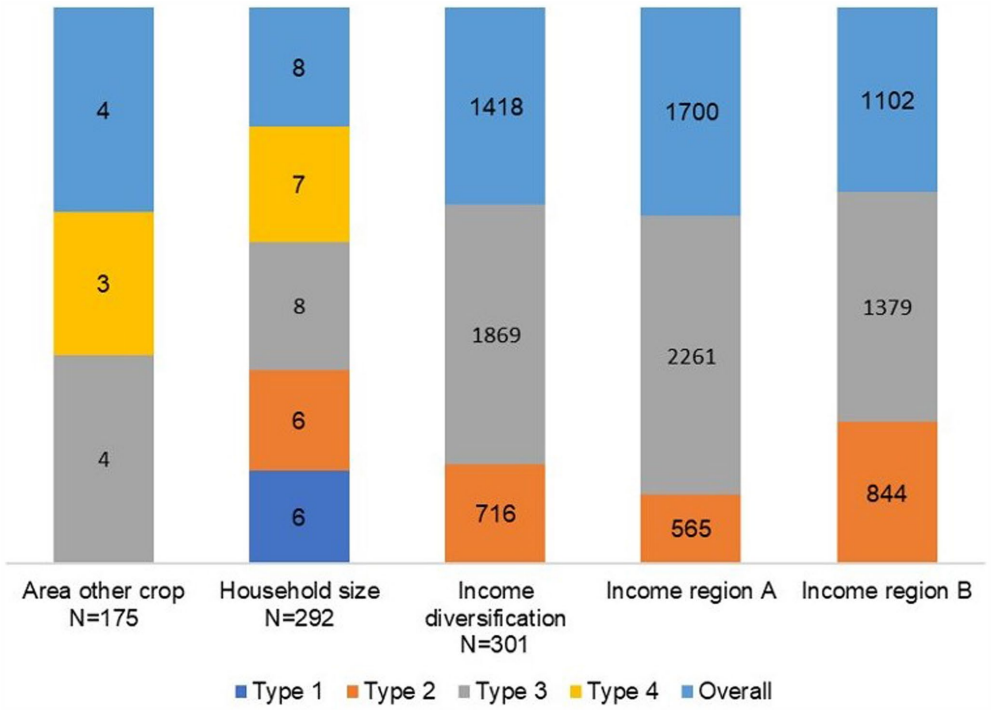

FIGURE 5
Production system and share income from diversification (US$).

3.4.2 Multivariate regression analysis of producers and farm characteristics on cocoa yield and costs

Multivariate regression analysis was used to identify those factors, such as producer and farm characteristics, that influence cocoa yield and production costs (Appendix). The results show a significant relationship between cocoa profit and cocoa area ($p < 0.0001$). This result suggests that larger cocoa plots provide more income. From the cocoa coast, only 36% of the variables listed in this study explain the variation. Thus, 64% of this variation is possibly due to other factors such as good climate and soil quality. So far, we noted that the cocoa yield increased with the use of chemical fertilizer and according to gender ($p = 0.0029$; $p = 0.002$). Regarding household size, and access to credit, we observed a positive relationship with cocoa production costs, respectively, ($p = 0.008$; $p = 0.053$). This result suggests large households' size, producers with access to credit tend to have more cocoa costs during cocoa production. This can be explained by the fact that, in addition to cocoa costs, the household must buy food for all its members during the cocoa activities while the credit allows producers to acquire the phytosanitary and labor needed to improve cocoa production.

4 Discussion

4.1 Producers' and farms' characteristics

Most surveyed producers are men (85.1%) versus women (14.9%). Indeed, several studies identify and discuss gender inequalities, such as differences in women's participation rates in cocoa production activities (Bymolt et al., 2018; Adou Yao et al., 2016). Across all regions, the majority of surveyed cocoa farmers (62.7%), are between 40 and 59 years old, in line with the averages ranging from 45 to 54 found in the literature (Bymolt et al., 2018). Correspondingly, there is a low proportion of young farmers aged 20 to 39 years (18%). This low rate of youth could also be explained by the movement of young people to urban areas. This assertion is confirmed by Kouassi et al. (2021) and Reinecke et al. (2012), who emphasize that the exodus of young people is due to problems with access to school education, the fact that there are no opportunities to learn a trade, and the low wages in the villages.

The results show an average area of 4.3 ha dedicated to cocoa, in line with the findings of Ruf et al. (2020), who estimated an average area of 4.6 ha dedicated to cocoa, and 4.4 to 5.7 ha found by Kouassi et al. (2023). It should be mentioned here that slight differences can be attributed to potential over or underestimation by farmers, mainly due to a lack of knowledge of the size of their plots. However, the average size of cocoa plots in our study area is larger than in other major cocoa-producing countries: 2.3 ha in Nigeria, 3.3 ha in Cameroon, and 1.5 ha in Indonesia (Fountain and Huetz-Adams, 2022).

4.2 Diversification strategies

The diversification strategies adopted and analyzed in this study depend on local conditions, available markets, and farmer preferences. Our analysis shows that women adopt more subsistence crops in their systems than men. As far as income, men have more income from subsistence crops than women. This could be because men, having

TABLE 7 Results of multivariate regression analysis of diversification and producers' socio-economic characteristics.

Dependent variables	Perennial		Subsistence		Vegetable		Fruits		Livestock		Total diversification	
Explanatory variables	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value	Coefficient	*p*-value
Number others plot	−0.037	0.971	1.817	0.071	0.676	0.500	−0.139	0.889	−0.344	0.731	0.474	0.636
Area others plots	8.02	< 0,0001	0.41	0.68	0.00	1.00	0.81	0.42	2.92	0.00	8.47	< 0,0001
Household	−1.17	0.25	1.81	0.07	0.71	0.48	1.33	0.18	0.80	0.43	0.42	0.68
Labor (laborer = 1 family labor = 0)	−1.96	0.05	1.78	0.08	1.98	0.05	−1.04	0.30	0.27	0.79	−0.97	0.33
Gender (men = 1 female = 0)	−0.66	0.51	1.90	0.06	0.64	0.52	1.40	0.16	1.25	0.22	0.01	0.99
Education (koranic = 0 none = 1 2 = primary 3 = secondary 4 = high)	0.99	0.32	−0.81	0.42	−1.26	0.21	1.00	0.32	−1.24	0.22	−0.07	0.94
Credit (yes = 1 no = 0)	0.63	0.53	−2.21	0.03	−1.28	0.20	0.22	0.82	−0.70	0.49	−0.44	0.66
Region (A = 1 B = 0)	1.23	0.22	−2.38	0.02	−0.93	0.35	−1.22	0.22	0.01	0.99	0.41	0.68
R^2	0.42		0.13		0.04		0.06		0.10		0.45	

10.3389/fsufs.2025.1524997

TABLE 8 Average cocoa yield (kg ha^{-1}).

Variables		Mean	Minimum	Maximum
Region	Region A	524.63 ± 315.41	62.5	1727.27
	Region B	511.29 ± 369.24	70	1700
	Overall	519.1 ± 338.11	62.5	1727.27
Production systems	Type 1	504.02 ± 272.64	257.5	900
	Type 2	553.34 ± 362.67	85	1,625
	Type 3	512.84 ± 340.58	62.5	1727.273
	Type 4	434.13 ± 141.25	160	637.5
Producers' origin	Ivorian	494.88 ± 317.44	70.00	1727.27
	No Ivorian	586.53 ± 384.62	62.50	1625.00
Cocoa yield interval	Producers' percentage	Region A	Region B	Overall
	0–250	19.44%	26.47%	22.36%
	[250–500]	4.86%	11.76%	7.72%
	[500–750]	38.19%	38.24%	38.21%
	[750–1,000]	22.22%	17.65%	20.33%
	>1,000	19.44%	26.47%	22.36%

TABLE 9 Cost of cocoa production and net income.

Cocoa production (US$ ha^{-1})	Minimum	Maximum	Mean	Standard Error
Cost of packaging	0.54	362.20	11.27	0.60
Cost of fertilizers	0.04	563.42	63.03	0.46
Cost of phytosanitary products	0.07	1593.66	37.07	0.36
Cost of cocoa pruning	0.03	88.22	11.39	0.78
Cost of materials	0.08	165.08	16.40	0.41
Others cost	1.61	364.88	18.94	0.65
Cost of herbicides	1.88	40.24	12.40	1.18
Labor costs	0.08	1663.41	120.44	0.37
Overall costs	0.03	1910.78	150.23	0.31
Price cocoa high season (US$kg^{-1})	0.16	1.61	1.42	0.30
Price cocoa light season (US$kg^{-1})	0.64	1.61	1.20	0.30
Net income (US$ha^{-1})	−981.15	3427.98	538.37	0.32

better access to land, invest more in diversification crops, enabling them to get a better profile and higher yields. Additionally, in most cases, male-headed households have better access to labor and agricultural credit, allowing them to cultivate a larger land area and diversify their crops. In the Ivorian context, most land is acquired through inheritance and this acquisition option limits women's access to land. On the other hand, as women are largely responsible for domestic work and childcare, they have less time to devote to their farming activities and to get the best out of them. Our results corroborate those of Kouassi et al. (2023), who report that women adopt diversification for household food security. Improved access to resources, particularly land, can strengthen women's autonomy and socio-economic status in their households, also increasing their interest in more profitable activities [Food and Agriculture Organization (FAO), 2023]. In the production system, both men and women are involved in household food production, but their roles are different following the crops (Bah and Laven, 2019). In this study, we examine household member differences in income management of crops other than cocoa. The results show that within the household, women are more likely to manage income from subsistence crops, vegetables, and fruit, while men are more likely to manage income from perennial crops and livestock. As expected, food crops are the most widely grown, followed by fruit trees, vegetables, and, finally, perennial crops. This trend can be attributed to the greater emphasis that rural women place on household food security, prioritizing the management of income from subsistence crops to ensure the availability of food for the family and additional income. These same observations were also made by Bah and Laven (2019). Moreover, managing income from subsistence crops can give women a degree of autonomy. However, it should be noted that within male-headed households, women also participate in cocoa production and are often responsible for growing other crops, so these results should be interpreted with caution (Bymolt et al., 2018).

Regional differences were also observed in the choice of crops. Cassava and plantain are grown by over two-thirds of farmers in both regions. This demonstrates how households adopt diversification as a strategy to ensure household food security and additional income. This confirms the result of Waarts and Kiewisch (2021) as well as Bah and Laven (2019), who argue that subsistence crops are of high importance to farming households. These results are supported when we look at crop distribution by gender. We can see that type 2 and 4 systems are used more for subsistence crop production and are kept mainly by women. Additionally, as these systems are, on average, small, this means that women with no access to land grow substance crops intercropped with cocoa or in small areas near the cocoa plot. Depending on the origin of the growers, non-Ivorian growers have much higher incomes than Ivorian growers. Non-Ivorian producers who have migrated to work in production systems are likely to be better able to manage the plots of land entrusted to them and, thus, diversify to a wider range of crops (Kouassi et al., 2021; Ruf et al., 2020). Having access to the land through leasing or shared plots, alongside having a longer time to use the land, they might devote more effort to producing more profitable crops for more profitable profits. Non-Ivorian producers may be more open to innovation and more willing to take risks in adopting new crops, which can lead to productivity and income gains. Concerning the socio-cultural structure and division of labor of households, in the majority of cases, all family members of non-Ivorian producers actively participate in production system activities. This type of system management could be at the root of the increase in productivity and, therefore, income. Region A seems to be characterized by farmers growing perennial

crops, like rubber and coffee, at a considerably higher level than region B, which grows more palm oil and cashew nuts. It could be explained by the fact that, as a result of the old age of the cocoa plantations and the disease attacks suffered by cocoa plantations in this region (First cocoa loop), producers have turned to other cash crops, such as rubber and palm oil. This expansion can also be seen in terms of acreage, where growers in region A have large areas of perennial crops, managed mainly by men. Ruf et al. (2019) already point to an increase in cashew cultivation in the Centre-West cocoa-growing regions in response to climate variability. Kouassi et al. (2023) also reports that, due to the challenges of cocoa farming, some producers are converting their cocoa plantations to alternative crops such as palm oil.

More than half of the farmers surveyed derive their main source of income from cocoa production and 14.13% from other crops, compared with 6% who derive their main source of income from non-agricultural activities. This rate is lower than that of Ochoa et al. (2019), who report a rate of 28% of Ecuador cocoa producers who derive their income from non-agricultural activities. However, the income from diversification per household remains significant as additional income. The different diversification strategies adopted by the producers of the study demonstrate that cocoa provides insufficient income to cover household needs (US$538.37 ha^{-1} $year^{-1}$). The study also shows that the income from the diversification of cocoa producers evolves according to the type of diversified products. This contribution of income from agricultural products other than cocoa could reach or exceed that of cocoa when limitations linked to the marketing of these products and investment limitations for these products are overcome. Waarts and Kiewisch (2021) and Bymolt et al. (2018) argue that the solution for farmers to break free from cocoa dependence is a result of low cocoa incomes due to low and unstable farm gate prices and low levels of productivity. When analyzing the income from diversification products by the production system, perennial crops generate more income per household than the income from fruits in both regions. This can be explained by the fact that perennial crops, in addition to being produced in monocultures over large areas, generate a regular income throughout the year. For example, rubber trees are harvested monthly, and palm oil every four months. Also, the significant gain in perennial crops, such as rubber and oil palm, could be due to the organization of points of sale and the fact that purchase prices are controlled by the buying society. Tano (2012) states that these perennial crops seem to be more profitable and provide more stable incomes than cocoa. The diversification of income streams through additional products from intercropping trees or food crops contributes to farmers' livelihoods (Kouassi et al., 2023).

4.3 Cocoa production

In terms of cocoa production, the average yield for this study was 519.1 ± 338.11 kg ha^{-1}, which is a little higher than the estimated national average of 498 kg ha-1 for the 2021 season (FAOSTAT, 2021). However, 22% of producers in our study achieved the commonly cited potential yield of 1,000–1900 kg ha-1 (Bymolt et al., 2018), which expresses a clear margin of potential yield increase for the rest of the surveyed farmers. This performance of 22% of the sample could be explained by the producer's participation in good agricultural practices training (75.8%), while Bymolt et al. (2018) note that only 17% of farmers in Côte d'Ivoire received training on cocoa farming. Good practices influence cocoa yields when inputs, maintenance, proper harvesting, and fermentation are correctly applied at the appropriate time (Kouassi et al., 2023; Makhloufi et al., 2018). The average yield in our study is higher than what Kalischek et al. (2023) found for Ghana (320 kg ha^{-1}) as well as what Kouassi et al. (2023) found in western Côte d'Ivoire. Nevertheless, the average cocoa production in our study area is lower than that found by Jagoret et al. (2017) in Cameroon (737 kg ha^{-1}). Differences in yields can be explained by the fact that Jagoret et al. (2017) assess the potential yield by counting and weighing cocoa nuts on the plantation while our work assesses self-reported yield through surveys. Self-reported yields are easier to collect in larger surveys but show limitations in terms of assessing agricultural losses and recall biases that can lead to over- and under-estimations. Furthermore, the regional difference was observed in terms of cocoa yield. In region A, the first cocoa loop characterized by aging cocoa systems with low yields presents higher yields than region B. The low yield of region B could be explained by the fact that it includes an area (loop 2), where low yields are reported due to the cessation of cocoa expansion, the aging of the orchard, and the decline in soil fertility (Kouadio et al., 2021; Adji et al., 2020). Additionally, the low yield can be due to the cocoa diseases perceived by 19.41% of the producers in region B. According to the production system, type 1 production systems (504.02 ± 272.64 kg ha^{-1}), considered in this study as single production systems, should have higher cocoa yields than the type 2 system an associated (553.34 ± 362.67 kg ha^{-1}). However, several studies show that simple cocoa systems have a higher yield than association systems. Simple systems have a higher yield than association systems when the Mercedes or full sun variety is adopted, followed by the application of synthetic fertilizer and good practices (Assiri et al., 2012; Kouassi et al., 2021; Kouadio et al., 2021). Indeed, the similarity of cocoa yields between the different production systems could be explained by the homogeneity of the variety combination adopted by producers. Varietal heterogeneity within cocoa plots makes it difficult to isolate the effect of each variety on yield. An experimental approach, controlling for variation factors, will be necessary to establish a clear link between the cocoa yield and the cocoa variety. Furthermore, the high yield of type 2 could be explained by the fact that intercropping promotes better soil health and also by the diversity of species that, by decomposing their leaves, fruits, or other organs, produce humus in the soil, creating nutrient availability for cocoa trees. This idea is supported by Dumont et al. (2014) and Orozco-Aguilar et al. (2021), who mentions that trees and crops associated with cocoa have a good capacity to improve the soil and create a favorable humid environment. Madountsap et al. (2020) also mention the ability of intercropping trees to control diseases through biocontrol and, thus, reduce pest-related yield losses.

4.4 Distribution of cocoa production costs and net income

The production costs of our study area (US$150.23 ha^{-1}) are much higher than the production costs (US$68.09 ha − 1) found by Kouadio et al. (2021). This high cost of production could be explained by the increase in the cost of inflation, thus leading to an increase in the price of inputs and labor (Bermudez et al., 2022). In addition, promoting the use of agricultural products that respect the environment could be the reason for high chemical prices on the market. Similarly, the

production costs are lower than those found by Krain (2022) in a recent study on modeling the income of cocoa production in the same (US$199.6 ha^{-1}) area as our study. This difference in high costs could be explained by the fact that the producers may not have been able to buy the same quantities of inputs and hire the same amount of labor due to the high costs of the products on the market and of the local services. Moreover, the real income is lower than that found (US$590 ha^{-1}) by Krain (2022). However, net income is influenced by production costs and the average selling price (True Price, 2018; Assiri et al., 2012). This difference in income could be explained by the difference in purchase prices. According to Ingram et al. (2018), low cocoa purchase prices hurt household income and can lead producers to "put to sleep" their cocoa plantations; that is to say, to abandon them completely or temporarily, or else, stop monetary investments. The positive relationship between production costs and cocoa area indicates that households with larger areas spend more in terms of producer costs. This specifically includes costs in terms of salaried labor and pesticides. In addition, there is also a significant positive relationship between area and cocoa income, which could be explained by the fact that the larger the farm, the more resources are required in terms of labor and other inputs, and the greater the yield. Thus, the results of this study suggest that there is no statistically significant relationship between cocoa area and cocoa yield, but rather between production costs and yield. As for the non-significant effect of farm size on yield, this could be explained by the fact that not all declared production areas may be used for cocoa production due to the lack of labor. Additionally, a lack of access to finance can lead to low cocoa yields due to a lack of investment.

In terms of access to finance, 38% of producers surveyed have access to finance, with only 7% loans from banks, compared with 27% of producers who have loans from national banks in Ochoa et al. (2019). Of this rate, few producers use their loans to purchase products for cocoa production. Once again, this shows that more needs to be done to facilitate producers' access to finance, enabling them to better invest in their production systems. Access to finance allows farmers to invest in quality inputs, such as fertilizers, pesticides, tools, and labor at the right time to enhance productivity and quality. Thus, with adequate finance, farmers can add value to their products through the processing of diversification products (tomatoes, bananas) thereby diversifying their sources of income (Johny et al., 2017; Alobo Loison, 2015). The positive relationship between the use of insecticide and yield also reflects the high incidence of disease in cocoa systems, which means that more insecticides were applied. When it comes to the positive relationship between yield and compost use, the first thing to note is the effectiveness of the compost applied by the producers, thus contributing to the sustainable production of the systems. Additionally, given the high cost of inputs cited by more than half of the respondents, producers are taking the initiative, in addition to training in good farming practices, to produce their fertilizers, making them innovators.

Optimized fertilization and pest control are the pillars of recommended farm management practices. Survey results show that almost all farmers apply fertilizers and use insecticides on their farms. The rate of farmers using fertilizers is high compared to results found in secondary literature, which estimate that between 16 and 37% of Ivorian cocoa farmers use fertilizers in their fields (Bymolt et al., 2018; Ruf et al., 2020). Balineau et al. (2016) also point out that if the majority of farmers do not use them, it is mainly due to a lack of financial means. Concerning pesticides, Bymolt et al. (2018) results for the use of insecticides and fungicides are also lower with producer rates of 75 and 15%, respectively, while herbicide use is higher with 32% of farmers. Raising awareness and strengthening training programs can improve farmers' knowledge of the benefits and appropriate use of agricultural inputs.

5 Conclusion

Ensuring household needs is a challenge facing cocoa farmers. This study shows how diversification strategies enable cocoa farmers to diversify their income and to adapt in the face of cocoa challenges. Perennial, food, vegetable crops, fruit, and livestock are the main forms of diversification, reflecting households' efforts to adapt to the uncertainties of the cocoa market and strengthen their resilience. Diversification generates additional household income for producers, showing that cash crops are the most important income source from diversification. Producers in our study area manage their systems for yield and income complementarity according to their objectives and land availability. Taking into account producers' objectives, preferences, and constraints in diversification can help develop strategies and policies to support diversification strategy decisions. Study results show producers with limited land access are adopting intercropping strategies to improve their cocoa production, as well as growing crops in association with other farmers, which generates significant annual income. Despite women's limited access to land, they use the small areas at their disposal for crop production, especially food crops, and thus potentially contribute to household food security. Although the cash crops included in diversification generate higher incomes, we note that producers in the area primarily invest financial credits in subsistence crops. Another important point to emphasize is that non-Ivorian producers are getting by with very high cocoa yields and income from diversification. Land tenure allows migrant farmers to make investment decisions without fear that they might weaken their hold on their land. Male-headed households with low-yield cocoa, produce more perennial crops while women adopt more food crops. However, food crops, in addition to household consumption, are marketed and also generate considerable additional income. The average cocoa yield in this study is still higher than the national average for the past few years. This could be attributed to the growing adoption of good farming practices. Our results underline that intercropping systems present the best cocoa yields. Despite these good practices, farmers cited the spread of pests and diseases, climate variability, and high input prices as the main threats to yields. Additionally, limited access to agricultural inputs and markets, as well as to agricultural credit, are major challenges for cocoa farmers. Further analysis of the type of land allocation and work time, the real value of shade trees on the farms, and the share of self-consumption could provide a better understanding and knowledge of producer profitability. Diversification strategies do not appear to significantly improve income from cocoa production in the systems observed. It is therefore recommended that cocoa farmers in Côte d'Ivoire, when renovating or restoring their old plantations, opt for sustainable cocoa varieties that are better adapted to the current challenges of integration into diversified farming systems. Co-learning of knowledge could be facilitated between producers of diversified cocoa plots and other

producers with lower diversification rates in each locality. It can enable farmers to share their experiences and best practices, leading to the adoption of more efficient and sustainable farming methods and reducing costs. Also, by working together, farmers can collectively address challenges such as climate variability, pests, and market fluctuations. Policies should aim to encourage producers to have easier access to credit for more diversification into food crops, to guarantee food security. Further studies could explore the market influence of diversification products and their impact on household income. Our work contributes to recent research on household strategies to increase resilience in cocoa production systems.

Data availability statement

The datasets presented in this article are not readily available due to concerns regarding participant/patient anonymity. Requests to access the anonymised participant data should be directed to the corresponding author.

Ethics statement

This study was approved by the University Félix Houphouët-Boigny (Côte d'Ivoire), Ref, and approved the study protocol: no. 642/MESRS/UFHB/UFRBIOS. Participation in the study was voluntary. All the research participants gave their informed consent to participate in this study.

Author contributions

BT: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. CC: Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. FM: Writing – original draft, Writing – review & editing. CY: Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. SS: Funding acquisition, Writing – review & editing. KL: Funding acquisition, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This work is conducted in the frame of the PRO-PLANTEURS Recherche project funded by the German Ministry of Economic Cooperation and Development (BMZ). The findings and conclusions contained within are those of the authors and do not necessarily reflect the positions or policies of the BMZ.

Acknowledgments

We thank all the producers and cooperative members who participated in the household surveys and shared their personal information for this study. We also express our sincere thanks to the local translators and technicians who facilitated the research work and provided remarkable insights into Ivorian culture and cocoa production during the surveys. We thank Franziska Ollendorf, Gianmarco Amato, and Asmaa Lamrhari for joining the data collection and survey, as well as Assi Jean of the PRO-PLANTEURS project for establishing links with cocoa-producing cooperatives.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2025.1524997/full#supplementary-material

References

Adetoye, A. M., Adewuyi, S. A., and Akerele, D. (2018). Determinants of forest land use decisions among rural farm households in southwestern Nigeria. *Agric. Trop. Subtrop.* 51, 83–91. doi: 10.2478/ats-2018-0009

Adji, B. I., Gore, B. B. N., Kadio, G. A., Gbotto, A. A., Assiri, A. A., and Akaffou, D. S. (2020). Identification des pratiques et types de systèmes agroforestiers à base de cacaoyers (*Theobroma cacao* l.) dans les trois principales zones de production de cacao en Côte d'Ivoire. *Agron. Afr.* 32, 323–342.

Adou Yao, C. Y., Kpangui, K. B., Vroh, B. T. A., and Ouattara, D. (2016). Pratiques culturales, valeurs d'usage et perception des paysans des espèces compagnes du cacaoyer dans des agroforêts traditionnelles au centre de la Côte d'Ivoire. *Revue d'ethnoécologie.* 9, 20. doi: 10.4000/ethnoecologie.2474

Alobo Loison, S. (2015). Rural livelihood diversification in sub-Saharan Africa. *J. Dev. Stud.* 51, 1125–1138. doi: 10.1080/00220388.2015.1046445

Amfo, B., and Ali, E. B. (2020). Climate change coping and adaptation strategies: how do cocoa farmers in Ghana diversify farm income? *Forest Policy Econ.* 119:102265. doi: 10.1016/J.FORPOL.2020.102265

Assiri, A. A., Kacou, E. A., Assi, F. A., Ekra, K. S., Dji, K. F., Couloud, J. Y., et al. (2012). Rentabilité économique des techniques de réhabilitation et de replantation des vieux

vergers de cacaoyers (*Theobroma cacao* L.) en Côte d'Ivoire. *Anim Plant Sci* 14, 1939–1951. Available at: http://www.m.elewa.org/JAPS

Asante, B. O., Villano, R. A., and Patrick, I. W. And Battese, G. E. Determinants of farm diversification in integrated crop-livestock farming systems in Ghana. (2018). Renew. *Agric. Food Syst.* 33, 131–149. doi: 10.1017/S1742170516000545

Bah, A., and Laven, A. (2019). *Closing the income gap of cocoa households in Côte d\u0027Ivoire - taking a gender-sensitive household approach. The Royal Tropical Institute (KIT).* https://www.researchgate.net/publication/341977779_Closing_the_income_gap_of_cocoa_households_in_Cote_d%27Ivoire_-taking_a_gender-sensitive_household_approach

Balineau, G., Bernath, S., and Pahuatini, V. (2016). Cocoa farmers' agricultural practices and livelihoods in Côte d'Ivoire. Insights from Cocoa Farmers and Community Baseline Surveys. Available at: https://www.afd.fr/en/ressources/cocoa-farmers-agricultural-practices-and-livelihoods-cote-divoire

Barima, Y. S., Danmo, K. G., Madeleine, K. A. T., and Jan, B. (2020). Cocoa production and forest dynamics in Ivory Coast from 1985 to 2019. *Land* 9, 1–22. doi: 10.3390/land9120524

Basantaray, A. K., Acharya, S., and Patra, T. (2024). Crop diversification and income of agricultural households in India: an empirical analysis. *Discov. agric.* 2:8. doi: 10.1007/s44279-024-00019-0

Bermudez, S., Voora, V., Larrea, C., and Luna, E. (2022). Global market report: cocoa prices and sustainability sustainable commodities marketplace series: International Institute for Sustainable Development and State of sustainable initiative.

Bymolt, R., Laven, A., and Tyszler, M. (2018). Demystifying the cocoa sector in Ghana and Côte d'Ivoire acknowledgements: KIT Royal Tropical Institute, 314p.

Cerda, R., Deheuvels, O., Calvache, D., Niehaus, L., Saenz, Y., Kent, J., et al. (2014). Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification. *Agrofor. Syst.* 88, 957–981. doi: 10.1007/s10457-014-9691-8

Djokoto, J. G., Afari-Sefa, V., and Addo-Quaye, A. (2017). Vegetable diversification in cocoa-based farming systems Ghana. *Agric. Food Secur.* 6, 10. doi: 10.1186/s40066-016-0082-4

Dumont, S. E., Gnahoua, G. M., Ohouo, L., Sinclair, F. L., and Vaast, P. (2014). Farmers in Côte d'Ivoire value integrating tree diversity in cocoa for the provision of ecosystem services. *Agrofor. Syst.* 88, 1047–1066. doi: 10.1007/s10457-014-9679-4

FAOSTAT. (2021). Available at: http://www.fao.org/faostat/en/#data/QC/visualize

Folefack, A. J. J., Eboutou, L. Y., Degrande, A., Moulende, T. F., Kamajou, F., and Bauer, S. (2015). Benefits from tree species' diversification in cocoa agroforests in the center region of Cameroon. *RJOAS* 47, 11. Available at: https://EconPapers.repec.org/RePEc:scn:031261:16372041

Food and Agriculture Organization (FAO) (2023). The status of women in agrifood systems. Rome, 264.

Fountain, A. C., and Huetz-Adams, F. (2022). Cocoa Barometer. 2022-USA Edition. VOICE Network. https://www.cocoabarometer.org

Gbongué, M., Abi, M. I., and Coulibaly, J. P. Analyse du revenu minimum d'existance des cacaoculteurs en Côte d'Ivoire. (2021). GIZ-PROGRAMME PROFIAB. 13p.

Gockowski, J., and Sonwa, D. (2011). Cocoa intensification scenarios and their predicted impact on CO2 emissions, biodiversity conservation, and rural livelihoods in the Guinea rain forest of West Africa. *Environ. Manag.* 48, 307–321. doi: 10.1007/s00267-010-9602-3

Gyau, A., Franzel, S., Chiatoh, M., Nimino, G., and Owusu, K. (2014). Collective action to improve market access for smallholder producers of agroforestry products: key lessons learned with insights from Cameroon's experience. *J. Environ. Sustain.* 6, 68–72. doi: 10.1016/j.cosust.2013.10.017

Hatløy, A., Tewodros, A K., Adeba, P J., and Core, E. (2012). Towards Cote d'Ivoire sustainable cocoa initiative. Baseline study report. Fafo Institute for Applied International Studies. 65p https://www.fafo.no/en/publications/other-fafo-publications/towards-cote-d-ivoire-sustainable-cocoa-initiative

He, H.-m., Liu, L.-n., Shahzad, M., Nawaz, H. B., Wang, Y., Yang, J., et al. (2019). Crop diversity and pest management in sustainable agriculture. *J. Integr. Agric.* 18, 1945–1952. doi: 10.1016/S2095-3119(19)62689-4

ICCO. (2021). ICCO quarterly bulletin of cocoa statistics, cocoa year 2021/22, International Cocoa Organization (ICCO).

Impact Institute. (2022). Revenu des producteurs de cacao. Le revenu des ménages des producteurs de cacao en Côte d'Ivoire et des stratégies d'amélioration. Amsterdam, Pays-Bas. Available at: https://www.icco.org/wp-content/uploads/Production_QBCS-XLVIII-No.-3.pdf,%20checked%20on%206/19/2023

Ingram, V., Rijn, F., van Waarts, Y., Dekkers, M., Vos, B., de Koster, T., et al (2018). *Towards sustainable cocoa in Côte d\u0027Ivoire: The impacts and contribution of UTZ certification combined with services provided by companies (No. 2018-041). Wageningen Economic Research.* https://library.wur.nl/WebQuery/wurpubs/fulltext/450223

Jagoret, P., Michel, I., Ngnogué, H. T., Lachenaud, P., Snoeck, D., and Malézieux, E. (2017). Structural characteristics determine productivity in complex cocoa agroforestry systems. *Agron. Sustain. Dev.* 60, 37. doi: 10.1007/s13593-017-0468-0

Johny, J., Wichmann, B., and Swallow, B. M. (2017). Characterizing social networks and their effects on income diversification in rural Kerala, India. *World Dev.* 94, 375–392. doi: 10.1016/j.worlddev.2017.02.002

Kalischek, N., Lang, N., Renier, C., Daudt, R. C., Addoah, T., Thompson, W., et al. (2023). Cocoa plantations are associated with deforestation in Côte d'Ivoire and Ghana. *Nat. Food.* 4, 384–393. doi: 10.1038/s43016-023-00751-8

Koffi, S. Y., and Oura, K. R. (2019). Les facteurs de l'adoption de l'anacarde dans le bassin cotonnier de Côte d'Ivoire. *Cah. Agric.* 28:24. doi: 10.1051/cagri/2019025

Kouadio, T. P. F. W. (2021). Capitalisation des acquis du projet chaîne d'approvisionnement zéro-déforestation (CAZ). Rapport final d'étude, GIZ. 49p.

Kouadio, V.-P. G., Kossonou, A. S. F., N'guessan, L. D., Kouamé, K. M. A., and Adou Yao, C. Y. (2021). Socio-economic assessment of different cocoa agroforestry systems in the forest-Savannah transition zone in central Côte d'Ivoire. *For. Trees Livelihoods* 30, 195–212. doi: 10.1080/14728028.2021.1958064

Kouassi, J. L., Diby, L., Konan, D., Kouassi, A., Bene, Y., and Kouamé, C. (2023). Drivers of cocoa agroforestry adoption by smallholder farmers around the Taï National Park in southwestern Côte d'Ivoire. *Sci. Rep.* 13:14309. doi: 10.1038/s41598-023-41593-5

Kouassi, J.-L., Kouassi, A., Bene, Y., Konan, D., Tondoh, E. J., and Kouame, C. (2021). Exploring barriers to agroforestry adoption by cocoa farmers in South-Western Côte d'Ivoire. *Sustain. For.* 13:16. doi: 10.3390/su132313075

Kpenavoun, C. S., Kpadé, P. C., Santos, F, and Mensah, A. G.. (2018). Efficacité technique et rentabilité économique de la production de soja au Bénin. BRAB. Available at: https://www.researchgate.net/publication/329357303

Krain, E. (2022). Cost, returns, and income modeling of farmer cocoa production in the project region of PRO-PLANTEURS. PRO-PLANTEURS project. 70p.

Komla, E. A., Arthaud, G., Balembois, E., Brou, J.-M., Castellier, L., Daubrey, M., et al. (2022). *Global Guide for Implementing Sustainable Cocoa Agroforestry Good Practices from West Africa and Latin America Countries. Report,* 104p. https://www.forestcarbonpartnership.org/sites/fcp/files/2022/Nov/wb_cocoa_report.pdf

Kraft, P., Rezaei, E. E., Breuer, L., Ewert, F., Große-Stoltenberg, A., Kleinebecker, T., et al. (2021). Modeling Agroforestry's Contributions to People—A Review of Available Models? *Agron.* 11:2106. doi: 10.3390/agronomy11112106

Laven, A., Bymolt, R., Tyszler, M., Steijn, C., Hütz-Adams, F., and Ruf, I. F. (2017). The importance of cocoa in a diversified farm. Available at: https://www.forbes.com/sites/simransethi/2017/10/10/why-an-oversupply-of-cocoa-is-bad-for-chocolate-lovers/#50c83e8d78f2

Living Income Community of Practice. (2024). The Concept. Available at: https://www.living-income.com/the-concept (Accessed 03rd August 2024).

Losch, B. (2001). La libéralisation de la filière cacaoyère ivoirienne et les recompositions du marché mondial du cacao: Vers la fin des « pays producteurs » et du marché international? Oléagineux, Corps Gras, Lipides. 8(6): 566–576 L'avenir des cultures pérennes, TA 60/15, 73, avenue J.-F.-Breton, 34398 Montpellier Cedex 5, France. 23p.

Madountsap, T. N., Simo, C., Kabelong Banoho, L.-P. R., Chimi, D. C., Ntsefong, G. N., and Ntonmen, A F Y. (2020). Ecological and economic potentials of cocoa agroforestry Systems in the Center Region of Cameroon. *AJAF* 8, 214–222. doi: 10.11648/j.ajaf.20200805.15

Makhloufi, A. El., Mujica, M., Dick Van Damme, M, and Langenberg, V. (2018). Towards sustainable agro-logistics in developing countries the case of cocoa's supply chain in San Pedro region/Côte d'Ivoire design rights and permissions towards sustainable agro-logistics in developing countries. Amsterdam University of Applied Sciences (AUAS) and the World Bank. 107p.

Manlosa, A. O., Schultner, J., Dorresteijn, I., and Fischer, J. (2019). Leverage points for improving gender equality and human well-being in a smallholder farming context. *Sustain. Sci.* 14, 529–541. doi: 10.1007/s11625-018-0636-4

McCorda, P. F., Cox, M., Schmitt-Harsh, M., and Evans, T. (2015). Crop diversification as a smallholder livelihood strategy within semi-arid agricultural systems near Mount Kenya. *Land Use Policy* 42, 738–750. doi: 10.1016/j.landusepol.2014.10.012

Michler, J. D., and Josephson, A. L. (2016). To specialize or diversify: agricultural diversity and poverty dynamics in Ethiopia. *World Dev. Xx* 89, 214–226. doi: 10.1016/j.worlddev.2016.08.011

Nandi, R., Krupnik, T. J., Kabir, W., and Jackson, T. (2024). Nurturing the sustainable food systems: crafting policies and practices for crop diversification in Bangladesh. *Front. Sustain. Food Syst.* 8:1459526. doi: 10.3389/fsufs.2024.1459526

Ochoa, W. S. M., Härtl, F. H., Paul, C., and Knoke, T. (2019). Cropping systems are homogenized by off-farm income – empirical evidence from small-scale farming systems in dry forests of southern Ecuador. *Land Use Policy* 82, 204–219. doi: 10.1016/j.landusepol.2018.11.025

Orozco-Aguilar, L., López-Sampson, A., Leandro-Muñoz, M. E., Robiglio, V., Reyes, M., Bordeaux, M., et al. (2021). Elucidating pathways and discourses linking cocoa cultivation to deforestation, reforestation, and tree cover change in Nicaragua and Peru. *Front. Sustain. Food Syst.* 5:635779. doi: 10.3389/fsufs.2021.635779

Owusu, V., and Frimpong, F. K. (2014). Impact of cocoa agroforests on yield and household income: Evidence from Ghana. In 88th Annual Conference of the Agricultural Economics Society 11.

Reinecke, J., Manning, S., and Von Hagen, O. (2012). The Emergence of a Standards Market: Multiplicity of Sustainability Standards in the Global Coffee Industry. Organ. Stud, 33, 791–814. doi: 10.1177/0170840612443629

Ruf, F., Kone, S., and Bebo, B. (2019). Le boom de l'anacarde en Côte d'Ivoire: transition écologique et sociale des systèmes à base de coton et de cacao. *Cah Agric.* 28:21. doi: 10.1051/cagri/2019019

Ruf, F., Salvan, M., and Kouamé, J. (2020). Qui sont les planteurs de cacao de Côte d'Ivoire. Paris Cedex 12: Agence française de développement. 1–111.

Ruf, F., and Schroth, G. (2015). Economics and ecology of diversification: the case of tropical tree crops.

Rusman, A., Adelhart Toorop, R., de Boer, J., and de Groot Ruiz, A. (2018). *Cocoa farmer income: The household income of cocoa farmers in Côte d\u0027Ivoire and strategies for improvement. True Price/Fairtrade. Report.* 47p. https://trueprice.org/wp-content/uploads/2022/07/2018-%2004_Report_Fairtrade_Cocoa_Farmer_Income.pdf

Schroth, G., and Ruf, F. (2014). Farmer strategies for tree crop diversification in the humid tropics. A review. *Agron. Sustain Dev.* 34, 139–154. doi: 10.1007/s13593-013-0175-4

Staritz, C., Tröster, B., Grumiller, J., and Maile, F. (2023). Price-setting power in global value chains: the cases of Price stabilisation in the cocoa sectors in Côte d'Ivoire and Ghana. *Eur. J. Dev. Res.* 35, 840–868. doi: 10.1057/s41287-022-00543-z

Stilmant, D, and Vanwindekens, F. M., Morel, K., Revoyron, E., Rossing, W., Colombo, L., and Messéan, A. (2019). Diversification des systèmes de cultures: les défis. Available at: https://hal.inrae.fr/hal-02939713

Tyszler, M., and Ríos, C. D. L. (2020). *Guidance manual on calculating and visualizing income gap to a Living Income Benchmark: Prepared for the Living Income Community of Practice.* 34p. https://www.kit.nl/wp-content/uploads/2020/08/KIT-Guidance-Measuring-and-visualizing-the-gap.pdf

Tano, A. M. (2012). Crise cacaoyère et stratégies des producteurs de la Sous-Préfécture de Meadji au Sud-Ouest Ivoirien. Available at: https://theses.hal.science/tel-00713662

Tondoha, J. E., Kouamé, F., Guéi, A. M., Sey, B., Koné, A. W., and Gnessougou, N. (2015). Ecological changes induced by full-sun cocoa farming in Côte d'Ivoire. *Glob Ecol Conserv.* 3, 575–595. doi: 10.1016/j.gecco.2015.02.007

True Price. (2018). Cocoa farmer income: the household income of cocoa farmers in Côte d'Ivoire and strategies for improvement.

Waarts, Y., and Kiewisch, M. (2021). Balancing the living income challenge: towards a multi-actor approach to achieving a living income for cocoa farmers. Report. 76 p. Available at: https://library.wur.nl/WebQuery/wurpubs/589449

Wessel, M., and Quist-Wessel, P. M. F. (2015). Cocoa production in West Africa, a review and analysis of recent developments. *NJAS* 74-75, 1–7. doi: 10.1016/j.njas.2015.09.001