

# Oil palm expansion, food security and diets: Comparative evidence from Cameroon and Indonesia

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## ABSTRACT

Farm households in the tropical regions of Africa, Asia, and the Americas continue to rapidly adopt oil palm, often at the expense of rainforests and traditional food crops. The environmental and income implications of oil palm expansion have been extensively documented, albeit primarily using data from Southeast Asia. Beyond a few case studies, research on the links between oil palm adoption, food security and dietary diversity among smallholders is scarce. This research gap is partly addressed in this study using data from Cameroon and Indonesia, two countries with different backgrounds in oil palm production, history and marketing systems. Oil palm is native to Cameroon but is an exotic crop in Indonesia that was commercialized a few decades ago. Household food insecurity experience scales and dietary diversity scores are computed, and descriptive and regression estimations are employed for the empirical analysis. Opposing results are revealed, reflecting the contextual differences between the two oil palm production frontiers. Oil palm farmers in Cameroon consume less diverse food than non-oil palm farmers. In Indonesia, on the other hand, oil palm farmers perform better than their non-oil palm counterparts and consume more diversified foods, possibly explaining why smallholders in Southeast Asia continue to adopt the crop rapidly. No statistically significant relationship is obtained between oil palm production and food security. The findings also suggest that income, employment, and farm production diversity may explain the observed relationship between oil palm adoption, food security and diets. Given this, oil palm production may not be a universally suitable strategy to improve food and nutrition insecurity but may be useful in some production frontiers. Context-specific and tailored policies are needed to make oil palm cultivation and food systems more nutrition-sensitive and environment-friendly.

## 1. Introduction

Food insecurity, hunger, and other forms of malnutrition remain significant challenges for global food systems, particularly in the tropics of Asia and Africa. These challenges pose a substantial threat to achieving sustainable food and nutrition targets in low - and middle-income countries, with severe negative health implications. It is estimated that more than 800 million people are malnourished (FAO et al., 2021). Current trends suggest that acute food insecurity will likely deteriorate further, with one in two people expected to be malnourished by 2025 (GBD 2017 Diet Collaborators, 2019). Ironically, hunger and malnourishment are severe among smallholder farm households, who produce a significant portion of the food consumed in low-income countries (FAO et al., 2021). These farmers rely on agriculture for

food and employment, which is why governments and international organizations are increasingly incorporating agriculture-based interventions and actions to address acute food insecurity and its underlying determinants (Sibhatu et al., 2022). In smallholder-dominated areas, one such intervention that governments in the tropics promote is the cultivation of plantation crops, particularly oil palm (Qaim et al., 2020).

Oil palm (*Elaeis guineensis*) is a vital food and cash crop cultivated in many parts of the humid tropics (Byerlee et al., 2017). Despite not being native to Southeast Asia, there has been a substantial increase in oil palm expansion in this region, particularly in Indonesia and Malaysia, the leading producers and exporters of crude palm oil worldwide (Qaim et al., 2020). These two countries account for almost 85% of globally exported palm oil (FAOSTAT, 2022). New hotspots are also emerging in

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Central and West Africa, which are native sites of oil palm production, such as Cameroon (Tabe-Ojong et al., 2023a), Ghana (Ruml et al., 2022), Côte d'Ivoire and Nigeria (Qaim et al., 2020).

Numerous socio-ecological concerns regarding the crop's expansion have been extensively documented (Obidzinski et al., 2012). The expansion of the crop has been associated with environmental degradation in the tropics, resulting in the loss of pristine and biodiversity-rich rainforests (Ordway et al., 2021) and escalating conflicts and tensions between local communities and agro-industrial companies (Abram et al., 2017; Sibhatu, 2023). Several studies have shown that oil palm production has contributed to significant income gains for smallholder households (Ayompe et al., 2021), while stimulating rural and community development (Santika et al., 2019). A recent study using data from the Jambi province in Indonesia has further shown that smallholder oil palm adoption is positively associated with greater household diets and nutrition (Sibhatu, 2019). However, in terms of sustainable food security, there is a critical need for evidence beyond such case studies, including evidence from the recent (new) hotspots of oil palm expansion. This is important, given that the food security and diet implications of oil palm expansion are likely to be heterogeneous and may vary under different production hotspots and contexts.

This study provides the first comparable evidence of the association between oil palm adoption, food security and dietary diversity among smallholder households in the African and Asian oil palm production frontiers. In particular, this study examines the association between oil palm adoption, food security and dietary diversity among farm households in Cameroon and Indonesia. This study also conceptually motivates and empirically examines the pathways and factors that may influence this relationship. These countries are interesting areas for investigating the implications of oil palm production on food security and dietary diversity. Oil palm production is native to West and Central Africa, including Cameroon (Tabe-Ojong et al., 2022). In contrast, it was first introduced in Indonesia as an ornamental plant in the 19th century and underwent massive expansion as part of the transmigration program in the 1980s and 1990s (Corley and Tinker, 2016).

In Indonesia, oil palm production is highly commercialized; smallholders are strongly linked to modern value chains that boost their incomes and livelihoods and promote rural growth and development (Euler et al., 2017). In Cameroon and other African countries, palm oil is an essential constituent of cultural diversity and food (Tabe-Ojong et al., 2022). Furthermore, palm oil processing in Cameroon principally relies on artisanal mills (Ordway et al., 2017), but is well-coordinated and industrial in Indonesia (Qaim et al., 2020). Moreover, many farmers in Indonesia are contracted and supply fresh fruit bunches to large industrial mills (Kühling et al., 2022) while farmers in Cameroon participate in traditional supply chains (Tabe-Ojong, 2023). This study uses Ordinary Least Squares (OLS) and Poisson regression models to estimate the relationship between oil palm production, food security and dietary diversity. For robustness purposes, non-linear models such as the Probit model and the Negative Binomial regression model are also used.

To the best of the authors' knowledge, this is the first study to provide oil palm's food security and dietary diversity implications from two production frontiers. The only study that provides comparative evidence from two oil palm production frontiers is by Ruml et al. (2022). The authors compare macro- and micro-policies and institutional features that influence oil palm production in Ghana and Indonesia. Given this background, new comparative evidence can provide valuable insights into addressing food and nutrition insecurity and improving farmers' welfare in oil palm-dominated rural and forested areas. The findings of this study indicate that oil palm production is positively associated with greater dietary diversity in Indonesia but has a contrasting negative association in Cameroon. These divergent findings may be attributed to differences in production systems, milling conditions, institutional support from external actors, and policy frameworks in the two

countries. The study, therefore, suggests that a one-fit-all solution to the development of the oil palm sector in many developing countries may have different implications for various production frontiers and systems.

The rest of the article is structured as follows. Section two establishes a brief conceptual framework, discussing the possible pathways linking oil palm adoption and food security. Section three presents the farm household surveys conducted in Cameroon and Indonesia and explains the variables measuring household dietary diversity and food (in)security. The results are presented and discussed in section four before concluding in section five.

## 2. Oil palm adoption, diets and food security

Oil palm is the world's greatest source of vegetable oil in 2020 while using only 10% of the 275.3 million hectares of land dedicated to oil crops and oilseeds, accounting for 40% of all vegetable oil produced (1062.7 million tonnes) (FAO, 2022). Indonesia is the world's top producer and exporter of crude palm oil, with an annual production of 256 million tons of fresh fruit bunches in 2020 (FAOSTAT, 2022). Cameroon, on the other hand, is Africa's third and world's ninth-largest palm oil producer, which produced 2.5 million fresh fruit bunches in 2020 (FAOSTAT, 2022). In both countries, farm households continue to adopt oil palm with substantial implications for rural development and food security (Qaim et al., 2020).

The Food and Agriculture Organization of the United Nations (FAO) refers to food security as "the condition in which all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 1996). It emphasizes the importance of ensuring access to food; promoting healthy diets and nutrition; and addressing the underlying social, economic, and environmental factors that can affect food availability and access. Also, the FAO defines dietary diversity as "the number of different foods or food groups consumed over a given reference period" (FAO, 2010). It refers to the variety of foods and food groups consumed by an individual or population over a certain period of time. A diverse diet is essential for a healthy and balanced diet, as it ensures that individuals receive a range of essential nutrients necessary for optimal health. More details on dietary diversity are provided in subsection 3.2.

Oil palm adoption can influence food security and dietary diversity through various mechanisms (Fig. 1). In the first place, it could lead to changes in income at both farm and household levels. Several studies have shown that oil palm adoption is profitable and associated with higher household income (Tabe-Ojong et al., 2023a). Such income gains may cause households to relax their liquidity constraints and purchase various food items from the market, thereby smoothing their consumption. Euler et al. (2017) established a positive association between oil palm adoption and consumption expenditure in Indonesia. Oil palm adoption is also associated with greater household dietary diversity and more consumption of calories, fruits, and vegetables (Sibhatu, 2019).

Oil palm production in Indonesia is solely for generating cash income, whereas in Cameroon, it constitutes a significant portion of household diets. Second, the consumption of red palm oil, classified as fats and oils, may improve food security and provide essential micronutrients, such as vitamin A. However, it may also reduce consumption diversity from own production, as the crop often expands at the expense of traditional (food) crops (Sibhatu, 2019). As a result, households that adopt oil palm may reduce their cultivation of other food crops and possibly animal-sourced foods, limiting food crop diversity and food availability for home consumption.

A third mechanism through which oil palm adoption could be associated with food security and dietary diversity is through off-farm employment. Oil palm production and its associated value chain may be labor-intensive, depending on the context. For instance, in Cameroon,

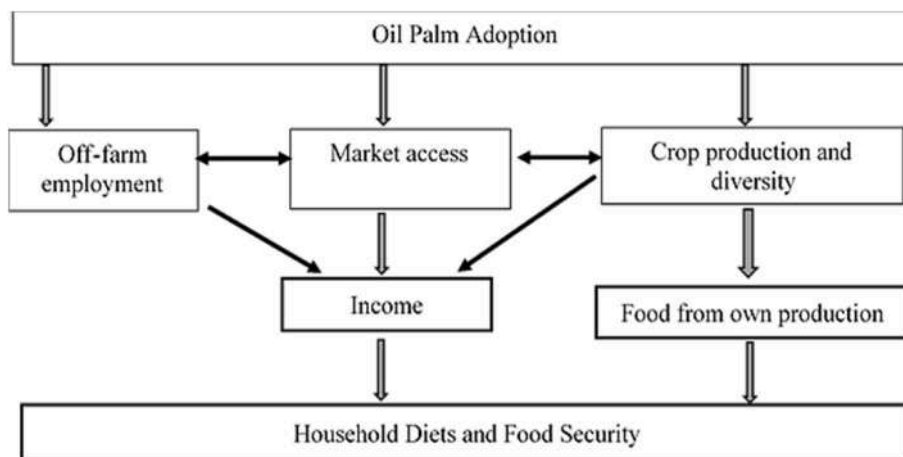


Fig. 1. Oil palm adoption and household diets and food security: Association pathways.

where the palm oil value chain is long and involves multiple household members since processing is usually done on-farm, the crop’s cultivation is generally labor intensive with the use of artisanal mills (Tabe-Ojong et al., 2022). Conversely, oil palm tends to be less labor-intensive in Indonesia than other competing crops, such as rubber and rice (Mehraban et al., 2021). Palm oil processing is also different in these two contexts, with Indonesia having a more industrialized and organized milling system, while Cameroon fully relies on artisanal mills (Ordway et al., 2017). The marketing system also differs, with many Indonesian farmers exploring modern value chains while farmers in Cameroon rely on traditional supply chains. These differences in value chain activities may have a differential association regarding off-farm employment, which is a crucial source of cash income that farmers often use to buy food particularly during lean seasons (Babatunde and Qaim, 2010).

Finally, the adoption of oil palm may lead to changes in gender roles, which could have implications for food security and dietary diversity (Chrisendo et al., 2020). Although men dominate oil palm production, women are also involved in the industry as household heads and spouses. However, cultural biases and other socioeconomic constraints may hinder women from producing oil palm as household heads and participating fully in the various nodes of the oil palm value chain. Either way, oil palm adoption may negatively or positively influence food security and dietary diversity through its effects on time allocation in activities such as home gardening and food preparation, which are relevant for food security and dietary diversity. Furthermore, any shift from food crop to cash crop production may result in the transfer of household income management and control from women to men (Tankari, 2017). Since women are more associated with household food security and dietary needs, this shift in income and time implications could negatively influence food and nutritional security.

### 3. Materials and methods

#### 3.1. Research methodology framework

This study followed a methodological framework that ensured that the study areas were well-defined, the sample selection was representative, the data collected were relevant and reliable, and the analysis was robust and valid. Fig. 2 portrays an outline of the materials and methods used in this study. The study started with the study area identification of oil palm cultivation hotspots in Cameroon (Tabe-Ojong et al., 2023a) and Indonesia (Drescher et al., 2016). This involved conducting a literature review and consulting experts to identify areas with a high concentration of oil palm cultivation. Next, representative samples of households were chosen from the study areas based on statistically valid procedures. Questionnaires were developed to collect information on farm and socioeconomic characteristics, food security, and dietary diversity, which were pilot tested to ensure clarity and validity. The collected data were analyzed using descriptive and regression estimation models to test the hypotheses and determine the association highlighted in the previous section. Each step of the methodological and analytical approach utilized in this study is described in detail in the following subsections.

#### 3.2. Farm household survey

As mentioned earlier, the data for this study come from two farm household surveys conducted in Cameroon and Indonesia. While the two surveys were conducted for different projects and in different years, they had identical objectives: to assess the socioeconomic (including contributions to food security and consumption) implications of oil palm

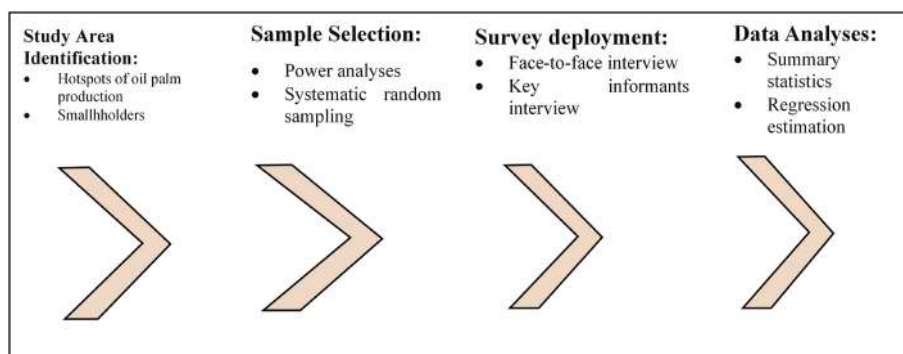


Fig. 2. Research methodology framework.

adoption on farm households. In both surveys, oil palm production hotspots were purposely identified, and villages and households were randomly selected. In other words, each household in a given village had an equal chance of being selected for the survey, thus making it representative. Because the two surveys focused on smallholder farm households, regions predominantly dominated by smallholder farm households were carefully identified. In Indonesia, smallholders cultivate about 40% of the total oil palm land, but in Jambi, historically covered by tropical rainforests, smallholder share is higher, at around 61% (Badan Pusat Statistik, 2019). For this reason, the Jambi Province was selected within Indonesia. Similarly, the Littoral region in Cameroon, which is home to the Ngwei tropical rainforest, is a vibrant oil palm production area where most of the land is cultivated by smallholder farmers (Jaza Folefack et al., 2019).

Both household surveys were developed and administered using similar survey-based tablets with the assistance of well-trained enumerators (12 and 7 enumerators in the Indonesian and Cameroonian surveys, respectively) under the supervision of the researchers. The questionnaires were tested before use, and interviews were conducted in local languages. The surveys captured information on farm activities, demographic characteristics, household-level food security, and food consumption (Table 1). The food security and food consumption sections of the questionnaires were identical in both surveys, making them useful for the objective of this study. Apart from the household survey, discussions were carried out with village chiefs and opinion leaders in Cameroon and village administrators in Indonesia to gather anecdotal insights at the village and community levels.

The farm household survey in Cameroon was conducted between August and September 2021, using a multistage sampling procedure that involved division and district-level stratification (Gebremedhin and Tweeten, 1994). Thirty-nine villages were randomly selected using the probability proportional to the size sampling framework (Tabe-Ojong et al., 2021a). From these villages, 13–17 households were randomly selected, representing a total of 582 households. The sample size was obtained after exploring various sample size calculation designs such as Yamane, Cochran, and the Morgan formula. The sample size at the village level depends not only on the size of each village but also on the ability to find randomly selected households or their replacements. The farmers in the Littoral region are typically smallholders who cultivate diverse crops and rear livestock (Tabe-Ojong et al., 2021b). They also produce cash crops like oil palms for home consumption and sales to earn cash income.

Similarly, the data from Indonesia consist of 624 representative farm households in the province of Jambi, located on Sumatra Island. The households were selected through a multistage-sampling strategy, with the aim of capturing agroecological diversity in the area. Five regencies covering lowland land-use systems affected by oil palm expansion were purposively selected. Within these regencies, 40 villages were randomly selected. Additionally, five villages were selected purposefully for collaborative studies with other projects (Drescher et al., 2011). Finally, 6–24 households were randomly selected, depending on the total number of households residing in a village. The household survey was conducted between August and November 2018. Unlike in the Littoral region, farmers in Jambi specialize in cultivating oil palm and rubber plantations, with only a few engaged in growing other crops, rearing livestock, and practicing aquaculture. One may argue that the data from 2018 are relatively old for appropriate policy development. However, the authors believe that the data are still relevant today for at least two reasons. First, oil palm is a perennial crop that grows and matures in many years and once planted stays planted for decades. Hence, a four-years period is not long enough for the data to be old for informing development policy. Second, as motivated in the introduction and illustrated in the conceptual framework, the data are used to answer scientific questions and test scientific hypotheses that do not rely much on a specific date or are outdated by any given date.

### 3.3. Measuring household food (in)Security and dietary diversity

This study examines the association between oil palm adoption, household food security, and dietary diversity among smallholder farmers in Cameroon and Indonesia. To accomplish this goal, the food insecurity experience scale (FIES) and household dietary diversity scores (HDDS) were used as the main outcome variables. Additionally, dichotomous dependent variables indicating the level of food insecurity were also used to provide a better understanding of the implications for food security.

The FIES is a standard tool to measure food (in)security (Smith et al., 2017). It comprises eight questions asked to respondents to assess whether they experienced food insecurity in the last four weeks (See Table A1 in the Supplementary Material for the list of the eight questions). The responses from households were recorded as dummy variables, with **1** indicating yes and **0** indicating no. The various responses from each of the questions per household were summed to obtain scores ranging from 0 to 8, which represents the food insecurity experience scale (FIES). Additionally, four different outcomes were computed that represent food insecurity measures based on the severity of food insecurity classifications: food security, mild food insecurity, moderate food insecurity, and severe food insecurity (Cafiero et al., 2018).

The HDDS on the other hand is a widely used tool to measure food access and availability in smallholder farmers and is very useful for cross-country comparisons and analyses (Sibhatu and Qaim, 2018). Recent studies have shown that HDDS is strongly correlated with individual-level indicators (Fongar et al., 2019). The score is derived from a 7-day food intake recall consumed by all household members. It is designed from 12 standard group scores, including cereals, white tubers and roots, legumes, nuts and seeds, vegetables and vegetable products, fruits, meat, eggs, fish and fish products, milk and milk products, sweets and sugars and syrups, oils and fats, spices, condiments, and beverages (Swindale and Bilinsky, 2006).

As can be observed, the standard 12 food groups in the HDDS also include foods with little or undesirable nutritional and health effects when consumed in large quantities (sugars and sweets, oils and fats, and condiments). Hence, the authors also computed a version of the HDDS that excludes unhealthy food groups, resulting in a score based on 9 food groups. Furthermore, the authors calculated the minimum acceptable diet (MAD), which assesses whether household dietary intake meets diversity in terms of micro - and macronutrients (Labadarios et al., 2011). MAD is constructed as a dummy from the 12 food groups HDDS and takes the value of **1** for households whose score is greater than 3, and **0** otherwise.

The association of oil palm adoption with household food security and dietary diversity may also be influenced by socioeconomic, cultural, farm, and demographic factors (Sibhatu, 2019). Thus, the regression estimation models (see Estimation strategy subsection) included farm, socioeconomic and demographic characteristics, such as farm and household sizes, credit access, age, ethnicity, and the education level of the household head as control variables.

### 3.4. Estimation strategy

Descriptive statistics and regression models are used to analyze the association between oil palm adoption, household food security and dietary diversity. The regression model estimation follows two steps. In the first step, the following regression model is used:

$$DD_h = \beta_0 + \beta_1 OP_h + \varepsilon_h \quad (1)$$

where  $DD_h$  is food security (FIES), dietary diversity (HDDS), and other food security dummies.  $OP_h$  is a dummy variable for oil palm adoption in household  $h$ .  $\varepsilon_h$  is a random error term, and  $\beta_0$  and  $\beta_1$  are coefficients to be estimated. The estimate for  $\beta_1$  is of particular interest. For HDDS, a positive and significant estimate for  $\beta_1$  implies that a household's oil

**Table 1**  
Descriptive statistics of the sample households disaggregated by oil palm adoption.

	Cameroon				Indonesia			
	(1) All	(2) Adopters	(3) Non-Adopters	(4) Diff. (2–3)	(5) All	(6) Adopters	(7) Non-Adopters	(8) Diff. (6–7)
Age of the household head (years)	49.61 (0.61)	52.73 (0.77)	45.56 (0.95)	7.17***	50.61 (0.46)	50.59 (0.62)	50.63 (0.67)	−0.04
Household head is male (1/0)	0.73	0.77	0.67	0.09***	0.85	0.87	0.84	0.03
Educational level (years)	9.91 (0.15)	10.09 (0.23)	9.67 (0.20)	0.41	7.25 (0.15)	7.34 (0.21)	7.16 (0.22)	0.18
Household size (number)	5.03 (0.17)	5.22 (0.26)	4.79 (0.20)	0.43	4.03 (0.06)	4.00 (0.08)	4.06 (0.09)	−0.06
Melayu ethnic group (1/0)	–	–	–	–	0.55	0.45	0.47	−0.02
Household is migrant (1/0)	0.74	0.91	0.51	−0.40***	0.55	0.59	0.51	0.08**
Distance to the market (km)	28.66 (0.88)	34.43 (1.16)	21.15 (1.22)	13.27***	4.38 (0.20)	4.14 (0.28)	4.61 (0.28)	−0.47
Cooperative membership (1/0)	0.18	0.22	0.13	0.09***	0.22	0.26	0.18	0.08***
Credit access (1/0)	0.18	0.20	0.15	0.05*	0.35	0.41	0.30	0.11***
Household income (‘000; FCFA/IDR)	110.28 (8.66)	144.14 (13.54)	66.27 (8.63)	77.87***	14.37 (1.13)	18.67 (2.05)	10.12 (0.91)	8.55***
Off-farm participation (1/0)	0.29	0.22	0.32	−0.10***	0.42	0.37	0.47	−0.1**
Livestock ownership (TLU)	0.11 (0.02)	0.05 (0.01)	0.17 (0.04)	−0.12***	0.66 (0.03)	0.68 (0.04)	0.65 (0.04)	0.03
Cultivate other crops (1/0)	0.90	0.88	0.92	0.04	0.21	0.17	0.26	−0.09***
Farm size (hectares)	19.75 (1.96)	26.50 (2.82)	10.98 (2.52)	15.52***	5.04 (0.29)	6.57 (0.55)	3.52 (0.22)	3.05**
Area of oil palm (hectares)	1.74 (0.13)	3.07 (0.21)	0.00 (0.00)	3.07***	1.57 (0.13)	3.15 (0.23)	0.00 (0.00)	3.15***
Hired labor (1/0)	0.54	0.58	0.49	0.08**	0.26	0.34	0.18	0.16***
Family labor (1/0)	0.95	0.99	0.91	0.07***	0.76	0.78	0.75	0.03
Asset index <sup>a</sup>	0.05 (0.07)	0.65 (0.10)	−0.83 (0.06)	1.49***	0.15	0.20	0.10	0.10***
Observations	582	329	253		624	310	314	

Notes: Mean values with standard errors are reported in parentheses. \*\*\*, \*\*, and \* indicate statistical significance at the 1, 5, and 10 percent critical levels, respectively. <sup>a</sup> Asset in Indonesia is “whether a household owns a car, jeep or truck (1/0)”. FCFA - Central African CFA Franc. IDR- Indonesian Rupiah. Adopters – farmers who cultivate oil palm. Non-adopters – farmers who do not cultivate oil palm at all. Diff – difference.

palm adoption is associated with higher dietary diversity. But for FIES, a negative and significant estimate of  $\beta_1$  indicates that a household’s oil palm adoption is associated with greater food security.

The model in Equation (1) does not include other covariates that might influence the association of oil palm adoption with food security and dietary diversity. In the second step, Equation (1) is extended by adding several covariates to improve the model precision and assess the influence of such variables as follows:

$$DD_h = \beta_0 + \beta_1 OP_h + \beta_2 X_h + \varepsilon_h \tag{2}$$

where  $X_h$  is a vector of variables repressing farm, socioeconomic and demographic variables, including farm size, off-farm income, household size, and age, education and gender of the household head.

Both HDDS and FIES are count variables. Thus, a Poisson regression model with maximum-likelihood estimation is estimated in Equations (1) and (2) (Greene, 2018). The Negative Binomial regression model is also estimated to test whether the results are in the same direction as the Poisson regression model.<sup>1</sup> Equations (1) and (2) are also estimated using the MAD and HDDS of the 9 food groups as a robustness check.

Furthermore, regression models are conducted to explore the possible association mechanisms. The outcome variables analyzed are household income, whether a household head is involved in any off-farm employment, and whether or not a household cultivates other crops. Household income is adjusted for household size and log-transformed, and the ordinary least squares (OLS) estimator is used. The other two variables, which are binary, are also estimated using the OLS estimator in the framework of the linear probability model. However, non-linear models such as the Probit model are also estimated. Based on a priori expectations, a positive association is anticipated between oil palm adoption and income, whereas a negative association is expected with household head off-farm employment and the cultivation of other crops. The regression models are estimated separately for each outcome variable and country. All models are estimated with robust standard errors to account for heteroscedasticity (Greene, 2018).

<sup>1</sup> Previous studies such as Tabe-Ojong et al. (2020) have also used both the Poisson model and the negative binomial regression model.

## 4. Result and discussion

### 4.1. Sample characteristics

Table 1 presents the summary statistics of the households’ socioeconomic and farm characteristics. The households in both samples exhibit many similarities. For example, the average age, gender, and education of household heads, household size, and area under oil palm cultivation are almost similar. The mean values for cooperative membership, credit access, and off-farm employment suggest that households’ access to institutional services and off-farm activities is low, with slightly better services in Indonesia than in Cameroon. The low institutional access and participation in off-farm activities align with other findings reported in rural areas of Africa and Southeast Asia (FAO, 2018). As expected, crop diversity is greater in Cameroon than in Indonesia, where rubber is the main alternative crop. While the area under oil palm cultivation is comparable in both countries, farmers in Cameroon have larger farm sizes than their counterparts in Indonesia. Table 1 also shows the differences in the means of these household and farm characteristics between oil palm and non-oil palm farmers. Significant differences exist between these farmers beyond their oil palm cultivation practices.

Figs. 3 and 4 show the food security and dietary diversity indicators used in the analysis. The results of the disaggregated binary responses to the eight questions of the FIES are presented in Table A1 in the Supplementary Material. Fig. 3 illustrates that dietary diversity scores are higher in Indonesia than in Cameroon. This observation remains valid even when the number of food groups is reduced from 12 to 9, excluding the less healthy food groups. Moreover, the minimum adequate diet (MAD) score is equal to 1 for the sample of farmers in Indonesia and nearly 1 for Cameroon, indicating highly diverse household food consumption bundles. Fig. 4 depicts that the FIES scores are approximately four times higher in Cameroon than in Indonesia, suggesting a higher prevalence of food insecurity in the former. Specifically, only about 13% of households in the surveyed areas in Cameroon are food secure, in contrast to 57% in Indonesia.

Figs. 3 and 4 also show significant differences in food insecurity and dietary diversity when the sample households are disaggregated by oil

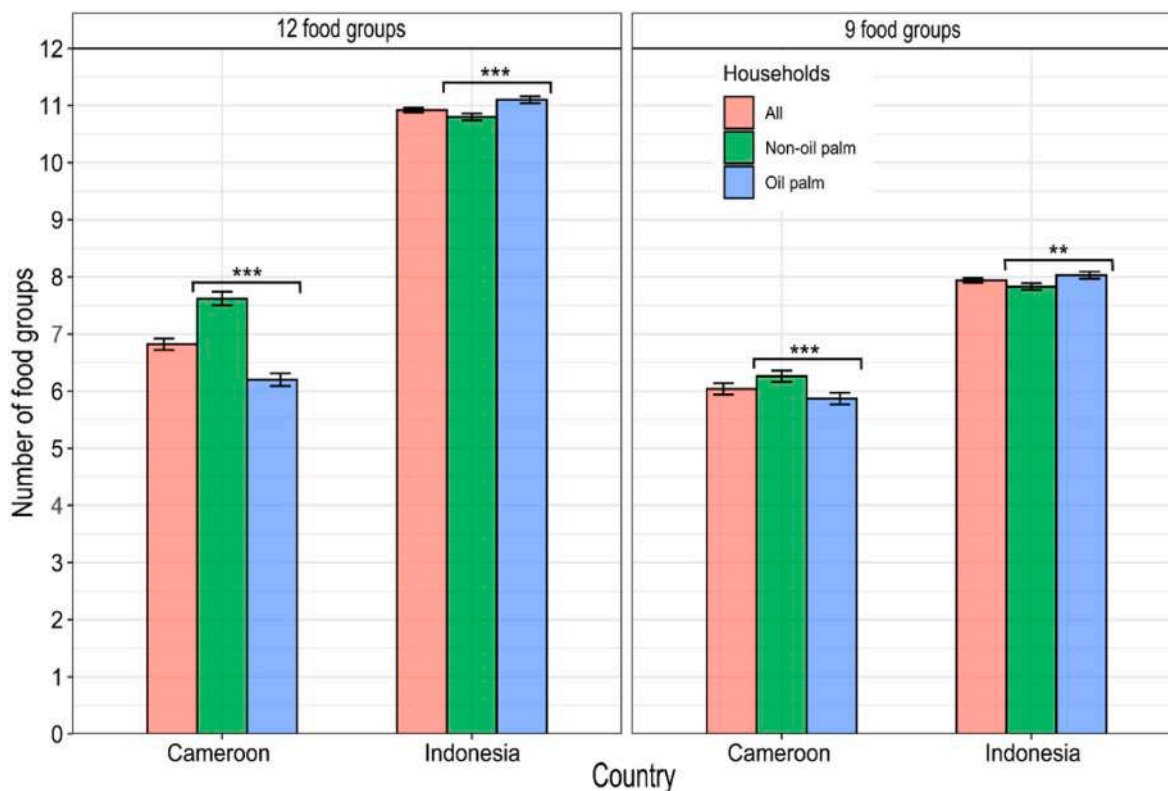


Fig. 3. Household dietary diversity scores in Cameroon and Indonesia disaggregated by oil palm adoption.

Notes: Mean values, from group mean comparison of adopters and non-adopters, are shown with standard errors in bars. \*\*\* and \*\* indicate statistical significance at the 1 and 5 percent critical levels, respectively.

palm adoption. Some contrasting relationships between adopters and non-adopters in Cameroon and Indonesia are further observed. Fig. 3 shows that non-oil palm farmers in Cameroon generally scored better in terms of consuming highly diverse food groups than oil palm adopters, which is the opposite of the observations in Indonesia. In other words, oil palm farmers consume less diverse foods in Cameroon, while in Indonesia, farmers who cultivate oil palm enjoy richer diets than farmers who do not. These findings suggest a divergent relationship between oil palm adoption and food and nutrition security in different production frontiers. However, they are largely descriptive and do not account for other confounding factors. In the following subsection, regression estimations are conducted to control for other factors that may influence the association between oil palm adoption, food security, and dietary diversity, thus providing further insights.

#### 4.2. Regression results

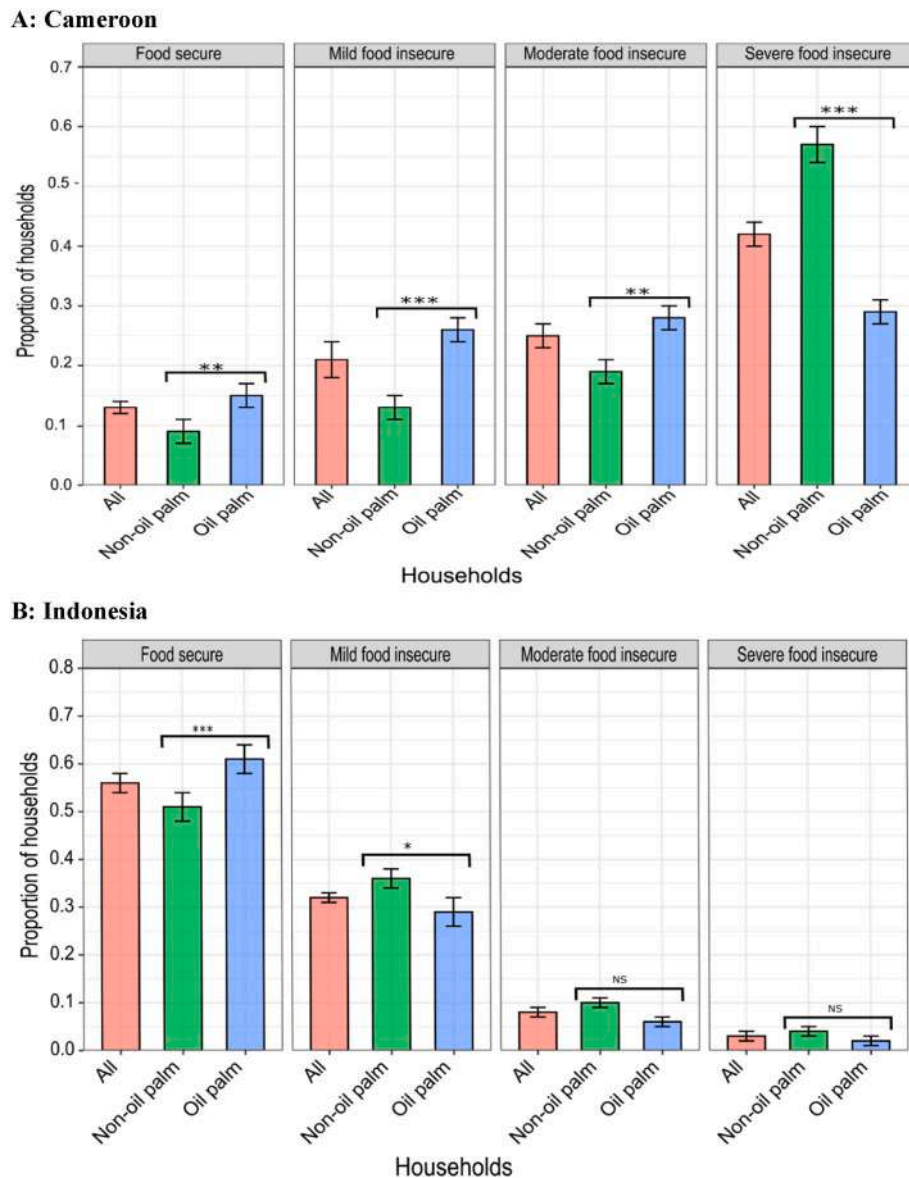
The study performed separate regressions for the food insecurity and household dietary diversity indicators. The findings for the household dietary diversity are first explained using the HDDS and the MAD. Eight models are estimated where various explanatory variables associated with dietary diversity are being controlled. The results are shown in Table 2. Contrasting results are observed for both production frontiers. In Cameroon, oil palm adoption exhibits a negative correlation with HDDS, whereas a positive association is observed in Indonesia. These coefficients remain consistent when other explanatory variables are controlled for. While oil palm adoption is associated with lower dietary diversity in Cameroon, it is also associated with higher dietary diversity in Indonesia. Concerning MAD, a negative relationship is revealed with oil palm adoption in Cameroon. As households in Indonesia consume more diverse food and are above the minimum threshold, no variation is recorded in the MAD. Thus, no regressions are performed, but the results

are similar to the insights learned when using HDDS as an indicator in the case of Cameroon. As highlighted earlier, these contrasting insights could speak of the important role of context, as the production systems and environments in Cameroon and Indonesia are different. In Cameroon, for instance, oil palm production has also been shown to be associated with lower dietary diversity for women as well as lower diet adequacy (Tabe-Ojong, 2023).

As a robustness check, separate estimates are also conducted using the 9 food groups in constructing the HDDS instead of the 12, and similar results are obtained (Table A2 in the Supplementary Materials). These findings lend support to the estimated positive association between oil palm adoption and dietary diversity in Indonesia and the opposite relationship observed in Cameroon, where dietary diversity is negatively associated with oil palm adoption.

The authors now examine the relationship between oil palm adoption and the prevalence of food insecurity. The results of the analyses are presented in Table 3, where four models are estimated for each country with two outcomes of food insecurity: the FIES score and a dummy for whether a household is food secure or not. The authors report a negative association between oil palm production and food insecurity measured by FIES and a positive association between oil palm production and food security when not controlling for other covariates. For instance, columns 3 and 7 show in Table 3 indicate that oil palm adoption is positively associated with food security by about 5.7 percentage points in Cameroon. In Indonesia, oil palm adoption is associated with an increase in the likelihood of being food secure by about 11 percentage points. When more explanatory variables are added to the regression model, the p-values become very large, suggesting no statistical evidence from the data about any relationship between oil palm production and food security.

Despite not establishing a statistical relationship between oil palm production and food security, the impact mechanisms (inherently non-



**Fig. 4.** Level of food (in)security in Cameroon and Indonesia disaggregated by oil palm adoption. Notes: Mean values, from group mean comparison of adopters and non-adopters, with standard errors in bars are reported. \*\*\*, \*\*, and \* indicate statistical significance at the 1, 5, and 10 percent critical levels, respectively. NS - not statistically significant.

causal) of oil palm adoption on food security may differ, given the difference in the production and marketing contexts between the two countries. Unlike in Indonesia, where households produce oil palm solely for sale, Cameroonians cultivate the crop for both cash and food (Tabe-Ojong et al., 2022). Thus, income from the oil palm business could be used to relax the liquidity constraints of farmers and enable them to purchase food in Indonesia. Furthermore, the authors additionally use food insecurity classifications based on the FIES scale (mild food security, moderate food security, and severe food security). Although statistically significant relationships are not established, this study finds some evidence that oil palm adoption is associated with a reduction in severe food insecurity in Cameroon. (Tables A3 and A4 in Supplementary Materials).

The findings in Indonesia are expected and are in line with previous research that has shown a positive association between oil palm adoption and household nutrition and diet (Euler et al., 2017). However, the findings from Cameroon are somewhat surprising, as oil palm has also been shown to be a profitable venture (Ayompe et al., 2021) with the ability to increase smallholder income (Tabe-Ojong et al., 2023a). It is

expected that income from the oil palm business would be used to purchase additional food categories in addition to palm oil, which is regularly consumed by households. However, it is possible that the income generated from oil palm may be allocated to other purposes and not entirely for household nutrition and diet purposes. In this case, depending on food crop diversity may be a viable option to mitigate food insecurity. Nonetheless, oil palm production in Cameroon is labor-intensive with a long value chain, which could potentially displace the cultivation of other staple crops such as maize, beans, groundnuts, fruits, and vegetables that could increase dietary diversity from own production. Oil palm production in Cameroon has been associated with lower farm production diversity entailing both the production of food crops and the rearing of livestock (Tabe-Ojong, 2023).

#### 4.3. Pathways of associations

Given the contrasting relationship between oil palm adoption and dietary diversity in Cameroon and Indonesia, the authors further descriptively explore some underlying factors that may explain this

**Table 2**  
Estimates of oil palm adoption and dietary diversity.

VARIABLES	Cameroon				Indonesia			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	HDDS	HDDS	MAD	MAD	HDDS	HDDS	MAD	MAD
Oil palm adoption (1/0)	-0.205*** (0.046)	-0.125*** (0.038)	-0.072** (0.034)	-0.075* (0.040)	0.223*** (0.083)	0.166* (0.091)	N/A	N/A
Age of household head (years)		-0.0001 (0.001)		0.001 (0.001)		-0.009** (0.004)		
Household head is male (1/0)		0.005 (0.026)		0.061* (0.031)		0.044 (0.103)		
Educational level (years)		0.013*** (0.004)		0.006* (0.003)		0.017* (0.010)		
Household size (number)		0.008*** (0.003)		0.001 (0.003)		0.113*** (0.036)		
Household is migrant (1/0)		-0.088** (0.043)		0.026 (0.034)		-0.038 (0.119)		
Distance to the market (km)		-0.001 (0.001)		-0.001 (0.001)		-0.016 (0.013)		
Cooperative membership (1/0)		0.055** (0.021)		0.046* (0.026)		0.022 (0.111)		
Credit access (1/0)		0.031 (0.032)		0.024 (0.026)		-0.099 (0.088)		
Livestock ownership (TLU)		0.028** (0.012)		-0.003 (0.008)		0.0032 (0.067)		
Farm size (hectares)		-0.001** (0.002)		-0.0003 (0.0003)		0.007 (0.005)		
Hired Labor (1/0)		0.078*** (0.029)		0.126*** (0.038)		0.091 (0.097)		
Family labor (1/0)		-0.067 (0.054)		0.002 (0.036)		-0.011 (0.104)		
Asset index <sup>a</sup>		-0.019* (0.011)		-0.015 (0.010)		0.249* (0.136)		
Melayu ethnic group (1/0)	-		-			-0.097 (0.113)		
Constant	2.031*** (0.041)	1.928*** (0.105)	0.957*** (0.020)	0.722*** (0.086)	2.38*** (0.01)	2.373*** (0.033)		
Observations	582	582	582	582	624	624		
Adj. R <sup>2</sup> /Pseudo R <sup>2</sup>	0.016	0.035	0.017	0.104	0.001	0.002		
Wald Chi2	19.56***	171.40***	4.53**	1.71*	7.12***	96.56***		

Notes: HDDS is the dietary diversity score of households, including 12 food groups. MAD is a minimum acceptable diet. The HDDS Models were estimated with a Poisson estimator. The MAD Models were estimated with a linear probability model. Marginal effects are shown with robust SEs in parentheses. \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1. <sup>an</sup> Asset in Indonesia is “whether a household owns a car, jeep or truck (1/0)”.

relationship. Since the pathways are explicitly addressed under the conceptual framework, the results and discussion of the pathways are brief to avoid repetition. As previously highlighted, oil palm adoption may explain food and nutrition security through various pathways, including income, off-farm employment, and crop diversity. All these mechanisms are tested formally in a regression setting by regressing oil palm adoption on household income, off-farm employment for household heads, and crop diversity. A summary of the results is provided in Table 4. Full model estimations are reported in Supplementary Tables A5 and A6.

The adoption of oil palm is associated with income increases in both Cameroon and Indonesia. Previous studies have confirmed this relationship, highlighting that oil palm is an income-increasing and profitable crop for farmers (Krishna et al., 2017). Increasing incomes from oil palm adoption could be used to purchase various food items, especially those not produced by households. This is particularly the case in Indonesia, where farmers only produce oil palm for cash income purposes. In the case of Cameroon, farmers also consume palm oil beyond selling it in markets (Tabe-Ojong et al., 2022).

Oil palm adoption is negatively associated with the participation of household heads in off-farm employment. This might be due to the long value chain of oil palm, which makes it difficult for households fully engaged in oil palm cultivation to participate in other off-farm activities. A reduction in off-farm income could potentially limit the purchase of food (Babatunde and Qaim, 2010). These results suggest a certain level of specialization, especially in the case of Indonesia, where oil palm

requires less labor and time than other crops, such as rubber and rice (Krishna et al., 2017).

Regarding crop diversity, a negative association with oil palm adoption is evident in both countries. This implies that farmers who adopt oil palm are less likely to cultivate other crops, which could be critical in addressing food insecurity concerns. However, it is vital to note that the definition of crop diversity differs between the two study areas. In Cameroon, crop diversity means cultivating other food crops such as maize, beans, plantains, and relevant staples, whereas, in Indonesia, it implies the cultivation of rubber – a non-food plantation cash crop (Mehraban et al., 2021). Thus, in Cameroon, oil palm adoption may reduce the cultivation of food crops, which is relevant for addressing food insecurity in many rural settings where households face liquidity constraints when purchasing food from markets. In contrast, in Indonesia, the relationship between oil palm adoption and crop diversity is possibly indicative of specialisation in oil palm production given its profitability.

To the extent that oil palm production displaces local food crop cultivation and reduces crop diversity, there may be far-reaching implications on food prices through reliance on local markets (Fafchamps, 1992). A reduction in food crop production could lead to price increases, making affordable and nutritious foods more expensive for households. This situation may even be further exacerbated when food markets are not well integrated with other local and regional markets due to information asymmetry and high transaction costs arising from poor roads, transportation networks, and rural infrastructure.

**Table 3**  
Estimates of oil palm adoption and food security.

VARIABLES	Cameroon				Indonesia			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	FIES	FIES	FS	FS	FIES	FIES	FS	FS
Oil palm adoption (1/0)	-0.280*** (0.066)	-0.069 (0.073)	0.057* (0.033)	0.004 (0.037)	-0.344** (0.155)	-0.052 (0.151)	0.110** (0.043)	0.050 (0.041)
Age of household head (years)		-0.004** (0.002)		0.001 (0.001)		-0.014* (0.008)		0.004** (0.002)
Household head is male (1/0)		-0.079 (0.059)		0.028 (0.028)		0.367 (0.239)		-0.064 (0.066)
Educational level (years)		-0.026*** (0.006)		0.007* (0.004)		-0.046** (0.022)		0.012** (0.005)
Household size (number)		0.016*** (0.006)		-0.008** (0.003)		0.062 (0.052)		-0.008 (0.016)
Migrant (1/0)		-0.138* (0.072)		0.032 (0.039)		-0.262 (0.187)		-0.033 (0.073)
Market distance (km)		0.000 (0.001)		-0.0003 (0.001)		0.019 (0.013)		0.057 (0.062)
Cooperative membership (1/0)		-0.028 (0.064)		0.011 (0.040)		-0.351** (0.146)		0.004 (0.005)
Credit access (1/0)		0.031 (0.071)		-0.067** (0.030)		0.274 (0.179)		0.093** (0.040)
Livestock ownership (TLU)		-0.054** (0.024)		0.008 (0.020)		-0.205 (0.135)		0.003 (0.050)
Farm size (hectares)		-0.000 (0.001)		0.0003 (0.0003)		-0.071** (0.034)		0.043 (0.029)
Hired labor (1/0)		0.072 (0.055)		-0.072** (0.033)		-0.323 (0.217)		0.005* (0.003)
Family labor (1/0)		-0.140** (0.062)		0.114*** (0.034)		-0.118 (0.202)		0.116* (0.059)
Asset index <sup>a</sup>		-0.079*** (0.021)		0.023** (0.010)		-0.847** (0.341)		0.027 (0.060)
Ethnicity: Melayu		-		-		0.156 (0.237)		0.114 (0.070)
Constant	1.733*** (0.053)	2.226*** (0.145)	0.095*** (0.025)	-0.037 (0.068)	0.271*** (0.099)	1.050* (0.530)	0.513*** (0.040)	0.142 (0.165)
Observations	582	582	582	582	624	624	624	624
R squared	0.017	0.054	0.007	0.068	0.007	0.092	0.012	0.083

Notes: FIES includes eight standard 8 questions. FS is food secure. The FIES Models were estimated with a Poisson estimator. The FS Models were estimated with a linear probability model (LPM) estimator. Marginal effects are shown with robust SEs in parentheses. \*\*\*p < 0.01, \*\*p < 0.05, \*p < 0.1. <sup>a</sup> Asset in Indonesia is “whether a household owns a car, jeep or truck (1/0)”.

**Table 4**  
Association of oil palm adoption and various impact pathway outcomes.

Sample	VARIABLES	(1)	(2)	(3)
		Income (log, FCFA/IDR)	Employment HH (dummy)	Crop diversity (dummy)
Cameroon	Oil palm production (1/0)	0.656*** (0.114)	-0.085** (0.039)	-0.109*** (0.030)
	Control variables included	Yes	Yes	Yes
	Constant	9.796*** (0.210)	0.528*** (0.155)	0.439*** (0.119)
Indonesia	Oil palm production (1/0)	0.172*** (0.0603)	-0.0830** (0.0342)	-0.0744** (0.0370)
	Control variables included	Yes	Yes	Yes
	Constant	2.506*** (0.205)	0.755** (0.302)	-1.975*** (0.527)

Notes: Model 1 is estimated with ordinary least squares (OLS). Models 2 and 3 are estimated with a linear probability model (LPM) estimator. Coefficients are shown with robust SEs in parentheses. Full model estimations are reported in [Supplementary Tables A5 and A6](#). FCFA - Central African CFA franc. IDR- Indonesian Rupiah. HH – household head.

Taking together, contextual factors matter and play a crucial role in understanding farm production dynamics and their relationships with various farm and household socioeconomic outcomes. Indonesia and Cameroon provide distinct contexts for oil palm production with different outcomes. The sector appears to be more profitable, with greater potential for reducing food insecurity and increasing dietary diversity in Indonesia compared to Cameroon. As such, it may be in the best interest of policy to consider the heterogeneity in production systems and local context when designing programs to support smallholder

farmers.

#### 4.4. Limitations of the study

Just like any empirical exercise, this study has some limitations that might be important to mention to guide future efforts and research endeavors. First, this study is not causal and should be understood from an associational point of view. The study used a cross-sectional dataset, making it difficult for the authors to claim causality. Future research

could address this limitation by using panel data and econometric techniques that move towards implying causality. Second, the study has provided evidence from two oil palm production frontiers in Africa and Asia, but it may be interesting to see other studies from different countries in these production frontiers or even other production frontiers from Central and South America. This will add to what is known (or not known) about the socioeconomic implications of oil palm production. Related to the above, the analysis may not be entirely representative of the oil palm sectors in both Cameroon and Indonesia, although the samples are from hotspots of oil palm production in the countries such as the Littoral region and the Jambi province. Furthermore, it may be argued that the data from 2018 in Indonesia are relatively old and inappropriate for policy development. However, the authors believe that the data are still very relevant today, given that the oil palm is a perennial crop that grows and matures over a long period, remains planted in the field for decades, and the scientific questions and research hypotheses tested using the data do not expire or apply to any specific date. Nonetheless, it would be beneficial to further explore the research question asked in this study using panel data and econometric techniques that go beyond associational analyses. Finally, while the study would have benefitted from additional analysis by exploring female participation in off-farm labor activities, the authors are data constrained to do so especially with deep granularity. Future efforts may want to build on this with more detailed datasets that address intra-household dynamics.

## 5. Conclusion and policy implications

This study examined the relationship between oil palm production, and food security and diets in Cameroon and Indonesia, two oil palm production hotspots with different backgrounds in oil palm history, and cultivation, processing and marketing systems. Using farm household survey data from both countries and employing different regression models, this study found three key results: (1) there is little evidence of a statistical relationship between oil palm production and food security in Cameroon and Indonesia; (2) while oil palm production is positively associated with dietary diversity in Indonesia, it is negatively associated with dietary diversity in Cameroon; and (3) different pathways could explain the relationship between oil palm production, food security and dietary diversity in Cameroon and Indonesia. These pathways (income, off-farm employment, and production diversity) could explain the contrasting findings between Cameroon and Indonesia. Oil palm production is associated with income, off-farm employment, and production diversity; however, the types of crops considered in the production bundle differ in both countries.

These findings highlight the important role of context in understanding the implications of oil palm production along different production frontiers and systems. As the authors clearly discussed and conceptualized, the production systems in Cameroon and Indonesia are different, and these differences could explain these contrasting results, especially in terms of dietary diversity. Farm households in Indonesia produce oil palm, which is industrially processed. In Cameroon, farm households still rely on artisanal mills, which are labor-intensive with the ability to displace labor from other important farm production-nutrition activities. Moreover, farmers in Indonesia are well connected to emerging modern value chains, whereas farmers in Cameroon are still semi-subsistence and gradually transitioning to sustained commercialization.

Some policy implications emerge from these conclusions. In the first place, the study highlights that policy development for promoting oil palm adoption in different production frontiers should be nuanced and address the specific needs of the production systems. Otherwise, there may be unintended effects. Focusing on some contextual differences in production systems for effective policy action remains crucial. It is intuitive to push for sustainable oil palm production in Indonesia, given that the already existing oil palm has led to growth and development in

the country. However, Cameroon may benefit from developments that have accelerated oil palm-led growth in Indonesia. Some of these would involve contracting farmers to agribusiness firms and agro-industries to reduce various aspects of transaction costs and providing inputs to farmers to improve the profitability of the sector. Such links with large agro-industries, especially those that offer oil palm processing, may be the way forward for labor savings in the oil palm sector in Cameroon. This could possibly enable the cultivation of other food crops, which could be critical for food security and ensuring dietary diversity. From a more sustainable point of view, moving farmers away from artisanal mills which have been associated with deforestation may make the sector more environmentally friendly.

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## CRediT authorship contribution statement

**Martin Paul Jr. Tabe-Ojong:** Conceptualization, Data collection, Sampling design, Methodology, Formal analysis, Writing – original draft, Writing – review & editing. **Zulkifli Alamsyah:** Data collection, Data curation, Writing – review & editing. **Kibrom T. Sibhatu:** Conceptualization, Data collection, Sampling design, Methodology, Formal analysis, Visualization, Writing – original draft, Writing – review & editing.

## Declaration of competing interest

There are no conflicts of interest to declare.

## Data availability

Data will be made available on request.

## Appendix A. : Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2023.138085>.

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