Context matters: Oil palm production and women dietary diversity in the tropical forest of Cameroon

Abstract

Oil palm is one of the most rapidly expanding food and cash crops in many tropical regions with significant environmental implications, but also economic gains. Previous analyses have established that this expansion is associated with changing gender roles and time allocation for women. Time allocation is an important determinant of maternal and child nutrition as well as wellbeing. However, few studies on the socio-economic implications of oil palm expansion have taken a gender focus. Here, we use a rich farm household data from a native oil palm production hotspot, Cameroon to examine the relationship between oil palm production and women dietary diversity. Using a couple of estimation and identification strategies with different sensitivity checks, we show that oil palm is associated with reductions in women dietary diversity measured both as minimum dietary diversity for women and the minimum adequacy diversity diet. These findings contrast with the literature that has established some positive dietary diversity implications of oil palm expansion in Southeast Asia. We explore heterogeneity in the various food groups consumed by women where we find consistent results that oil palm production is associated with the reduced consumption of mainly pulses, fruits and vegetables. We carefully discuss these findings and argue that context matters and may explain these differences. Particularly, we show that oil palm production is negatively associated with the cultivation of food crops which have been shown to be relevant for dietary diversity. That notwithstanding, we also confirm previous findings that highlight that oil palm production is income increasing. However, these gains are not associated with improved dietary quality and adequacy for women, possible owing to less autonomy and control over farm management and income. These insights are crucial and add to the debate on the implications of oil palm expansion in tropical environments. Moreover, they can guide policy in designing more tailored gender-equitable interventions that address intra-household issues and improve rural development.

Keywords: oil palm production; women dietary diversity; food production; income; rural employment; Cameroon

1. Introduction

Oil palm is one of the most rapidly expanding food and cash crops in many tropical regions (Byerlee et al. 2017). This expansion which can be described as explosive has been associated with both adverse environmental and social factors (Obidzinski et al. 2012; Qaim et al. 2020). From an environmental viewpoint, oil palm has been shown to distort land-use systems and lead to significant deforestation and landscape alterations (Busch et al. 2015; Ordway et al. 2021). Socially, the amassment of large parcels of land in many tropical areas by oil palm investing companies has resulted to conflicts in many oil palm hotspots (Gerber 2011; Abram et al. 2017). Similarly, there has been various child labour and low school enrollment concerns (UNICEF 2016; Li 2018).

Besides these socio-environmental implications, it has also been highlighted that oil palm is economically sustaining with numerous gains (Qaim et al. 2020). These benefits could explain this explosive expansion in many smalholder communities. Oil palm has been shown to increase incomes, sustain livelihoods and lead to significant welfare improvements (Rist et al. 2010; Krishna et al. 2017; Kubitza et al. 2018; Ayompe et al. 2021a). These gains are valid both for the farmers, but also for their communities (Santika et al. 2019; Krishna and Kubitza 2021). Income gains have been shown to have secondary implications on food and nutrition security (Euler et al. 2017; Chrisendo et al. 2020). That is oil palm increases consumption expenditure and household dietary diversity (Euler et al. 2017; Sibhatu 2019). It is however not clear whether these income gains translate to other nutritional outcomes for individual household members such as women[1]. This is a valid, but not well studied question especially given that oil palm production has been associated with changing gender roles and time allocation implications for women (Elmhirst et al. 2017; Rowland et al. 2022; Mehraban et al. 2021).

Given this, we examine the relationship between oil palm production and nutrition security for women. Specifically, we investigate whether oil palm production is associated with dietary diversity gains for women. We leverage a farm household survey from an emerging oil palm hotspot in Cameroon and employ the Minimum Dietary Diversity for Women (MDD-W) indicator as the proxy for women dietary diversity (FAO and FHI 360 2016). We also compute the

[1] Since women are having less control and decision-making power over farm management and income, there may be loss in female autonomy which may affect their nutrition. Mehraban et al. 2022 speaks to this loss in autonomy owing from increase time allocation to non-profitable activities.

Minimally adequate diet diversity (MADD) indicator that further speak to aspects of diet adequacy and quality. We estimate different regression models, including the Poisson regression model, linear probability model and the two stage least squares regression approach. We also estimate a Kinky least square regression model and Oster bounds as robustness checks on the main study findings. In contrast to the narrative that oil palm increases food security and dietary diversity, we find that oil palm is associated with reductions in women dietary diversity. We explore heterogeneity in these result by performing separate regressions for all the 10 food groups of the MDD-W indicator. We show that oil palm production is inversely associated with the intake of pulses and legumes, dark vegetables, vitamin A rich fruits and vegetables, other fruits, and other vegetables.

To understand what may be driving these contrasting results, we explore four pathway mechanisms (food crop production, cash crop production, income, and off-farm employment for women) and perform some heterogeneity analysis. We find that oil palm production is associated with displacements in food crop production as it associated with a reduced likelihood that households cultivate food crops. We also show that oil palm production is correlated with the cultivation of other local cash crops such as cocoa, plantains, groundnuts, egusi, and banana. Going further, we confirm that oil palm production is income increasing with gains even at the per capita basis. However, we do not find any support from the data that oil palm production is associated with off-farm employment for women. We discuss these findings in the context of the rich literature on the welfare implications of oil palm production. Important to mention here is the role of context as the sectors in Cameroon and Southeast Asia particularly Indonesia may be substantially different. An analysis of the sectors in Ghana and Indonesia speaks to these contextual differences (Ruml et al. 2022). Of course, the policy context, institutional systems, associated land-use changes, milling conditions and access to markets may be structurally different and could largely explain these results.

Our analysis and findings offer a couple of contributions to the growing literature on the socio-economic and nutritional implications of oil palm expansion. In the first place, we offer new and contrasting insights on the nutritional implications of oil palm production by exploring its implications for women dietary diversity. A focus on women is important given that oil palm has been associated with changing gender roles for women in oil palm producing households

(Chrisendo et al. 2020). Moreover, given that women are mostly responsible for household food security (Tibesigwa and Visser 2016), insights from this analysis are quite informative since poor maternal nutrition can lead to lower household food security through jeopardizing their ability to care for the food demands of their children and participation in income generating activities (Malapit and Quisumbing 2015). Oil palm production has been associated with time allocation and decision making implications for women which may have nutritional and health implications (Rowland et al. 2022; Mehraban et al. 2022). Our second contribution is in explaining what could be driving this adverse relationship between oil palm production and women dietary diversity. We show that oil palm production significant displaces food production. This is an interesting finding given that production diversity has been shown to be important for food security and dietary diversity in many rural communities, although not universally applicable (Sibhatu and Qaim 2018). Third and related to the second, we provide empirical support to the literature that has underscored that oil palm production is income increasing with significant welfare gains (Rist et al. 2010; Kubitza et al. 2018; Ayompe et al. 2021a; Ayompe et al. 2021b). Although, we observe income gains, this does not translate to women dietary diversity likely due to less autonomy and as well as less control over farm management decisions and income control (Mehraban et al. 2022). Finally, we offer a different perspective to oil palm production in a unique environment. Cameroon, like many other oil palm producing countries in West and Central Africa are native zones of production. However, yields and production are low and lag far behind the sector in Southeast Asia (Jaza Folefack et al. 2019). Here, we argue and show that context matters, and policy developments should take this into account when pushing for interventions and programs to stir the sector.

The rest of the article is structured~~s~~ as follows. Section 2 highlights the context of oil palm production in Cameroon and explores the pathways between oil palm production and women dietary diversity. The farm household survey and measurement of variables is presented in section 3 while section 4 delves into the econometric estimation and identification strategy. Section 4 discusses both the descriptive and econometric results while the article concludes with some policy reflections and thoughts.

2. Oil palm production and Dietary Diversity

Oil palm production can influence dietary diversity through different mechanisms: food production, cash crop production, income increases and off-farm employment for women. We consider and discuss all these mechanisms and pathways to ease the interpretation of the study findings. First, oil palm production can lead to changes in farm and household income. Studies in Southeast Asia but also in West and Central Africa show that oil palm leads to income gains (Rist et al. 2010; Krishna et al. 2017; Kubitza et al. 2018; Ayompe et al. 2021a). This is most often through increased commercialization that arises from marketed surplus especially in the case of Cameroon since palm oil is part of diets (Tabe-Ojong et al. 2022). Household gains are expected to increase food purchases which can greatly improve dietary diversity (Chrisendo et al. 2020).

Second, oil palm production can also affect dietary diversity through its impacts on food crop production. Given the profitability of the oil palm sector, it may displace the production of other food crops which are necessary for food security and dietary diversity (Sibhatu 2019). Since the sector is profitable, households may abandon food production to harness the gains from oil palm. This is particularly the case in Cameroon where the competing crops for oil palm are mainly food crops. Here, oil palm is produced with other food crops like maize, cocoyams, beans as well as fruits and vegetables. Food production has been shown to be associated with dietary diversity in many rural communities where households are usually cash strapped to rely on income for food purchases (Sibhatu and Qaim 2018; Ecker 2018; Hirvonen and Hoddinott 2017). In these conditions, dietary diversity may reduce if the gains from oil palm are not sufficient to relax the liquidity constraints of households.

Third, and closely related to the above, oil palm farmers may be attracted to other cash crops given the profitability with oil palm which is itself a cash crop. Some of the cash crops cultivated in the study area are cocoa, banana, plantains, groundnuts, and egusi. Cash crop production have generally been shown to crowd out food production. Using the example of two cash crops in Ghana, Anderman et al. (2014) show that oil palm and cocoa cultivation is associated with food insecurity in Ghana. To the extent that oil palm production displaces the cultivation of local food crops, reducing crop diversity, there may be far reaching implications on food prices through reliance on local markets (Fafchamps 1992). Reduction in food crop production could lead to price increases which may render affording nutritious foods expensive. This may even be exacerbated when the food markets are not well integrated with other local and regional markets due to information asymmetry and high transaction costs arising from poor roads as well as inefficient transportation networks and rural infrastructure. But it is also possible that gains from cash crop production are used to purchase food and increase food security and dietary diversity.

Finally, oil palm production could affect dietary diversity through off-farm employment. Previous studies have highlighted that oil palm production could lead to changing gender roles (Chrisendo et al. 2020). Thus, it goes without saying that oil palm production may affect the time use of women in oil palm producing households by either making them busy or less busy depending on the context. In both cases, the implications would be different as women have different opportunity costs for their time in these settings. In situations where they are less busy, they can maximize on off-farm employment which could earn them income to relax their liquidity constraints, enabling them to purchase food. Otherwise, it could be the other way round and rather reduce their dietary diversity.

From this discussion, one would expect an ambiguous relationship between oil palm production and women dietary diversity. Oil palm could either increase or decrease dietary diversity, depending on the agronomic system, policy support environment, and institutional context. In the case of Cameroon, oil palm production is both for the consumption of red palm oil and commercialization (Tabe-Ojong et al. 2022). The value chain is long and involves many members of the households, including women (Nkongho et al. 2014; Ordway et al. 2017). This may increase their time commitments with little ability to work off-farm and earn income to improve their nutrition.

3. Farm household survey

This study relies on a farm household survey that was conducted in the Littoral region of Cameroon. The Littoral region is one of the hotspots of oil palm expansion and is home to the Ngwei forest which has been associated with recent oil palm production increases (Jaza Folefack et al. 2019). Our sampling is based on both the Nkam and Sanaga Maritime divisions which is home to the Ngwei forest. The sampling framework follows a two staged procedure where 39 villages were randomly selected using the probability proportional sampling technique. From these villages, 13-17 households were further randomly selected using the random walk sampling approach. Support for these procedures were received from the village chiefs, herdsmen, and some village leaders. A total of 582 households were interviewed between August and September 2021.

Interviews were designed on survey-based tablets and implemented by a group of enumerators supervised by the author. The survey instrument was pretested before the interviews and data collection to enable the enumerators have a firm grip of the instrument, but also to adapt most of the questions to the local context. This was especially the case for the sections on dietary diversity and food security. Interviews were usually conducted in French, but also in the native language of the area. Data was collected both at the household and at the plot level. At the plot level, we mostly collected information on farm characteristics and input use, management practices and farm outputs. At the household level, we collected information on socio-economic characteristics, access to institutional services, income and asset ownership, off-farm participation, and rural employment as well as psychological factors. A huge section of the questionnaire was devoted to food security and dietary diversity where we obtained information on both household dietary diversity and women dietary diversity. At the village level, interviews and meetings were also held with village chiefs and some opinion leaders. This provided some qualitative and anecdotal insights on the oil palm sector and its implications. We describe how we measure our variables of interest below.

3.1 Measurement of women dietary diversity

We measure dietary diversity for women based on the Minimum Dietary Diversity for Women (MDD-W) indicator. This is a population-level indicator of dietary diversity that has been validated for women (FAO and FHI 360 2016). It is an improvement of the highly used women dietary diversity score (WDDS) which has been used to capture women dietary diversity so far (Arimond et al. 2010). Its main advantages lie in the fact that it is easy to collect, tabulate, interpret, and communicate. It is also culturally adaptable, giving room for adaptability to different geographical contexts. Unlike WDDS which is based on the intake of 9 food groups, MDD-W relies on 10 food groups and is increasingly considered the standard of measuring population-level dietary diversity for women of reproductive age (FAO and FHI 360 2016). It is measured as a dichotomous variable that captures whether households are consuming the following 10 food groups: starchy staple foods, beans and peas, nuts and seeds, diary (milk and milk products), meat and fish, eggs, vitamin A-rich dark green leafy vegetables, other vitamin A-rich vegetables and fruits, other vegetables, and other fruits. Table 1 shows the various disaggregated groupings based on the types of food. For the analysis, computed MDD-W scores show the number of food groups women are consuming. This way of computation enables comparisons over space and time.

Table 1 MDD-W Food group classification

Food group	Type of food
Starchy staple foods	Grains, white roots and tubers, and plantains
Pulses (legumes)	Beans, peas, and lentils
Nuts and seeds	Tree nuts (cashew), groundnuts and seeds
Dairy (milk and milk products)	Tinned, powdered or ultra-high temperature (UHT) milk, soft and hard cheeses, and yoghurt
Flesh foods	Meat, poultry, and fresh and dried fish, seafoods and shellfish
Eggs	Eggs from domesticated poultry and wild birds
Vitamin A-rich dark green leafy vegetables	Cassava leaves, bean leaves, pumpkin leaves, amaranth leaves, cassava leaves, carrots, and lettuce and red pepper (capsicum)
Other vitamin A-rich vegetables and fruits	Ripe mango, pawpaw, and bananas, melon, apricot, red palm fruit/pulp, passion fruit
Other vegetables	Stems, fruits, and flowers of plants (culinary), Green beans, cucumber, tomato, and okra
Other fruits	Apple, pear, grapes, guava, lemon, lime, kiwi, jackfruit, orange, pineapple, plum, soursop, tangerine

3.2 Other indicators for Women dietary diversity

One advantage of the MDD-W is that it enables the computation of another proxy for dietary diversity, the minimally adequate diet diversity (MADD). It is constructed as a dummy that takes the value of 1 for households whose MDD-W score is greater than 5 and 0 for those less than 5. That is, women who have consumed at least 5 out of the 10 food groups are classified as having the minimum adequate diet diversity while those not reaching this threshold are considered not. It is thus a dichotomous based indicator. Given the computation of MADD, one could argue that it shows whether the dietary intake of households speak to diversity both in terms of micro and macronutrients. This argument is in line with the premise that indicators of dietary diversity are positively associated with micronutrient adequacy which is an important constituent of diet quality.

3.3 Measurement of pathway outcomes

As we highlighted in the introduction, there are four pathways that we consider in the analysis: food production, cash crop production, income, and off-farm employment for women. We measure food production based on a proxy that takes the value of 1 for households that produce food crops and 0 otherwise. Some of the food crops cultivated by households are mainly some of the crops consumed by them. They include cocoyams, yams, tomato, maize, beans, egusi, kolanuts, coconuts, plums, and citrus fruits. We measure cash crop production through a proxy that takes the value of 1 for households that produce cash crops and 0 otherwise. Some of the cash crops that households produce in the study area are cocoa, plantains, egusi, groundnuts, and banana. For the income measures, we rely on per capita income to first understand if oil palm production increases the standard and quality of life of all members of the household and whether these increases could translate into dietary diversity for women. For off-farm employment of women, we generate a variable consisting of off-farm employment for both household heads that are females and spouses of household heads that are males.

4. Material and methods

4.1 Econometric approach

We are interested in estimating the relationship between oil palm production and women dietary diversity. Given this, we estimate regression models of the type:

$$W_i = \beta_0 + \beta_1 OP_i + \boldsymbol{\beta_2 X_i} + \in_i \tag{1}$$

Where W_i is the women dietary diversity outcome for women i. As earlier mentioned, we have two main proxies for this outcome: MDD-W and MADD. OP_i is a dummy capturing oil palm production, $\boldsymbol{X_i}$ is a vector of control variables thought to be associated with women dietary diversity and $\in_i$ is the error term. Our control variables include household, individual and farm level characteristics like age and number of schol years completed, household size, extension contact, membership in producer organizations, access to credit, distance to oil palm plot, use of family and hired labour, farm size, asset ownership and livestock ownership. We estimate different models with and without the control variables to observe coefficient stability. Our parameter of interest is β_1 which tells us the magnitude and direction of the relationship between oil palm production and women dietary diversity.

Since our two proxies of women dietary diversity are structurally different, we estimate two separate regressions to reflect these differences. We employ a Poisson regression model for the MDD-W outcome given they can be regarded as counts. For the MADD, we can either estimate probit and logit models given the dichotomous nature of this outcome variable, but we rather prefer to run ordinary least squares regression in the framework of the linear probability model (LPM). Since we are interested in the effect of oil palm production on women dietary diversity, LPMs avoid identification by functional form which is common in non-linear models (Angrist and Pischke 2008). Additionally, they are also easy to interpret. We also perform some heterogeneity analysis where we run separate regressions for all the 10 food groups of the MDD-W indicator. Given that these are dichotomous outcomes, we again use the linear probability model.

4.2 Identification strategy

Estimating the above regression model could lead to biased estimates as there may be unobserved factors such as risks, managerial ability, nutrition knowledge and various institutional barriers that may jointly influence oil palm production and women nutrition. Of course, we have used a large set of control variables, but this may not be sufficient. Moreover, there may be reverse causality issues given that oil palm production could increase women dietary diversity and women with more diversified diets may be more fit and healthy to engage in various chains in oil palm production. We use an instrumental variable (IV) in a two stage least squares (2SLS) approach to account for these endogeneity issues. For the MDD-W outcome, we estimate an IV Poisson model as it accommodates the count nature of this variable. We use the village non-self-production rate of oil palm as an instrument. For an instrument to be valid, it must be relevant (strongly correlated with the endogenous variable) and exogenous (only correlated with the outcome variable through the endogenous variable). Our instrument is valid based on the strong correlation it exhibits with oil palm production as shown in the supplementary material. The F statistics is large and above the threshold value of 10 for strong instruments. For exogeneity, apart from theoretically motivating this, it is hard to claim this condition when using one instrument. However, we cannot think of any pathway except through oil palm production that the instrument may influence women dietary diversity[2]. Nevertheless, we perform a couple of robustness checks around the 2SLS approach and unobserved heterogeneity to better inform the reliability of our estimates.

For the 2SLS, we estimate a Kinky Least Squares (KLS) regression to provide some sensitivity checks for the instrumental variable. Kinky least squares regression is an instrument-free approach that avoids the problems associated with the search for strong and valid instruments (Kripfganz and Kiviet 2021). Beyond that, this approach enables testing of any potential exclusion restrictions. Given that it does not rely on IVs for identification, one could in principle compare both regressions and obtain more insights on identification. If the Kinky confidence intervals are smaller than the confidence intervals of the IV regression, this would suggest that the instruments are particularly weak. As we show in ahead, we obtain results that highlight that there are no statistical differences between the KLS and 2SLS estimates.

For the unobserved heterogeneity, we run two sets of regressions for each outcome with and without control variables. This is done to obtain some prior insights about coefficient stability, given that selection on observables could be informative about selection on unobservables. That notwithstanding, we still follow the procedures of Oster (2019) to estimate bounds at which unobserved heterogeneity may explain away the estimated relationship between oil palm production and women dietary diversity. We discuss these procedures more in the robustness checks, but it is important to further highlight that we observe significant coefficient stability, suggesting that unobserved selection may not be much of an issue for the analysis. It is important to mention here that eliminating all sources of bias is hard using non-experimental data. That said, we refer to our estimates as associations that are suggestive of the effect of oil palm production on women dietary diversity.

4.3 Pathways

To explore what may be driving the relationship between oil palm and women dietary diversity, we explore the four pathways of food production, cash crop production, income, and off-farm employment of women. We estimate four different models where we regress all these outcomes on oil palm production. The mathematical model here follows the same format as in Equation (1)

[2] It is important to mention here that our instrument may be biased due to the reflection problem associated with such aggregated Ivs.

except that we now change the outcomes. In this regard, β_1 speaks to the relationship between oil palm production and food production, cash crop production, income, and off-farm employment for women. For all the models, we again use simple linear regressions given the nature of the outcome variables.

5. Results and discussion

5.1 Characterization of sample

Table 1 presents the summary statistics of some of the variables used in the regression models. Households have a monthly income of about 110,000 FCFA (USD approximately 190) which reduces to 34000 FCFA when viewed from a per capita basis. Households consume an average of 5 food groups which is above the threshold for an adequate diet. However, just about 38 percent of women are observed to be above the minimum adequate diet, hence somewhat low dietary diversity. About 90 percent of households are producing different types of food crops while 22 percent are producing cash crops. Off-farm employment among women is low as only about 11 percent of women are involved in some sort of off-farm activity.

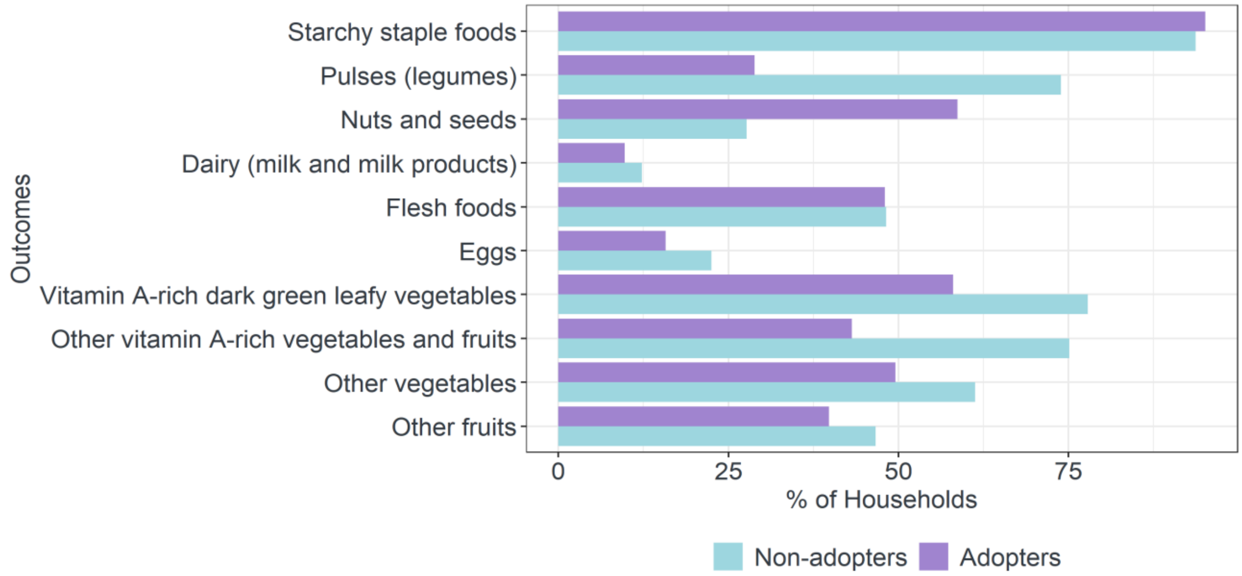
Table 1 Summary statistics of regression variables

Variable	**Mean**	**Std Dev.**
Outcome and pathway variables		
Household income (FCFA)	110288.10	209027.20
Per capita income (FCFA)	34164.97	69364.02
MDD-W (score)	5.07	1.67
MADD (1/0)	0.38	0.48
Food crop production (1/0)	0.90	0.29
Cash crop production (1/0)	0.22	0.42
Off-farm employment for women (1/0)	0.11	0.32
Control variables		
Age of the household head (years)	49.61	14.95
Household head is male (1/0)	0.73	0.44
Educational level (years)	9.91	3.75
Household size (number)	5.03	4.16
Experience in crop production (years)	19.96	14.67
Years lived in the village (years)	22.11	17.37
Extension access (1/0)	0.18	0.39
Cooperative membership (1/0)	0.18	0.39
Credit access (1/0)	0.18	0.38

Livestock ownership (TLU)	0.11	0.51
Farm size (hectares)	19.75	47.31
Area of oil palm (hectares)	3.29	3.91
Hired labour (1/0)	0.54	0.49
Family labour (1/0)	0.95	0.20
Asset index	0.05	1.70
Number of crops cultivated	2.46	1.61

Given that we are interested in understanding the relationship between oil palm production and women dietary diversity, we compare dietary diversity by oil palm production. Figure 1 shows the various categories of food consumed by women in the sample and differentiates them based on oil palm production. As can be seen, the most consumed food groups are starchy staple foods, followed by vitamin A-rich dark green leafy vegetables and other vitamin A-rich vegetables and fruits. Also, non-adopters of oil palm are generally better off than adopters of oil palm when it comes to the consumption of a more diverse food group. However, for two food groups, starchy staple foods as well as nuts and seeds, we find different results suggesting that oil palm farmers are more likely to eat more cereals than non-oil palm farmers. This already suggests that women in oil palm producing households are more likely to rely on poorer diets as compared to non-oil palm producing households. That said, these insights are only descriptive and really do not point in any direction as we do not control for many confounding factors that may be in the way of this relationship. The next section presents results where we control for several confoundings.

Figure 1 Food groups consumed by women



5.2 Empirical results

We begin by presenting the baseline regression estimates of the relationship between oil palm production and women dietary diversity. We present estimates of both the MDD-W and MADD. As shown in Table 2, oil palm production is adversely associated with both MDD-W and MADD, that is oil palm production reduces women dietary diversity, both in terms of the expected counts of the various food groups and the diet adequacy. These results are stable to the inclusion and exclusion of controls given that the estimated coefficients only change in small amounts. The results contrast the growing literature that has established that oil palm production increases consumption expenditure and dietary diversity in Southeast Asia (Euler et al. 2017; Sibhatu 2019; Chrisendo et al. 2020). However, as earlier highlighted, most of these studies are based on oil palm production in Indonesia where the context is significantly different from production in Cameroon and other West African countries on several fronts (Ruml et al. 2022).

Table 2 Oil palm production and women dietary diversity

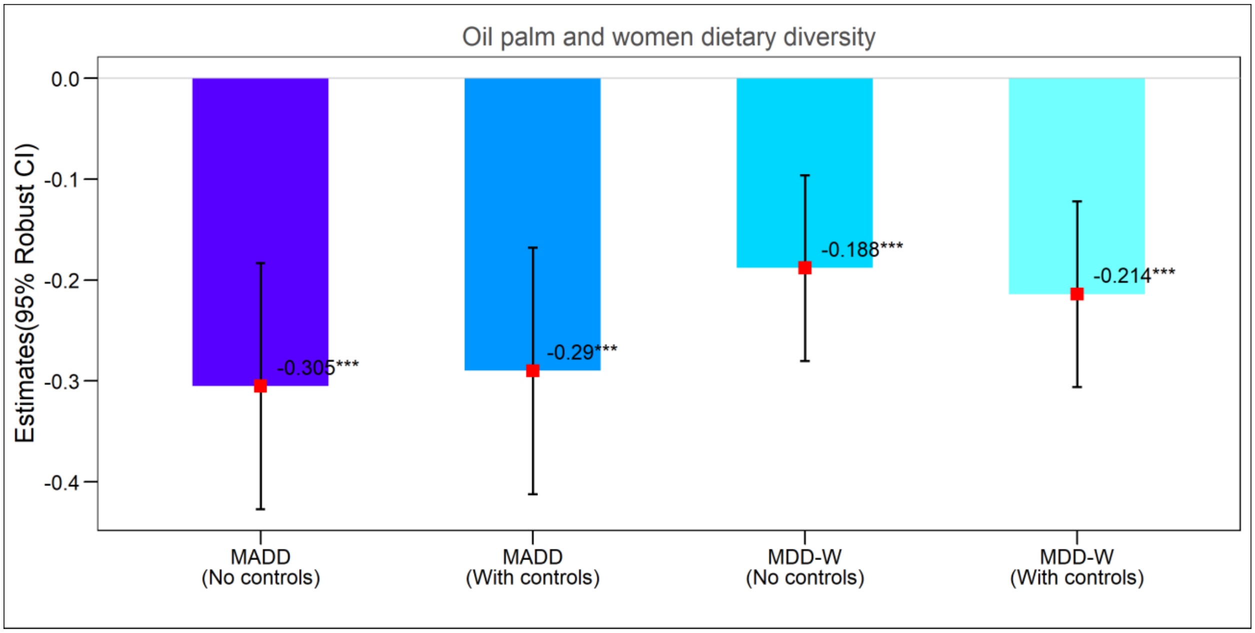
	(1) **MDD-W**	(2) **MDD-W**	(3) **MADD**	(4) **MADD**
Oil palm production (1/0)	-0.188*** (0.047)	-0.214*** (0.047)	-0.305*** (0.060)	-0.290*** (0.060)
Constant	1.685***	1.466***	0.557***	0.476***

	(0.039)	(0.132)	(0.062)	(0.147)
Additional controls	No	Yes	No	Yes
Pseudo (R squared)	0.01	0.02	0.097	0.137
F statistic			25.92***	8.45***
Wald chi2	16.10	334.15***		
Model	Poisson	Poisson	LPM	LPM
Observations	582	582	582	582

Additional controls include age and educational level, gender of the household head, household size, access to extension services and cooperative membership, credit access, livestock ownership, distance to farm, farm size, hired labour, family labour, and asset index. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Full results are presented in the supplementary material.

We also present the 2SLS estimates of the relationship between oil palm production and women dietary diversity. As shown in Figure 2, we obtain somewhat similar results like in the baseline OLS models. Again, oil palm production is negatively associated with women dietary diversity. In terms of numbers, oil palm production is associated with a reduction in the log of expected counts of women dietary diversity by about a quarter. However, it is correlated with approximately a 30-percentage point reduction in diet adequacy and quality. These magnitudes are somewhat large given that dietary diversity can be influenced by several factors.

Figure 2 Oil palm production and women dietary diversity



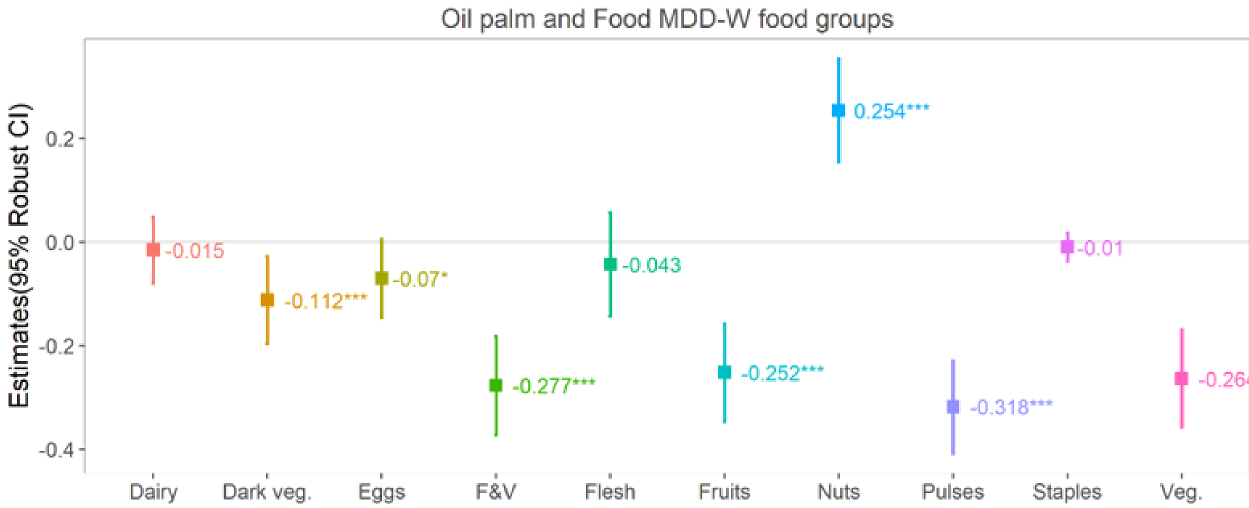
Additional controls include age and educational level, gender of the household head, household size, access to extension services and cooperative membership, credit access, livestock ownership, distance to farm, farm size, hired labour, family labour, and asset index. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Full results are presented in the supplementary material.

As earlier highlighted, these results are novel and contrast findings of the sector in Southeast Asia, although no work has considered women dietary diversity. Closely related studies have looked at women's time allocation decisions resulting from oil palm cultivation in Indonesia but found contrasting results. While Mehraban et al. (2022) found that the sector saves time for women and increases on their leisure and chores times, Rowland et al. (2022) rather found the sector to induce time scarcity and adversely affect the leisure and sleep time of women. All these time allocation implications could drive such changes in maternal nutrition. We explore other pathways that could explain our results but before presenting that, we perform some heterogeneity analysis to see which food groups are affected more.

5.3 Heterogeneity analysis by food groups

As our outcome variable is a dichotomous variable, we perform some heterogeneity analysis using the linear probability model on each of the respective food groups to understand differential associations. We run both OLS and 2SLS models. Both models offer very similar insights, so we only show the results of the 2SLS approach and push the LPM to the supplementary material. As shown in Figure 3, we observe negative significant associations for pulses, eggs, dark vegetables, vitamin A fruits and vegetables, other vegetables, and other fruits. These results add more insights to the original findings of the negative association between oil palm production and dietary diversity. The only food group exhibiting a positive association is the nuts and seeds group. This result makes intuitive sense since this groups includes crops like groundnuts which can be considered cash crops since farmers heavily sell them. Of course, households would only commercialize these crops to the extent that their household food demands are met.

Figure 3 Oil palm and MDD-W food groups

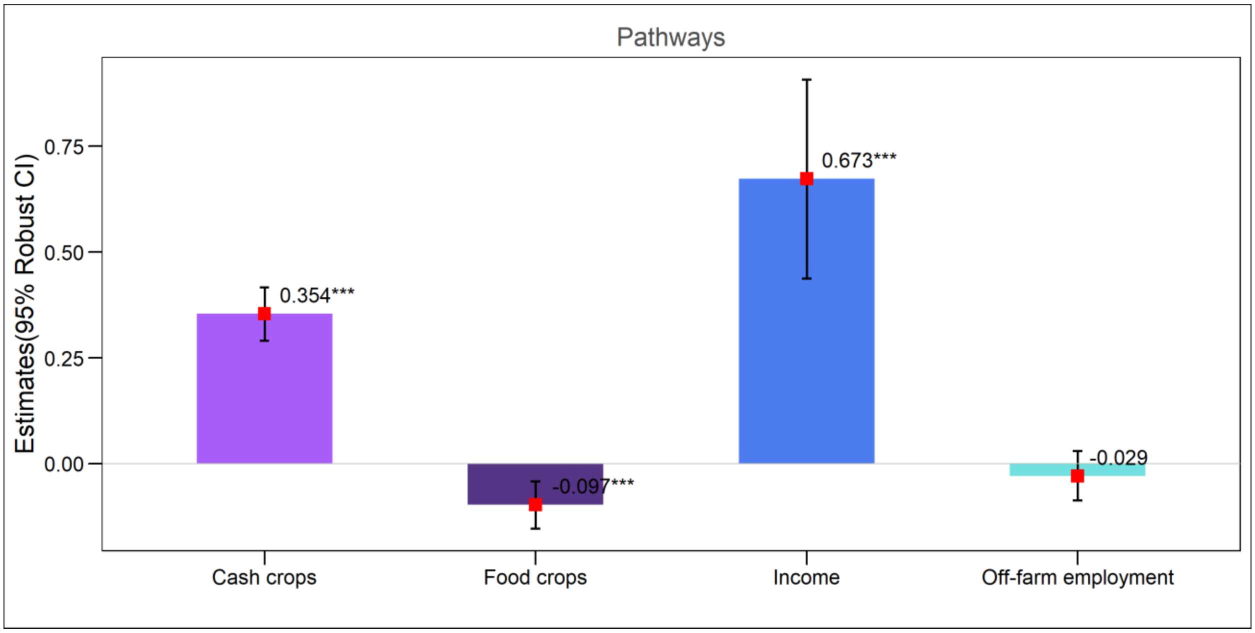


Additional controls include age and educational level, gender of the household head, household size, access to extension services and cooperative membership, credit access, livestock ownership, distance to farm, farm size, hired labour, family labour, and asset index. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Full results are presented in the supplementary material.

5.4 Pathway results

Now that we have established a negative relationship between oil palm production and dietary diversity, we explore some of the pathways that may be driving these results. Figure 4 shows the results of the four pathways considered. The results speak and confirm most of the *a priori* expectations argued in section 2. Specifically, we observe that oil palm production is associated with a reduction in food crop production by about 9.7 percentage points. Oil palm production has a long value chain in Cameroon given that households also undertake milling activities and sell in markets (Tabe-Ojong et al. 2022). All these activities are time consuming and may reduce time invested in food crop production. Moreover, anecdotal evidence suggests that farmers are heavily clearing new lands for oil palm (extensification) rather than practicing intensification. These extensification activities are not only time consuming but also very labour intensive and costly for famers.

Figure 4 Impact pathways



Additional controls include age and educational level, gender of the household head, household size, access to extension services and cooperative membership, credit access, livestock ownership, distance to farm, farm size, hired labour, family labour, and asset index. Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Full results are presented in the supplementary material.

We also observe that oil palm production is associated with the production of other cash crops. Some of the cash crops in this context are cocoa, banana, groundnuts, egusi and plantains. Given that these sectors are clearly profitable, it has been argued that most of them are controlled by men where women are excluded (Li 2015; Vos and Delabre 2018). The exclusion of women may reduce their autonomy and decision-making power especially on income. We also confirm that oil palm production is income increasing but found no support from the data about any discernible association with off-farm employment. The results that oil palm production is income increasing is expected as highlighted by previous studies (Rist et al. 2010; Krishna et al. 2017; Kubitza et al. 2018; Ayompe et al. 2021a). However, given that we observe a negative association between oil palm production and women dietary diversity, it may be that income gains do not translate to women dietary diversity owing to little or no control of farm resources and income (Mehraban et al. 2022). However, these results could also speak to the fact that farmers are not fully exploiting the opportunities available in the sector due to the various constrainsts they are facing like little institutional support, high labour costs which have some environmental costs as households tend to extensify rather than intensify.

Our results on the negative association between oil palm production and women dietary re-echoes earlier work on deforestation, tree cover and child nutrition. Ickowitz et al. (2014) established that tree cover is positively associated with improved nutrition and diets for children. Building on this analysis, Jones et al. (2017) showed that forest loss (deforestation) is adversely associated with children diet diversity and consumption of nutritious foods in West Africa. Given the increased deforestation that has been associated with the rise of artisanal mills in Cameroon (Ordway et al. 2021), our results on the negative association with women dietary diversity should be in order. Some additional pathways that could explain these results could be (1) loss of income from forest products and activities such as non-timber forest products; (2) loss of access to wild fruits and vegetables from the forests (Ickowitz et al. 2014).

5.5 Robustness checks

As mentioned under the identification strategy, we perform a couple of robustness /sensitivity checks on unobserved selection and the 2SLS estimation. For unobserved selection, we estimate various bounds that are informative of the impact of unobserved selection. We estimate both delta and beta values that tell two different stories but in the same direction. The delta value estimates how large unobserved selection is to be relative to observed selection to explain away the estimated relationships. The beta values on the other hand show the bias adjusted estimates which is indicative of the change in the estimated coefficients if selection on unobservable is assumed equal to selection on observables. Table 3 shows the beta adjusted coefficients and the delta values for the MADD outcome. We obtain a beta value of -0.27 which is an upper bound of the true estimated coefficient of oil palm and diet quality for women. This finding already highlights that unobserved selection may not be an issue in the analysis. The delta value of 1.88 further confirms this insight given that unobserved selection must be 1.8 times the observed selection to explain away the estimated relationship.

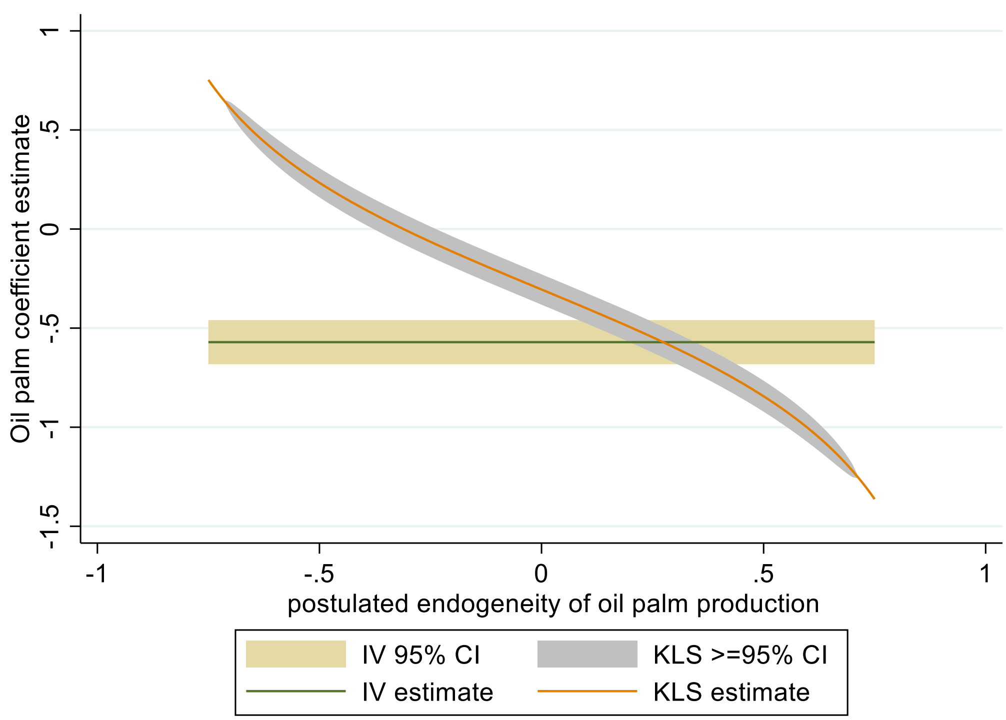
Table 3 Estimated Oster bounds

	MADD	
	(1)	**(2)**
Beta adjusted coefficients	0	-0.27
Delta	1.88	1
R^2 max	0.16	0.16
Observations	582	582

Notes: In specifications (1), (3) and (5), the degree of omitted variable bias is calculated after setting the estimated coefficients to zero. In specifications (2), (4) and (6), the omitted variable bias is assumed to equal the additional controls used, from which bias-adjusted beta coefficients are estimated.

The second check is the KLS regression which we compare with the 2SLS regression approach. As shown in Figure 5, the confidence intervals of the IV estimation are somewhat narrow, suggesting that the instrumental variable may not be weak. Moreover, the confidence intervals of both the KLS and 2SLS approaches overlap for relatively large positive endogeneity correlations. Noteworthy here is the fact that the point estimates also overlap as they cross at some point of the range (-0.75 -0.75). There seems to be no statistically significant difference between the KLS and 2SLS approach based on the overlapping confidence intervals and the p-values > 0.05 of the exclusion restriction tests within the correlation range (cf supplementary material). All these observations strengthen the insights and earlier arguments that the instruments may be valid, hence implying that the estimated results are unlikely to be biased.

Figure 5 KLS and 2SLS coefficient estimates and confidence intervals for oil palm



6. Conclusion and policy implications

In this study, we estimate the relationship between oil palm production and women dietary diversity from a native but emerging oil palm hotspot in Cameroon. We show that although oil palm production is associated with income increases, the gains are not translated to improve the dietary diversity of women possibly due to less autonomy and control fo farm income. Exploring some mechanisms that may be explaining these relationships, we show that oil palm production is adversely associated with food crop production which has been shown to be an important determinant of food consumption and dietary diversity. We also establish significant heterogeneity in the various food groups whereby pulses and legumes, green vegetables, vitamin A rich vegetables and fruits as well as other fruits and vegetables are the food groups affected by oil palm production.

Our findings offer a couple of implications for policy development. In the first place, we offer empirical support to the literature highlighting the income gains from oil palm production in a native but emerging hotspot of oil palm expansion. Given the limited policy and institutional support offered to oil palm farmers, it may be important for policy to consider various ways of supporting and promoting oil palm development. This support has the possibility of not only increasing welfare at the household level but also at the community level. Despite these advantages, income gains in the Cameroonian context are not able to translate to improved nutrition for women. Oil palm production reduces women dietary diversity. In this regard, the second entry point for policy could be to ensure gender-equitable rural development in oil palm producing regions. Given that the underlying mechanisms behind this negative relationship are displacement in food production, possibly due to time allocation. Oil palm production in Cameroon has a long value chain that involves most members of the household, although the gains go to the household heads in most cases. Reducing the time allocation to oil palm cultivation could greatly increase cultivation of food crops which are necessary for consumption and dietary diversity. One way to reduce this time allocation may be to get farmers involved in various institutional coordination mechanisms like cooperatives and contract farming which could improve input provision but also processing which is very time consuming given that it is done rudimentarily.

One other leverage point to reduce labour cost and manpower may be to improve milling conditions. This also has the potential of fully maximizing and increasing income gains as well as reducing inefficiencies along the value chains. This is one crucial area where the oil palm sector in West and Central Africa can learn from the Indonesian case. Most oil palm farmers in Indonesia are contracted to large milling companies that buy fresh fruit bunches from farmers and process them. In Cameroon on the other hand, processing is done by farmers using artisanal mills. These mills have been highlighted to lead to significant deforestation in Cameroon (Ordway et al. 2021). Thus, improving access to industrial mills may have far reaching welfare implications with the potential to reduce some of the environmental effects of oil palm expansion. On another front, providing support to existing oil palm farms to boost intensification instead of extensification may also reduce the trade-off between socio-economic gains and ecological safeguards.

Like every study, we end by pointing out some limitations and directions for future research. Our first limitation stems from the nature of our data which makes it hard for us to claim causality. We have used a lot of empirical and identification strategies to move towards causality, but we prefer to refer to our estimates as associations given that we just one period cross-sectional data. Future endeavours may want to delve more into panel data to obtain more causal and dynamic effects. Second, we guide against the generalization of our study given that context really matters. That said, our analysis may be generalized to other oil palm production hotspots in Africa given that the systems and constraints farmers are facing are similar. Nevertheless, it may be worthwhile to have other studies in different contexts to increase the external validity of these findings.

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