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Oil palm expansion among non-industrial producers in Cameroon: Potentials for synergy between agro-economic gains and ecological safeguards

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ABSTRACT

Regardless of the environmental and socio-ecological implications of oil palm cultivation, oil palm is considered one of the most important oil crops in the world because of its high production efficiency which has seen a marked increase in the area under cultivation. While previous studies have analyzed the implications of this increase in cultivation on various socio-economic and environmental indicators, less is known about the drivers and constraints of production, especially concerning economic and profitability motives. In this study, we used a survey of non-industrial producers in the humid rainforest zone of Cameroon to assess the drivers of oil palm production. We employ a double hurdle model in a two-step regression framework to characterize oil palm production by smallholder farmers, and the extent of oil palm production. For comparison purposes, a Tobit model is also estimated. We find that different socio-economic and institutional factors have a differential relationship with both the likelihood of cultivating oil palm and the area under oil palm cultivation. Key among these are expected profitability measures such as market orientation and access to market information, land tenure security, and access to improved farm inputs. Some aspects of transaction cost and labour availability also come into play in determining oil palm production. Across a range of different farm classifications related to the scale of production, we find that oil palm cultivation is prevalent among all farm groups, although highly predominant in large farms. We also show that our results are robust over several linear specifications such as the linear probability model and the lasso linear model. Our study thus provides evidence of several entry points for improving the oil palm sector for non-industrial producers while safeguarding the environment.

1. Introduction

It is assumed by diverse stakeholders that expanding agricultural production for livelihood and welfare gains comes at the expense of environmental welfare. This perception of creating wealth at the behest of ecological stability has mandated the resolutions of many national and international fora. Building on the Human Environment Conference which was held many years ago in Stockholm, the United Nations Conference on Environment and Development, also known as the Rio de Janeiro Earth Summit, highlighted how different social, economic and environmental factors are interdependent and must evolve together, and that 'success in one sector requires action in other sectors to be sustained over time (UN, 1992; UN, 2002; UN, 2012; UN, 2015). Agriculture that meets the needs of growing populations cannot, therefore, be undertaken at the behest of deforestation and ecological disequilibrium (Grass et al., 2020; Pirker et al., 2016; Vijay et al., 2016; Carrasco et al., 2014).

The construction of production spaces to protect ecological assets poses challenges for agricultural stakeholders to operate ecologically smart agro-economic systems that meet the triple objectives of economic, ecological and social sustainability. The wealth of knowledge generated on circular economic systems, nonetheless, indicates that sustainable production and consumption is possible. Agricultural production and consumption do not require a trade-off with ecological stability and environmental health. Oil palm (*Elaeis guineensis*) is one crop that provides an opportunity to demonstrate the plausibility of sustainable production which heralds multiple benefits for the society,

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the economy and the environment (Quezada et al., 2019; Dislich et al., 2018).

Oil palm is considered one of the most important vegetable oil crops in the world because of its high production efficiency. This has led to increasing conversion of land and deforestation to fully tap from the opportunities inherent in oil palm cultivation. However, there is widespread concern about its environmental and social impacts (Grass et al., 2020; Carrasco et al., 2014). Most of the social impacts pertain to conflicts and land disputes between agro-industrial companies and the local communities (Obidzinski et al., 2012; Abram et al., 2017). Similarly, not all producers benefit from oil palm expansion, especially in remote forested areas (Santika et al., 2019). Despite the undesired social and environmental effects, oil palm expansion has increased at an unparalleled rate (Taheripour et al., 2019; Vijay et al., 2016). Global demand for vegetable oils is also increasing and is expected to double to an estimated 240 Mt. by 2050 (Corley, 2009; Sayer et al., 2012). A major proportion of this increase may be due to oil palm[1] since it has the comparative advantage of having the lowest production cost with the ability to generate more vegetable oil per unit land area than any other crop (Qaim et al., 2020). In terms of share of production, sub-Saharan Africa (SSA) accounts for about 6% of global oil palm production, yet stands out as one of the largest importers of palm oil (7.9Mt) (FAO, 2020). Despite the region being suitable for oil palm – which is native to forests in West and Central Africa[2] – production is low and lags behind the global level.

An extensive literature has analyzed the diverse impacts of oil palm expansion on various livelihood, socio-economic and environmental outcomes (Corley, 2009; Feintrenie, 2011; Sayer et al., 2012; Vijay et al., 2016; Pirker et al., 2016; Euler et al., 2016a; Euler et al., 2017; Ordway et al., 2017; Bou Dib et al., 2018; Jaza Folefack et al., 2019; Xin et al., 2021; Qaim et al., 2020). Studies on the sector in South and Southeast Asia have established that oil palm production is associated with increased government revenue and the creation of private goods (Krishna and Kubitza, 2021), household income (Bou Dib et al., 2018; Ahmed et al., 2019), and consumption expenditure (Euler et al., 2017; Krishna et al., 2017; Kubitza et al., 2018a). Beyond income and welfare effects, unprocessed palm oil, widely consumed in West and Central African households, also improves nutrition and food security, ensuring caloric intake and dietary quality (Euler et al., 2017; Sibhatu, 2019; Chrisendo et al., 2020;). Oil palm production also has the potential to improve food security through income gains, which can translate to better nutrition outcomes (Sibhatu, 2019). However, there are concerns that the increased production of oil palm (especially at large scales) may threaten long-term food and nutrition security as well as environmental stability if such production is carried out in competition with or at the expense of food crop production.

Despite the crop's economic and food security importance, empirical evidence of the drivers and constraints in the cultivation of oil palm remains scarce. Few exceptions are Euler et al. (2016b) and Xin et al. (2021), who examined the various biophysical and socio-economic characteristics driving oil palm expansion in Indonesia. While Xin et al. (2021) employed spatial panel modelling approaches at spatial scales using land-use and land cover (LULC) maps, Euler et al. (2016b) used duration models to understand drivers of oil palm adoption at the household level with a specific focus on land-use change. Here, we build on the research by Euler et al. (2016b), who directly examined the production and adoption decision of farmers. While understanding such binary decisions as whether to cultivate oil palm or not is essential, especially concerning socio-economic outcomes, effects likely vary depending on the extent of production (area under cultivation) (Euler et al., 2017). Important questions to answer are: what are the principal drivers of oil palm production and expansion? Does the characterization of producers provide potentials for synergy between the farm economy and the environment?

We answer the above questions and contribute to filling this knowledge gap by examining both the adoption and extent of oil palm production in the Southwest region of Cameroon. By the extent of production, we refer to the area under oil palm cultivation. Examining the area under production allows us to internalize the excavation of new forest lands for cultivation.

We used a double hurdle model and address our objectives as a two-stage process where a farmer first decides to cultivate oil palm, and conditional on this, decisions about the land area to devote to oil palm cultivation are made. We found various socio-economic and household contextual characteristics to have a different relationship with both farmer decisions. Precisely, market orientation, access to market information, and land tenure characteristics depict a positive association with oil palm cultivation and its extent. Labour availability also matters immensely given that oil palm cultivation is somewhat labour demanding and energy-consuming, especially for some farm tasks like pruning and harvesting. The results are robust to other regression specifications, including the linear probability model and lasso linear[3] regressions. Given that oil palm adoption may have a heterogeneous relationship with different farm structures, we verified this in the case of oil palm cultivation in Cameroon. Using three farm size typologies (small, medium and large scale farms) based on Ordway et al. (2017), we show that oil palm adoption is positively associated with all farm classifications. That is, small farms, as well as large farms, are engaged in the cultivation of oil palm, though this is largely predominant in large farms. Insights from this heterogeneous association are relevant for policy development in identifying policy options and entry points that address the needs of a diverse socio-economic group.

Cameroon is an important location to understand the drivers of oil palm production among non-industrial producers for several reasons. First, oil palm production in Cameroon has an import substitution advantage. Oil palm can be regarded as a strategic crop with the opportunity to leverage the import-export equilibrium. While the country is among the top palm oil producers in Africa, it still imports about 57,000 tons of crude palm oil (CPO) per year.[4] Second, oil palm production is increasingly grown by non-industrial producers who are usually asset poor and cash-constrained. From a policy perspective, interventions that support the participation of these groups will have significant effects in reducing poverty and accelerating rural development.

Third, oil palm expansion in Cameroon is predominantly driven by non-industrial producers and coordinated around a burgeoning informal milling sector (Ordway et al., 2019). Cameroon can thus be looked upon as a major region of growth when it comes to oil palm production and expansion in Africa. Since oil palm production in Cameroon is driven by non-industrial producers and given the rise and income-generating effect of such farms in many parts of sub-Saharan Africa (Chamberlin and Jayne, 2020), understanding what motivates farmers to cultivate oil

[1] In terms of productivity oil palm production, as compared to other vegetable oil crops has a higher yield potential (Sayer et al., 2012). However, in most West and Central African countries yields remain low and entirely below potential compared to major producing regions in Southeast Asia.

[2] In this region, Cameroon is a key player in the oil palm sector as it produces on average 230,000 tons/year of palm oil Jaza Folefack et al. (2019). Cameroon ranks as the 9th and 3rd oil palm producing country in the world in Africa respectively.

[3] LASSO stands for Least Absolute shrinkage and selection Operator. It is an estimation method that minimizes the sum of squares residual when the sum of the sum of the absolute value of the coefficients is less than a constant. It improves stability in ridge regressions while producing models that are easily interpretable like in subset selections. It thus retains the positive features of ridge regressions and subset selection.

[4] This statistic is obtained from the Annual International Trade Statistics by Country, https://trendeconomy.com/data/h2/Cameroon/1511.

palm as a food or cash crop can reveal pathways for enhancing rural livelihoods and increasing smallholder incomes. Moreover, oil palm cultivation can link farmers to new and evolving value chains, generating on, off and non-farm employment, with further welfare implications.

The market for palm oil is expanding with its increasing use in the pharmaceutical and confectionary-food industry. Despite incisive criticism associated with oil palm plantations linking them to deforestation, biodiversity loss, air pollution and climate change, the rising global demand for vegetable oil means that it will not be possible to replace palm oil with other types of oil without further increasing deforestation. In addition, the wide-ranging advantages of oil palm include its high yields for farmers, financial profitability, efficient land use, source of income for the local economy, tax revenue, job creation, and nutrient-rich oil that can be used for many food products. Moreover, it is suitable for energy generation through biofuel production. This attractiveness of oil palm means its substitution may not be cost-effective, and other cultural constraints functions require seeking knowledge by examining how to optimize its adoption and carefully manage its expansion.

The rest of the paper is structured as follows: Section two provides the context of oil palm production in Cameroon. In section three, the research area and data are presented alongside the measurement of variables and some descriptive statistics. Section four delves into the materials and methods where the empirical model is specified and discussed. The empirical results are presented and discussed in section five, while the paper concludes with policy implications and limitations in section six.

2. Oil palm production in Cameroon

The cultivation of oil palm has been historically crucial for Cameroon. Colonial plantations before the country gained its independence in 1960 remained productive throughout the 1960s and 1970s (Fig. 1). In the 1980s, yields doubled compared to the 1960s, with a slight decline in 1991 following external shocks and depressed world prices. However, yields continued to rebound and peaked at 212,746 hg per hectare in 2007. By 2009, following global shocks in agricultural commodity prices, there was a sharp decline, and this later rebounded in 2011. However, since 2013 the yields of oil palm have experienced a steady decline. While this decline may seem to augur well for environmental motives, it has nonetheless come with extensive expansion seeking new lands with new entrants into the sector converting additional forest lands.

Historically, in the 1960s to 1990s, high production levels resulted in export surpluses for Cameroon (Fig. 2). In 1997, export revenues peaked at US$ 13,403. The steady decline after that rebounded in 2005 to US$ 13,628. However, the country's population growth and expansion of its manufacturing base have meant increased demand for palm oil by consumers and local industries with fewer surpluses for export since 2006. Since 2005, imports have surpassed exports every year.[5] The most considerable import expense was US$ 71,021 in 2014. Though imports of palm oil declined in 2015, Cameroon remains a net importer. This is largely due to a growing domestic demand for palm oil combined with already low and declining productivity of aging plantations, as well as fewer new entrants being recorded in the sector as land values improve with alternative land-uses attracting quick returns compared to plantation agriculture.

Cultivation of oil palm is more prevalent in the Southwest, South, and Littoral regions of Cameroon (Li et al., 2015). In these regions, the expansion of oil palm is mostly carried out by non-industrial producers at the expense of secondary forests, with minimal expansion into pristine forests. For instance, Nkongho et al. (2014) reported that about two-thirds (67%) of oil palm cultivation by non-industrial producers in Cameroon occurred at the expense of secondary forest with only 4% attribution to primary forests. As noted by the authors, expansion into primary forests is carried out by agro-industrial enterprises and large timber companies. Their findings suggest that non-industrial oil palm developments have less impact on the degradation of intact forests, although a great deal of research has demonstrated the biodiversity and ecosystem service values of secondary forests as well (Chazdon et al., 2009; Matos et al., 2020). In terms of yields, the non-industrial production of oil palm averages 5–7 tons of fresh fruit bunches (FFBs/ha) (Ordway et al., 2017), leaving a large yield gap (Jaza Folefack et al., 2019). Closing this gap may require the use of various intensification techniques, which may increase potential gains and offset undesired socio-environmental effects.

3. Empirical data

3.1. Research area and data

This study relies on a farm household survey conducted in 2015 to examine oil palm production in Cameroon's Southwest region (Fig. 3). The survey data was then cross-referenced with field visits and available agricultural census data from the Ministry of Agriculture and Rural Development. A multi-stage sampling technique was used to select farms to be studied. In the first stage, 50 predominantly oil palm village communities were randomly selected from 5 divisions (Fako, Meme, Ndian, Kupe-Muanenguba, and Manyu) in the Southwest region. These divisions represent the mono-modal rainforest agro-ecological zone, which is suitable for oil palm production. Villages were selected using the probability proportional to size (PPS)[6] approach. From the 50 villages, household lists were compiled and updated based on census information provided by the village chiefs and in some instances the sub-delegation of agriculture and rural development. From this list, 10–15 farm households were randomly selected from the different villages, resulting in 545 farm households.

A paper questionnaire was then used to collect information from the farmers. Interviews were conducted at two levels: at the household level (N = 545) and the plot level (N = 1526). We collected information on socio-economic and demographic profiles at the household level, including institutional characteristics like access to information and extension support, and market orientation. At the plot level, we collected information on production and management practices as well as land tenure security. For the analysis, the plot level data were collapsed and aggregated to the household level. A team of well-trained research assistants supervised by one of the researchers administered the questionnaire by interviewing de facto and de jure household heads.

To obtain qualitative and anecdotal insights into production and its associated constraints, supplementary key informant interviews and surveys were undertaken with artisanal mill owners, plantation managers, palm oil retailers and traders, field staff of the Ministry of Agriculture and Rural Development, local agronomists, and reference farmers, as well as staff from non-governmental and development organizations.

[5] Due an agreement in the 2000s between the government, agro-industrial companies, and other stakeholders, CPO is not supposed to be exported out of the country. This is to avoid the closure of downstream industries. However, what is encouraged for export is refined CPO, savon and other products. While the market for CPO from agro-industrial companies is regulated by the government, the sale of palm oil from artisanal mills depends on the price in the local market.

[6] This approach provides a method for calculating unequal probabilities of selection for the PSU based on a measure of PSU size. It ensures that, given the higher likelihood of sampling villages from larger districts, all villages have the same probability of being sampled regardless of the district they are in due to weighting by district size.

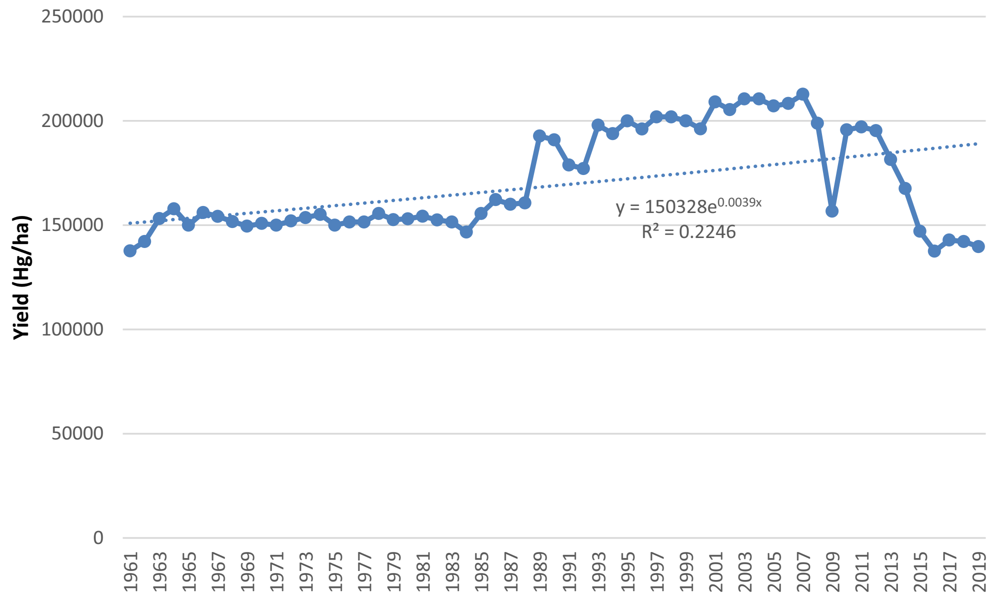

Fig. 1. The yield of fresh fruit bunches of oil palm in Cameroon, 1961–2019 (Authors' construction with data from FAOSTAT, 2021).

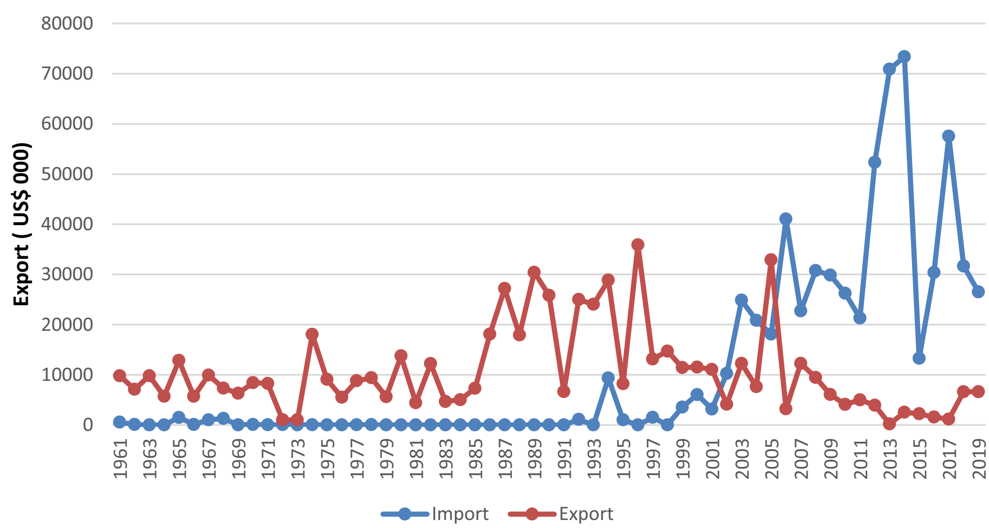

Fig. 2. The values of export and import trade of palm oil, 1961–2019.
(Authors' construction with data from FAOSTAT, 2021.)

3.2. Variable description and descriptive statistics

Our outcome variables are the decision to cultivate oil palm and the extent of oil palm cultivation. The first outcome is a binary variable that takes 1 for households that produce oil palm and 0 otherwise. The second outcome is the extent of production. We use the area under oil palm cultivation as a proxy for this outcome. About 70% of farm households are involved in oil palm production, with an estimated average area under production of about 10 ha (Table 1). This is consistent with Hoyle and Levang (2012) who found non-industrial producers to constitute approximately 70% of oil palm land area. Oil palm cultivation in Cameroon has been in the hands of agro-industries since it was first planted in 1907 (Hoyle and Levang, 2012). In the 1970s, only about 10% of the oil palm area was managed by non-industrial producers (Ordway et al., 2017). This growth was stimulated by the rural development bank, *Fonds National du Développement Rural* (FONADER) which focused on expanding non-industrial production through the provision of inputs, credit and technical support (Nkongho et al., 2015). Households are also engaged in the cultivation of other cash crops like cocoa as well as food and staple crops like cassava and grain legumes (Ordway et al., 2017; Molua et al., 2020; Tabe-Ojong et al., 2021a). Most of the households are headed by middle-aged males.

We find that households are somewhat bounded by transaction cost characteristics, like distance from the homestead to the farm and the artisanal mills. While household members have to travel on average 3.6 km to their farms, they only have to travel 1.8 km on average to the nearest artisanal mills. Only about 35% of farmers reported receiving advice from an agricultural extension worker. More than 80% of the farmers receive marketing information about oil palm either from traders, retailers, wholesalers, or artisanal mill owners. However, market engagement is low as only about 15% of farmers participate in markets.[7] Farmers who do not participate in markets either retain their produce for personal consumption or sell their FFBs to processors who

[7] Households participate in markets to sell other plantation and food crops like rubber and banana.

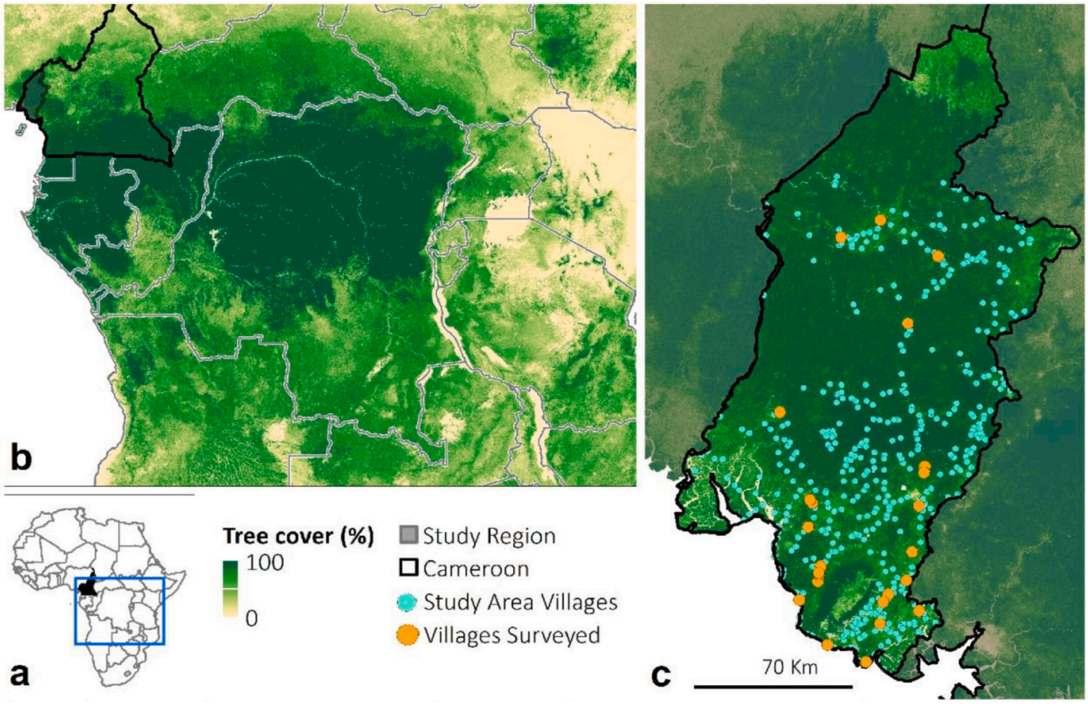

Fig. 3. Study area: Cameroon is located in West-Central Africa(a), an area in the Congo Basin with large tracts of remaining tropical forest(b). Surveys were conducted across villages in the Southwest region of Cameroon, an important oil palm production region in Africa(c.)

Table 1
Summary statistics of variables.

Variable	Mean	Std. dev.
Outcome variables		
Oil palm cultivation (1 = Yes)	0.707	0.394
Area of cultivation (hectares)	9.670	39.109
Explanatory variables		
Age of household head (years)	47.521	14.343
Head is Female (1 = Yes)	0.126	0.333
Formal education (1 = Yes)	0.491	0.500
Extension contact (1 = Yes)	0.346	0.476
Family labour[a] (1 = Yes)	0.777	0.415
Hired labour (1 = Yes)	0.666	0.472
Head is migrant (1 = Yes)	0.559	0.496
Distance to farm (km)	3.602	4.235
Distance to mill (km)	1.844	2.775
Tenurial security (years)	14.706	10.977
Off farm income (1 = Yes)	0.322	0.468
Access to credit[b] (1 = Yes)	0.161	0.368
Market information (1 = Yes)	0.866	0.340
Market engagement (1 = Yes)	0.146	0.354
Improved inputs (1 = Yes)	0.675	0.468
Yields (tons/ha)	7.70	9.62
Farm size (hectares)	14.20	22.23
Small farms (hectares)	1.66	0.39
Medium farms (hectares)	5.19	2.18
Large farms (hectares)	44.25	91.16

Notes: Tenurial security refers to the number of years households have claimed ownership over land without any interference from a third party. Improved inputs refer to the use of improved seeds, fertilizers, and pesticides in production. Market orientation refers to farmers that participate in markets as sellers.

[a] Family labour here refers to the use of working age household members.

[b] Access to credit is defined as a dummy indicating whether the household receives credit from cooperative societies, producer organizations, microfinance institutions and other rural lending services.

then engage in market activities (e.g., trading and selling). As a means of rural diversification, about 32% of farmers in the study area engage in other off-farm activities for income. About 60% of farmers in the study area migrated to the area where they now live and farm.

As oil palm is a perennial crop, land property rights matter a lot (Kubitza et al., 2018a, 2018b). In the study area, land property rights are customary and most households claim ownership based on customary titles issued by chiefs and other village heads. As of 2008, only about 2% of rural land in Cameroon had a land title[8] (AfDB, 2009). We, therefore, proxied for land tenure security using the number of years a farmer has owned land.[9] About 87% of farmers reported owning land, although only 5% had official state land titles.

4. Materials and method

4.1. Empirical specification

Adoption and production decisions have been estimated using various econometric approaches and techniques. The choice of an appropriate approach largely depends on the type of dependent variable. Our dependent variable is a censored type with zeros. Hence the best econometric technique should address the source of the zeros. Zeros in this case represents the non-production of oil palm which can be driven by different factors. The most common sources among smallholder farmers are high transaction costs and low profitability. Another reason may be low yields, especially when yields are low as a result of agronomic, environmental, and other stochastic conditions.

Many production and adoption studies evaluate adoption either as one stage, where binary regression models like the probit and logit are employed, or a two-stage decision process. For the two-stage process, sample selection models such as the Heckman's sample selection model

[8] In this regard, the Government of Cameroon, through the Land Ordinance laws encouraged establishing a physical presence and visible usage of the land to signify land ownership. This also includes clearing forest land and cultivating on otherwise fallow land.

[9] It is unclear whether households only claim ownership to land after clearing virgin forests or prior, or when the land is inherited from an earlier generation. This is ultimately a vital observation that warrants further investigation.

or a corner solution model (Double hurdle model and the more restrictive type 2 Tobit model) are used. The Heckman's correction model is a two-stage model that corrects for non-random sample selection, which might be considered more suitable for addressing our research objectives. However, this model is designed for incidental truncation wherein zeros are unobserved values, which is not the case for this analysis. A corner solution model would be more appropriate because the zeros represent the household's decision, possibly due to high transaction costs and other agronomic reasons (Tabe-Ojong et al., 2021b).

A Tobit model (Tobin, 1958) can be used to model the household's decision to cultivate oil palm. However, it will do so as a one-stage decision process assuming that the same covariates determine both the decision to produce oil palm and its extent. Furthermore, the partial effect of any covariate on the probability of a farm household cultivating oil palm and the extent of cultivation, if the household cultivated has the same sign (Wooldridge, 2016). These assumptions are very restrictive and make the Tobit model not representative of our objectives.

We thus employ the Double Hurdle model (DH), as a flexible extension of the Tobit model. It relaxes the Tobit model's restrictions by allowing different processes (factors) to determine the two production decisions. Being a two-part model makes it possible for the same covariates to affect both decisions in distinct ways. In the first stage, we estimate a probit model of the households' decision to cultivate oil palm, while a truncated normal distribution is used to understand the extent of production, proxied by the area under oil palm cultivation. For comparison purposes, we present both the Tobit model and the DH model results.

4.2. Econometric model

The mathematical model for the two stages in the DH is expressed as:

The decision to produce:

$$y_i^{p*} = \theta_i + \boldsymbol{\alpha x_i} + \varepsilon_i$$

and

$$y_i^p = \begin{cases} 1 & if\ y_i^{p*} > 0 \\ 0 & otherwise \end{cases} \tag{1}$$

The extent of production:

$$y_i = \varphi_i + \boldsymbol{\beta v_i} + \mu_i \tag{2}$$

$i = 1, 2, \ldots, N$.where y_i^{P*} is a latent variable representing utility differences in the cultivation of oil palm, and y_i^P is the extent of production. Eq. (1) is a binary choice of whether to cultivate oil palm or not. It takes the value of 1 if the household cultivates oil palm or 0 otherwise. Eq. (2) signifies the extent of production and it is truncated at zero and defined as the area under oil palm. $\boldsymbol{x_i}$ and $\boldsymbol{v_i}$ represents a set of vector explanatory variables that affect both the production decision and the extent of production of oil palm. Their coefficient estimates, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ signify the various parameters that are correlated with oil palm production and the extent of production respectively. ε_i and μ_i are the error terms.

4.3. Robustness checks

To confirm the consistency of our study findings, we performed two robustness checks. We begin by conducting an ordinary least squares regression (OLS) in the framework of a linear probability model (LPM). As highlighted by Angrist and Pischke (2008), the advantage of using a LPM lies in its non-reliance on the distributional assumptions for the error term as opposed to probit and logit models. Moreover, as probit and logit models are only asymptotically valid, they may not be ideal for limited samples. The LPM is not without its demerits. LPM regressions produce heteroskedastic errors which we adjust by using robust standard errors in all estimations. Further, we employed lasso linear regressions to confirm the results of the LPM regressions. LASSO is a machine learning technique for estimation in linear models (Tibshirani, 1996).

4.4. Heterogeneity analysis

As highlighted in the introduction, oil palm cultivation may have a heterogeneous association with various household and farm characteristics. Particularly, oil palm cultivation may be prevalent among large scale farms, which may lead to inequality in rural settings. To evaluate this relationship, we performed regressions using three different farm structures as identified in Ordway et al. (2017). These farm sizes range from small to medium to large scale farms. As shown in the summary statistics, the average size of small- and medium-scale farms is <1 and 5 ha respectively, while the large farms in the sample are 44 ha on average. We estimated additional OLS regressions for these different farm size groupings.

5. Results and discussion

We begin by verifying the suitability of the DH against the Tobit model. For this, we used a likelihood ratio (LR) test and hypothesize that a farmer's production decision depends on a two-stage decision process. Based on our low p-value ($p < 0.0001$), we find convincing evidence not to reject the hypothesis and forge ahead with the use of the DH model, although reporting results from the Tobit model.

5.1. Drivers of oil palm production

Table 2 presents the DH model results of the drivers of oil palm adoption and the extent of production. While columns (1,2) present the estimates of the DH model, column (3) presents the estimates of the Tobit model. Despite similar insights from the two models, we focus the discussion on the DH model. We find that older farmers are more likely to cultivate oil palm than their younger counterparts. Since age is usually regarded as a proxy variable representing experience and social networks, older farmers likely perceive greater benefits associated with oil palm production. Farmers' experience plays an important role in protecting and improving the farm environment e.g. adopting soil and water management. In addition, experienced farmers are attracted to innovative ideas and solutions and can make the right choices to protect and improve the environment. The larger social networks of older farmers offer greater information access and possible greater access to land ownership. Our findings corroborate earlier insights from Nkongho et al. (2014), who reported that younger farmers participate less in oil palm cultivation due to limited land access. Moreover, most young people are leaving rural areas to look for jobs in many peri-urban and urban centres (IFAD, 2018). Oil palm is a perennial plantation crop requiring significant investments, for which access to information on production or marketing has a time value to safeguard both profitability and sustainability of the investment.

Despite female farmers having a higher likelihood (though not statistically significant) of cultivating oil palm than male farmers, they tend to allocate less land for oil palm cultivation. This is plausible given that women generally have less access to land for cultivation as documented by a wide literature (Deininger and Castagnini, 2006; Ali et al., 2014; Nkongho et al., 2014; Doss et al., 2015). This is particularly problematic when land rights are customary, as in Cameroon (Chigbu, 2019; Deininger et al., 2017). Cameroon's customary land tenure system exacerbates land-ownership disadvantages and biases against women and youth. Allocating less land for oil palm even though its cultivation is attractive to women despite the inherent land constraints, acknowledges women's capacity to manage natural resources at the farm and community levels which allows them to fight against environmental degradation and protect biodiversity.

Concerning labour availability, family labour is a positive driver of

Table 2
Double hurdle model estimation results.

	DH model		Tobit model
Variable	(1)	(2)	(3)
Age of household head (years)	0.010* (0.005)	−0.032 (0.127)	0.023 (0.095)
Age square	−0.010* (0.005)	0.002 (0.133)	−0.004 (0.009)
Head is female (Yes = 1)	0.005 (0.045)	−1.551*** (0.541)	−1.394*** (0.474)
Formal education (Yes = 1)	−0.055 (0.070)	−1.621 (1.474)	−1.791 (1.254)
Extension contact (Yes = 1)	0.001 (0.032)	0.151 (0.763)	0.034 (0.514)
Family labour (Yes = 1)	0.262*** (0.035)	0.519 (0.958)	2.451*** (0.598)
Hired labour (Yes = 1)	−0.041 (0.037)	1.743*** (0.635)	1.073** (0.464)
Head is migrant (Yes = 1)	0.033 (0.031)	0.346 (0.664)	0.439 (0.473)
Distance to plot (Km)	−0.007** (0.004)	0.034 (0.022)	0.013 (0.017)
Distance to mill (Km)	−0.006 (0.006)	0.234 (0.222)	0.208 (0.193)
Tenurial security (years)	0.004*** (0.001)	0.066** (0.032)	0.088** (0.037)
Farm size (hectares)	0.425 (0.365)	0.024 (0.072)	0.031 (0.083)
Off farm income (Yes = 1)	0.025 (0.033)	−0.540 (0.665)	−0.357 (0.515)
Access to credit (Yes = 1)	−0.001 (0.042)	1.432* (0.862)	1.224* (0.741)
Market information (Yes = 1)	0.089** (0.039)	−1.887 (1.456)	−0.378 (0.885)
Market engagement (Yes = 1)	0.156*** (0.060)	2.916*** (1.109)	3.393*** (1.250)
Improved inputs (Yes = 1)	0.067** (0.033)	−0.080 (0.823)	0.314 (0.677)
Constant	1.728*** (0.721)	7.285* (4.170)	1.940 (2.551)
Prob > chi2	0.000	0.000	0.000
Pseudo R^2	0.217		0.022
Observations	545	385	545

Notes: In all columns, the marginal effects are reported with their standard errors in parentheses. The marginal effects are obtained using the margins command in STATA. The standard errors are obtained by the delta method *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Own computation from 2015 survey data.

oil palm cultivation. The availability of family labour is associated with a higher probability of cultivating oil palm by 0.26 percentage points. It does not, however, affect the extent of production. Hired labour on the other hand is positively associated with the extent of production despite demonstrating a negative association with the decision to cultivate oil palm. Since labour markets generally fail and are undergoing significant changes in many rural areas (Chand and Srivastava, 2014; Dillon and Barrett, 2017), hired labour is scarce and usually expensive. In the face of such missing labour markets, households may decide not to embark on a labour-intensive farm activity like oil palm cultivation. However, conditional on the adoption of oil palm, the availability of hired labour drives their production intensity. Alternatively, since most farm activities can be carried out by farm households, family labour matters in the first production decision. However, conditional on growing oil palm, hired labour comes into play since farm size is considered and more farm tasks are involved (Nkongho et al., 2014). Hired workers[10] may be necessary for critical tasks like harvesting and pruning, for which specific skills and knowledge are needed that may not be available in the family. In Southwest Cameroon, hired labour is often scarce and is usually performed by temporary migrants,[11] primarily from the Northwest region of Cameroon who migrate seasonally, especially in the peak growing and harvesting seasons. Ensuring environmentally friendly farming practices requires more effort from experienced farmhands. As the demand for palm oil increases, so is the need for more plantation workers, for a production system that is managed to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity. This puts pressure on the workforce with an increased risk of labour exploitation, and pushes farm-owners to seek for seasonal hired labour essentially for modern environmentally farm practices, e.g. to keep and build good soil structure and fertility, to control pests, diseases and weeds, as well as to efficiently use water resources. At peak seasons more labour is needed for weeding, harvesting and collecting fruits.

Regarding location and transaction cost variables, distance to the farms of the households has a negative effect on oil palm production and is statistically significant at the 5% level of probability. This indicates that farmers who live further away from their cultivated fields are less likely to further expand their oil palm plantation. This is similarly the case for the extent of production outcome, which is also negative and significant. The distance to the artisanal mills has no statistically significant relationship with the decision to produce oil palm or the extent of production. These findings are suggestive of the role of transaction costs in promoting both production and creating a market, especially for palm oil products. If oil palm producers are to reap financial rewards from their investments, transaction costs are shown here to be important for cost-effective production and marketing. The significant and negative coefficient of the proportional transaction cost measure, distance, implies a negative correlation for both participation and intensity of participation. Distance as a proxy for transaction costs is expected to be proportional to the volume transacted.

As expected, land tenure and ownership is positively associated with both the probability of oil palm adoption and the area under production. Given that oil palm is a perennial crop, this positive correlation can be attributed to three main effects highlighted in the empirical literature on property rights (Deininger et al., 2011; Kubitza et al., 2018b). These effects are the assurance, the collateralization and the realizability effects. Most relevant to this study is the assurance effect, where farmers may be incentivised to cultivate given that longer-term benefits of cultivation are guaranteed. Farmers will not invest in a perennial crop like oil palm (given high establishment costs) if their land ownership status is unclear or contested. This relationship may also work in the opposite direction when the cultivation of perennial crops are used as a way of securing land tenure. With the collateralization effect, secure landowners may obtain better access to investment capital given that they can use their lands as collateral. When households depict secure ownership status, land can be allocated more efficiently, as land-based market transactions are possible. In addition, oil palm production being a plantation tree crop is associated with secure land tenure and property rights which encourage both medium and long-term investments. Secure land tenure is thus linked to better land use which in turn leads to environmental protection. A plethora of studies reviewed in Tseng et al. (2021) reported positive links between improved tenure security and human well-being and environmental outcomes. The presence of clear property rights can increase the incentive to implement long-term resource measures. Since most of the plantations are on privately-owned land, farmers strategically undertake soil protection measures, plant fruit trees, live hedges and improve pastures since they expect to hold their lands long enough to receive the benefits of their investments.

[10] At this point, it is important to acknowledge that “hired labour” is likely to be endogenous (reverse causality). Households that cultivate more land with oil palm are likely to need also more hired labor, in particular for processes such as harvesting which is mostly done by young men which might not be available in every household.

[11] As some trees grow very tall, harvesting is mostly performed by these labourers who climb the trees to harvest the FFBs.

We obtained positive and significant effects regarding institutional and market variables, like access to market information and market engagement. Households with access to market information are more likely to be households with higher rates of oil palm adoption. Access to information can be regarded as a form of fixed transaction which is reflected in search costs. As highlighted by Naeher and Schuendeln (2021), information access depends on both the supply and the demand for information. Households who demand and have access to market information on oil palm cultivation would be more inclined to produce oil palm than their counterparts. This can be explained by the fact that oil palm cultivation has significant welfare and livelihood effects. This also speaks directly to the perceived expected profitability of the sector. Our finding here supports the adoption literature that identifies information access to be a significant driver of smallholder production decisions (Feder and Slade, 1984). Furthermore, we find access to markets and market information to have a positive relationship with both the probability of cultivating oil palm and the area under oil palm cultivation. As participation in output markets could signify farmers perceived expected profitability, these results are not surprising. The inference here is that access to market information and efficient management of information and knowledge can lead not only to enhanced performance and competitive advantage, but that integrating environmental management with other key managerial processes can improve the financial and environmental performance of non-industrial oil palm farms.

Finally, households that use improved farm inputs have a higher likelihood of cultivating oil palm than non-users of such inputs. Every additional use of improved farm inputs leads to an associated increase in the probability of cultivating oil palm by 6.7 percentage points. Regardless of directionality, this indicates that access to improved inputs matters for the cultivation of oil palm. Given that significant yield gaps exist in oil palm production (Euler et al., 2016a; Jaza Folefack et al., 2019), the use of improved farm inputs and other farm intensification methods may be a potential way of off-setting the undesired environmental effects of oil palm cultivation while also enhancing the socio-economic benefits. However, it is also important to note that the overuse and misuse of fertilizers and agricultural inputs can result in negative environmental outcomes, for example, eutrophication (Vitousek et al., 2009). In addition, intensification does not inherently result to reduced extensification or associated deforestation (Hamant, 2020). Thus, efforts to support oil palm intensification would benefit from a careful evaluation of the potential environmental impacts before implementation.

Table 3
Linear estimation of oil palm cultivation.

	Production		Extent of production	
	LPM	LASSO	OLS	LASSO
Variable	(1)	(2)	(3)	(4)
Age of household head (years)	0.010*	0.010*	−0.032	0.039
	(0.006)	(0.006)	(0.141)	(0.099)
Age square	−0.009	−0.001	0.002	−0.006
	(0.005)	(0.006)	(0.137)	(0.010)
Head is female (Yes = 1)	0.019	0.012	−1.551	−1.537**
	(0.046)	(0.049)	(1.007)	(0.632)
Formal education (Yes = 1)	−0.071	−0.072	−1.621	−1.852
	(0.074)	(0.087)	(1.647)	(1.342)
Extension contact (Yes = 1)	−0.003	−0.001	0.151	−0.019
	(0.332)	(0.033)	(0.721)	(0.635)
Family labour (Yes = 1)	0.364***	0.366***	0.519	2.551***
	(0.044)	(0.051)	(1.092)	(0.698)
Hired labour (Yes = 1)	−0.052	−0.048	1.743**	1.261**
	(0.036)	(0.034)	(0.798)	(0.526)
Head is migrant (Yes = 1)	0.027	0.031	0.346	0.597
	(0.032)	(0.033)	(0.714)	(0.526)
Distance to plot (Km)	−0.010*	−0.009	0.034**	0.018
	(0.006)	(0.006)	(0.017)	(0.013)
Distance to mill (Km)	−0.005	−0.004	0.234**	0.235
	(0.005)	(0.004)	(0.119)	(0.177)
Tenurial security (years)	0.004***	0.005***	0.066**	0.102***
	(0.001)	(0.001)	(0.033)	(0.034)
Farm size (hectares)	0.007**	0.007*	0.024***	
	(0.004)	(0.004)	(0.007)	
Off farm income (Yes = 1)	0.022	0.020	−0.540	−0.429
	(0.033)	(0.031)	(0.714)	(0.625)
Access to credit (Yes = 1)	0.001	−0.006	1.432	1.118
	(0.041)	(0.390)	(0.902)	(0.835)
Market information (Yes = 1)	0.120***	0.119***	−1.887*	0.404
	(0.045)	(0.055)	(1.110)	(0.907)
Market engagement (Yes = 1)	0.102**	0.110***	2.916***	3.721***
	(0.047)	(0.035)	(0.960)	(0.960)
Improved inputs (Yes = 1)	0.058*	0.058*	−0.080	0.337
	(0.033)	(0.033)	(0.733)	(0.739)
Constant	0.137		7.285**	
	(0.162)		(3.651)	
F statistic	9.13***		4.15***	
Prob > chi2	0.000	0.000	0.000	0.000
R^2	0.227		0.143	
Observations	545	545	385	385

Notes: Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1. Source: Own computation from 2015 survey data.

5.2. Robustness of results

The results of both the LPM and the lasso linear models are presented in Table 3. For both of the hurdle stages, we obtain consistent results. The magnitudes and significance of most of the explanatory variables are maintained. We thus confirm our earlier insights and findings that market orientation, access to market information, and land tenure security are positively associated with oil palm adoption and area cultivated. The availability of family labour and to a large extent hired labour also matters in oil palm cultivation. In general, oil palm plantations have very high labour requirements during the establishment phase, and in the operational phase for tree-crop maintenance and harvesting. The robust findings also suggest that the oil palm sector is dominated by experienced farmers which is consistent with the findings of Nkongho et al. (2014).

Overall, the results in Table 3 are robust and instructive of the synergy between agro-economic gains and ecological safeguards required in operating oil palm plantations. The results bring to light the plausibility of sustainable agriculture when the subsector is characterized by operators who are aware of the associated need to conform to agricultural practices that benefit the environment. First, the factors that drive adoption and the factors that determine expansion can be exploited to answer the core questions of resource stewardship. This would mean according experienced farmers with tenure security information on production and market information, sharing knowledge, adopting new practices, and maximizing both output and postharvest benefits that relate to environmental stewardship. Second, the results show that oil palm farmers may have the capacity to manage productive farms, as well as engage in environmentally-smart agriculture linking ecology, culture, economics, and sound agricultural practices to sustain healthy farm environments. This will require an external push from policy and institutions tailored to encourage farmers to (a) sustainably increase agricultural productivity and incomes, (b) adopt and build ecological resilience; and (c) avoid deforestation and environmental degradation (Molua et al., 2012; Molua et al., 2015). These efforts are plausible, and if well-tailored can yield good results for land-use changes in oil palm dominated tropical landscapes with carbon-neutral expansion (Quezada et al., 2019; Dislich et al., 2018).

5.3. 5.3 Heterogeneous association in oil palm adoption

Table 4 shows oil palm adoption across different farm size classifications of small, medium and large-scale producers. Over all specifications, we include the same set of controls and control for village level heterogeneities. We find that all three farm structures have a positive

Table 4
Heterogeneity estimates of oil palm adoption.

	Small farms	Medium farms	Large farms
Farm size	0.008*** (0.001)	0.038*** (0.003)	0.062*** (0.017)
Other controls	Yes	Yes	Yes
Pseudo R^2	0.058	0.093	0.125
Village Fixed effect	Yes	Yes	Yes
Observations	211	248	86

Notes: Other controls include head of household's age, education, gender, extension training, off-farm income, access to credit and labour availability, land tenure, access to market information, market orientation, distance to market and distance to the plot. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Source: Own computation from 2015 survey data.

association with the cultivation of oil palm. Oil palm adoption is associated with different farm structures ranging from small-scale farms to large-scale farms. This indicates that oil palm is a widely adopted crop across farm structures, indicating accessibility to small and large-scale farmers alike but highly predominant among large farms. Although not a strong finding, this could suggest that oil palm may be an important crop for stirring inclusive rural development.

6. Conclusion and policy implications

The economics and agro-ecology of oil palm production is taking center stage because of its global and local importance and the associated welfare implications for households and rural communities. A globally important oil crop, this study attempts to put into perspective the scientific underpinnings of adoption via production expansion in a developing country such as Cameroon. The goal of this paper is to examine the nature and size of oil palm expansion by non-industrial producers in Southwestern Cameroon and to identify key socioeconomic variables associated with rural households, farm-owners, and farm-level factors associated with oil palm adoption and production.

Using different corner solution model specifications, like the double hurdle model and the Tobit model, we find that variables related to the profitability of the sector as well as the institutional context of production are significantly associated with oil palm adoption. These include land ownership and issues of land property rights, and access to market information and market engagement. Additionally, we found that the availability of family labour matters immensely in the early stages of setting up an oil palm plantation, and late in production at the critical stages of harvesting and pruning which require skilled hired labour. Our findings are robust and consistent over different linear estimators, including the limited probability model and lasso linear regressions.

One particularly strong finding is the fact that older, male farmers are more likely to produce oil palm. While age[12] is reflective of experience, expanded social networks, and the accumulation of knowledge over time, farming needs not be dominated by an aging population. While the massive outflow of young people from rural areas to urban areas is being reported in Cameroon and many other African countries (IFAD, 2018), a lack of rural opportunities and institutions biased towards older farmers may also be contributing to the observed urbanization. An example is the access to productive land under customary land property systems. Interventions and programs that would enable young people, including women, to gain access to land may be a pathway to boosting smallholder oil palm production. Given that younger farmers are more likely to take up new farming technologies and farm intensification methods, the potential benefits from production could be large enough to offset costs associated with investing in engaging younger people and women in oil palm production.

In general, our findings highlight novel insights into oil palm adoption and expansion from an interesting case study in a major African oil palm producing region, which has received little attention in the empirical literature thus far. Like Qaim et al. (2020) rightly argued, new perspectives from Africa are necessary to reduce the knowledge gap in the sustainability of global oil palm production. This is even more warranted given that much of the future growth of oil palm production is expected from this region (ibid). Given the rise of non-industrial producers in Cameroon, our findings have important implications for both sustainability and agricultural growth and development efforts. Policies to support these farmers agronomically and institutionally will go a long way towards improving smallholder incomes and strengthening the livelihoods of rural communities.

Non-industrial small and medium scale oil palm farmers would have to adopt Good Agricultural Practices (GAP) for oil palm, which promotes ways to produce safe and wholesome FFBs without harming the natural environment. The GAP should address environmental, economic, and social sustainability for on-farm and off-farm processes. According to the objectives of GAP codes, standards, and regulations for Cameroon and neighbouring states in the Congo Basin would have to include, (a) ensuring the safety and quality of produce in the food chain; (b) capturing new market advantages by modifying supply chain governance; (c) improving natural resource use, workers' health, and working conditions; and (d) creating new market opportunities for farmers and exporters.

We end by noting two limitations of this study. First, inferences made are from an association perspective. As we did not control for many confounding factors, despite obtaining results that are robust over different specifications, we do not infer causality. Our analysis should be seen as suggestive evidence of various socio-economic and contextual characteristics associated with oil palm production among non-industrial producers in Cameroon. The second caveat pertains to the external validity of our findings. Context always matters when understanding the relationship between different socio-economic variables and production outcomes. Although the institutional context in Cameroon may be different from other regions globally, there are likely many similarities with other rural African communities where production is usually hampered by similar household and socio-economic characteristics. In this regard, our findings may be generalizable to other African non-industrial farm settings, though not likely to other oil palm producing communities beyond Africa. As one of the first economic studies on oil palm adoption in an African context, we encourage further research into this area to explore and validate our study findings in other settings. Promising avenues for future research may include the design of experiments and the use of panel data to infer causality in oil palm expansion drivers. Overall, however, this study robustly supports a growing literature on smallholder crop production that reinforces arguments for resilient institutional efforts as an important pillar for better policy making.

Declaration of Competing Interest

None.

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[12] Age also influences to an extent the accumulation of financial resources for oil palm development and field upkeep until the crop attains the age of production.

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