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Land-use change, nutrition, and gender roles in Indonesian farm households

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ABSTRACT

Many tropical countries are experiencing massive land-use change with profound environmental and socio-economic implications. In Indonesia, oil palm cultivation is rapidly expanding at the expense of more traditional crops – such as rubber and rice – and forest land. While environmental effects of the oil palm boom were analyzed in many studies, much less is known about social effects. Here, we analyze how oil palm cultivation by smallholder farmers is associated with nutrition through changing income and gender roles. The analysis uses panel data collected in Jambi Province, Sumatra, one of the hotspots of Indonesia's recent oil palm boom. Regression models show that oil palm cultivation is positively associated with nutrition and dietary quality. These associations are related to income gains that improve smallholders' access to nutritious foods from the market. Oil palm requires less labor than traditional crops, so a switch to oil palm could potentially free family labor for off-farm economic activities. We find that oil palm cultivation is positively associated with off-farm employment of male but not female household members, which may be related to unequal opportunities and social norms. Independent of oil palm cultivation, female off-farm employment is positively associated with nutrition, even after controlling for household income.

1. Introduction

Many countries in tropical regions are experiencing massive land-use change. In Indonesia and other countries of Southeast Asia, the expansion of oil palm at the expense of more traditional crops and forest land is particularly noteworthy (Feintrenie et al., 2010; Byerlee et al., 2017; Euler et al., 2016; Kubitza et al., 2018a). Indonesia is now the largest producer of palm oil in the world. Between 2005 and 2015, Indonesia's area under oil palm more than doubled from around 5 million hectares to over 11 million hectares (Ministry of Agriculture Indonesia, 2016). The rapid expansion of oil palm has been criticized on environmental grounds, as it is associated with deforestation, loss of biodiversity, greenhouse gas emissions, and other environmental problems (Marlier et al., 2015; Susanti and Maryudi, 2016; Grass et al., 2020). There are also social concerns, often related to land tenure conflicts (Hidayat et al., 2018). Government concessions for large companies to grow oil palm sometimes overlap with land for which local communities have informal usufruct rights under customary law (Krishna et al., 2017a). On the other hand, the oil palm boom has positive effects, as it contributes to economic growth, poverty reduction, and broader rural development (Rist et al., 2010; Zen et al., 2016; Bou Dib et al., 2018a; Bou Dib et al., 2018b; Purnomo et al., 2018; Qaim et al., 2020).

In Indonesia, oil palm is not only cultivated on large company plantations; around 40% of the palm oil is produced by smallholder farmers (Gatto et al., 2015; Euler et al., 2016). These farmers benefit economically because oil palm is more profitable than the production of food crops and less labor demanding than traditional cash crops like rubber (Euler et al., 2017; Kubitza et al., 2018b). Beyond profits and income, effects of oil palm cultivation on other social dimensions of household welfare – such as nutrition – have hardly been analyzed up till now. Oil palm could potentially threaten food security if it replaces the cultivation of local food crops and thus decreases local food availability (Cassman and Liska, 2007; Li, 2015). On the other hand, oil palm cultivation may also improve food security and nutrition through income gains and thus better economic access to nutritious foods (Sibhatu, 2019).

Here, we analyze the association between oil palm cultivation and nutrition in smallholder farm households. Nutrition effects may be channeled through various mechanisms, including changes in food production, income, and gender roles within the household. We develop a conceptual framework and test a set of concrete research hypotheses related to these mechanisms. The empirical analysis uses two rounds of household panel data collected in Jambi Province, Sumatra,

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one of the hotspots of Indonesia's recent oil palm boom.

2. Background

2.1. Oil palm expansion in Jambi

During the first half of the twentieth century, forest, rice, and natural rubber were the main land-use types in Jambi. Rice was mainly produced for subsistence, while rubber was the dominant cash crop. Rubber was initially grown in agroforestry systems, but more intensively-cultivated rubber monocultures gained in importance over time (Gatto et al., 2015; McCarthy and Zen, 2016). Until the late-1960s, oil palm did not play an important role in Jambi, but in the 1970s and 1980s, several large oil palm plantations were established by state-run companies. The Indonesian government also actively encouraged smallholder farmers to participate in oil palm cultivation (Zen et al., 2016; Gatto et al., 2017). Initially, smallholder oil palm cultivation was associated with the government's transmigration programs, which were implemented to reallocate people from overpopulated Java to scantly-populated islands such as Sumatra (Fearnside, 1997). Transmigrant families were given some land for settlement and the production of food and cash crops, especially oil palm. Hence, transmigrants were the first smallholders in Jambi to cultivate oil palm, whereas the autochthonous population – mainly from the Melayu tribe – continued to cultivate rubber as their traditional cash crop (Zen et al., 2016).

During the transmigration programs in the 1980s and early-1990s, most oil palm-cultivating smallholders had contracts with large plantation companies under the so-called nucleus estate and smallholder (NES) schemes (Feintrenie et al., 2010; McCarthy and Zen, 2016). Through the NES schemes, smallholders received subsidized credit, which was necessary because the establishment of oil palm plots is a capital-intensive investment. Some of the autochthonous communities were also offered similar contracts and credits when they were willing to give up some of the community lands for company plantations (Rist et al., 2010). While these arrangements between palm oil companies and autochthonous communities worked well in some situations, there are also reported cases of conflict over land rights and over-indebtedness of farmers who were unable or unwilling to repay the credits received (Li, 2015; Levang et al., 2016; Zen et al., 2016). Often the contract and credit conditions were not sufficiently transparent for the farmers involved (Gatto et al., 2017).

Since the early-2000s, contracts between oil palm companies and smallholder farmers have lost in importance, also because most of the related government subsidies had been phased out in the 1990s. The number of oil palm smallholders in Jambi continues to rise, but nowadays, most smallholders cultivate oil palm independently without company contracts (Qaim et al., 2020). Smallholders either use previous forest or fallow land, or they convert old rubber plantations for the establishment of new oil palm plots (Gatto et al., 2015; Grass et al., 2020). Over the last 20 years, many rubber farmers entered the oil palm business or switched entirely to oil palm, because oil palm requires less labor than rubber and leads to higher household incomes (Krishna et al., 2017b). However, access to capital remains a constraint for some, so oil palm contributes to rising inequality among farm households in Jambi (McCarthy et al., 2012; Euler et al., 2017; Bou Dib et al., 2018a).

2.2. Gender, agriculture, and nutrition

Women's roles within households and societies are known to be critical factors for food security and nutrition (Ruel and Alderman, 2013; Malapit and Quisumbing, 2015; Niehof et al., 2018). Strengthening women's roles and gender equity is typically associated with better nutritional outcomes for the family as a whole, and children in particular (Ruel and Alderman, 2013). However, gender roles can be very diverse, as they depend on a multitude of socioeconomic conditions. This is especially true in Indonesia, with its vast socioeconomic and ethnic diversity (Niehof et al., 2018; Pangaribowo et al., 2019). Here, we discuss a few general aspects that seem to be of particular importance in the context of Indonesia's recent oil palm boom.

In rural Indonesia, women are traditionally actively involved in agricultural work and farm management. However, women's involvement can vary depending on farm size and the types of crops grown (Villamor et al., 2015). When households start cultivating oil palm, women's involvement in farming often tends to shrink. On the one hand, the most labor-intensive activity in oil palm cultivation is harvesting, which is mostly done by men as it requires substantial physical strength. On the other hand, there are also institutional features that contribute to shrinking women's involvement. In the NES schemes with palm oil companies, women are often excluded because of prevailing gender norms. Women are generally not considered as the head of the household and are therefore restricted in carrying out business negotiations (O'Shaughnessy, 2009; de Vos and Delabre, 2018). In some cases of oil palm contracting, women also lost their control over land and other productive assets (Park et al., 2015; Elmhirst et al., 2017).

In addition to activities on the family farm, rural women are also involved in off-farm economic activities. International research shows that women's involvement in off-farm employment can be associated with greater female decision-making power within the household (Majlesi, 2016; Debela et al., 2020), and that greater female decision-making power is associated with better family nutrition and health (Ruel and Alderman, 2013). However, this also depends on the educational level and the type of employment. In rural Indonesia, women's educational levels are often low, and their access to better-paid jobs is limited. Under these conditions, women in poor households often pursue off-farm employment primarily as an economic necessity and opt-out when household incomes increase (Schaner and Das, 2016). The time spent by women at work is also an important variable with possible nutrition implications. High levels of female off-farm labor supply can have negative consequences for family nutrition, as women working away from home may be less involved in household food preparation due to time constraints (Johnston et al., 2018; Debela et al., 2020).

3. Conceptual framework

We aim to analyze how oil palm cultivation by smallholders is associated with household nutrition, considering possible mechanisms such as changes in income and gender roles. We first explain possible mechanisms before developing a set of concrete research hypotheses.

3.1. Possible mechanisms

Ruel and Alderman (2013) discuss different mechanisms of how agriculture can influence nutrition in smallholder farm households. We discuss these mechanisms with a particular focus on oil palm cultivation. The possible mechanisms are summarized in Fig. 1. A first mechanism is through own food production. Smallholder farm households are often subsistence-oriented, meaning that much or their food consumption comes from own farm production. In subsistence situations, the types of crops grown on the farm directly affect household diets and nutrition. When household resources are limited, the adoption of a cash crop, such as oil palm, will likely reduce the extent and diversity of food production on the farm, which may lead to a negative partial effect on family nutrition (Li, 2015).

A second mechanism is related to food prices in the local context. More cash cropping may decrease food production, not only on the individual farm but also regionally (Santika et al., 2019). This may increase local food prices, especially when local food markets are not well integrated with national or international markets. Higher food prices make food less affordable for market consumers, including farm and non-farm households (Anderman et al., 2014).

A third mechanism is through possible changes in household income

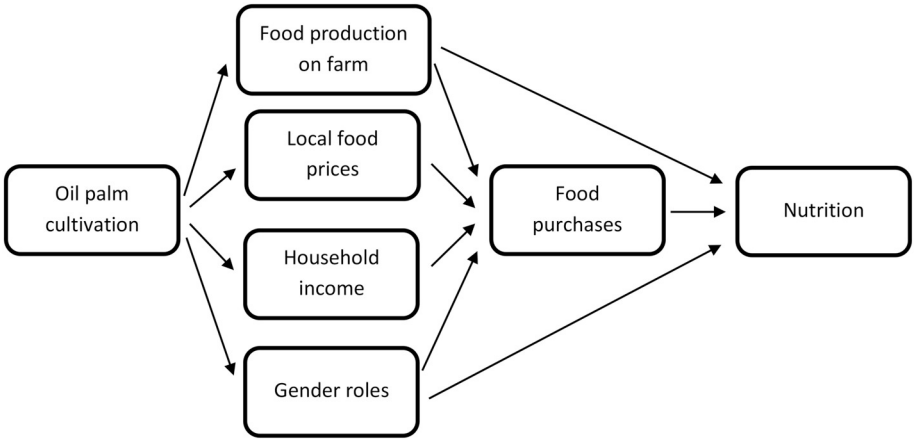

Fig. 1. Possible mechanisms of the association between smallholder oil palm cultivation and nutrition.

resulting from oil palm cultivation. Several studies with data from Indonesia showed that the adoption of oil palm by smallholder farmers can lead to significant income gains (Rist et al., 2010; Euler et al., 2017; Krishna et al., 2017b; Kubitza et al., 2018b). The additional cash income can improve households' access to food and dietary quality from the market (Sibhatu, 2019).

A fourth mechanism is related to the possibility of changing gender roles within the household. Gender roles matter for nutrition in at least three ways, namely women's social status and empowerment, women's time allocation, and women's health status (Ruel and Alderman, 2013; Lecoutere and Jassogne, 2019). Agricultural commercialization – meaning a shift from subsistence farming towards producing cash commodities – can be associated with a loss in female financial autonomy because income from cash commodities is often controlled by men (Chiputwa and Qaim, 2016; Tavenner and Crane, 2018). The exclusion of women in cash crop cultivation can also decrease their control over resources and assets, which influences their decision-making power within the households (de Vos and Delabre, 2018). Loss in female decision-making power may entail a negative partial effect on household nutrition, as women tend to have a stronger emphasis than men on family health and nutrition (Taridala et al., 2010; Debela et al., 2020).

In terms of women's time allocation, oil palm is known to be more capital-intensive but less labor-intensive than traditional agricultural crops grown in Indonesia (Feintrenie et al., 2010; Euler et al., 2017). Hence a switch to oil palm could free labor time and enable household members to get involved in other economic activities, including off-farm employment. As mentioned above, female off-farm employment could increase women's decision-making power and thus contribute to improved nutrition (Majlesi, 2016; Debela et al., 2020), even though this also depends on the type of employment, possible time constraints, and other socioeconomic conditions.

In terms of women's health, agricultural and non-agricultural employment can have various health implications. For instance, Li (2015) argued that women working in oil palm plantations suffer several health risks, such as physical injury or respiratory problems associated with exposure to agrochemicals and other toxic substances. Poor health can affect women's nutritional status directly.

3.2. Research hypotheses

The first and overarching hypothesis that we want to test is that oil palm cultivation is positively associated with household nutrition and dietary quality. This will be tested with regression models of the following type:

$$N_i = \alpha_0 + \alpha_1 OP_i + \alpha_2 Z_i + \varepsilon_i \quad (1)$$

where N_i is a measure of nutrition (we will use different indicators, as explained below) of farm household i, OP_i is a dummy variable that captures whether or not household i is involved in oil palm cultivation, Z_i is a vector of control variables, and ε_i is a random error term. In this model, we are particularly interested in α_1. A positive and significant estimate for α_1 would lend support to the first hypothesis.

We develop additional hypotheses to analyze some of the mechanisms discussed above. The mechanisms related to own food production and food market prices are relevant in general, but do not apply to the particular context in Jambi. Food crop production in Jambi was very low even before the oil palm boom started. As discussed above, rubber has been the dominant crop grown in Jambi already for many decades, and rubber is a pure cash crop itself. Oil palm has partly replaced rubber, or new plantations were established on fallow and forest land (Clough et al., 2016; Drescher et al., 2016). The substitution of oil palm for food crops was hardly observed in Jambi. Most farm households in Jambi buy all of their food from the market, regardless of whether or not they are involved in oil palm cultivation (Sibhatu et al., 2015). Furthermore, food markets in Jambi are well integrated with other national and international markets, so that food prices are not primarily determined by what is cultivated locally.

Concerning the income mechanism, previous studies with the same farm survey data from Jambi showed that oil palm cultivation contributes to significant income gains in smallholder households (Euler et al., 2017; Kubitza et al., 2018b). We build on these previous results, but additionally test the hypothesis that higher incomes are associated with better nutrition and dietary quality. This hypothesis is tested with regression models of the following type:

$$N_i = \beta_0 + \beta_1 INC_i + \beta_2 Z_i + \varepsilon_i \quad (2)$$

where INC_i is the income of farm household i, and the other variables are as defined before. A positive and significant estimate for β_1 would confirm that additional household income is associated with improved nutrition and dietary quality.

Concerning the gender role mechanism, we do not expect oil palm cultivation to affect gendered control of cropping income. While the income from oil palm is primarily controlled by male household members (Elmhirst et al., 2017), the same is true for the income from rubber. Both crops are pure cash crops in Indonesia, for which the marketing is primarily managed by male household members. However, rubber is more labor-intensive than oil palm (Krishna et al., 2017b), so a switch of crops may be associated with re-allocation of household labor time. We test the hypothesis that oil palm cultivation is associated with a lower amount of household labor involved in farming than rubber cultivation. Moreover, as we want to understand possible implications for gender roles, we differentiate between female and male labor, estimating models of the following type:

$$FL_i = \gamma_0 + \gamma_1 OP_i + \gamma_2 Z_i + \varepsilon_i \quad (3)$$

$$ML_i = \delta_0 + \delta_1 OP_i + \delta_2 Z_i + \varepsilon_i \quad (4)$$

where FL_i and ML_i are the amounts of female and male household labor involved in farming, respectively. Negative estimates for γ_1 and δ_1 would mean that a switch from rubber to oil palm frees female and male household labor time.

In the next step, and related to a possible reduction in labor time on the farm, we test the hypothesis that oil palm cultivation is associated with higher off-farm employment:

$$FOF_i = \theta_0 + \theta_1 OP_i + \theta_2 Z_i + \varepsilon_i \quad (5)$$

$$MOF_i = \vartheta_0 + \vartheta_1 OP_i + \vartheta_2 Z_i + \varepsilon_i \quad (6)$$

where FOF_i and MOF_i denote female and male off-farm employment, respectively. Positive θ_1 and ϑ_1 coefficients would indicate that oil palm cultivation is positively associated with female and male off-farm employment, respectively.

Finally, we test the hypothesis that off-farm employment is positively associated with nutrition and dietary quality:

$$N_i = \rho_0 + \rho_1 FOF_i + \rho_2 MOF_i + \rho_3 Z_i + \varepsilon_i. \quad (7)$$

If female off-farm employment is positively associated with women's decision-making power within the household, and women's decision-making power has a positive effect on nutrition, we would expect a positive coefficient ρ_1, also after controlling for household income.

4. Materials and methods

4.1. Farm household survey

We surveyed farm households in Jambi Province on the island of Sumatra, Indonesia. Our survey was implemented in two rounds, in 2012 and 2015. Sample farm households were selected in 2012 through a multi-stage sampling procedure. We first selected five regencies that cover the largest part of Jambi's lowland areas: Batanghari, Bungo, Muaro Jambi, Sarolangun, and Tebo. In each of these regencies, we randomly selected four districts. In each district, we randomly selected two villages, resulting in a total of 40 villages. In each of these 40 villages, we randomly selected 6–25 farm households, depending on the village size. This resulted in a sample of 598 households, which is representative of farm households in Jambi's lowland areas, where most of the Province's oil palm and rubber are grown.

Besides, we collected data from 103 farm households in five other, purposively selected villages in Jambi. In these five villages, we are involved in joint research with colleagues from various natural science disciplines (Drescher et al., 2016; Grass et al., 2020). For the empirical analysis, we use the entire sample of 701 households from 45 villages but control for observations from non-randomly selected villages in all regression models. For the 2015 survey round, the same 701 households were targeted, but due to attrition, 41 households had to be replaced through additional random selection in the same villages. For the analysis, we use the unbalanced panel, including all observations from both survey rounds.[1]

The survey involved face-to-face interviews with the household head (or, in some cases, the spouse) using a carefully designed and pre-tested structured questionnaire. The interviews were conducted in Bahasa Indonesia by local enumerators that were trained and supervised by the researchers. The questionnaire included sections on general household characteristics, farming activities, employment on and off the farm, and household food and non-food consumption. Further details of the data and the definition of key variables are explained below.

4.2. Measuring nutrition

Nutrition can be measured in several ways, including anthropometric measures and food consumption based surveys (de Haen et al., 2011). Here we use food consumption data from a household-level recall that was included in the survey questionnaire. We used a 7-day recall period and a list of 120 different food items tailored to local consumption habits. Seven-day food recall data collected at the household level have become a popular tool to analyze diets and nutrition (Zezza et al., 2017). Household consumption data cannot provide precise measures of individual-level food intakes, but research shows that household-level dietary indicators are correlated with individual-level indicators (Sununtnasuk and Fiedler, 2017; Fongar et al., 2019). One general problem that relates to both household- and individual-level data is that food consumption during a short recall period does not reflect seasonal variation. However, as mentioned, farm households in Jambi purchase almost all of their food from the market. Rubber and oil palm are both harvested all year round, which leads to a stable stream of cash revenues. Thus, seasonal variation in food consumption is expected to be small in this context.

A first dietary indicator that we calculate based on the household-level food consumption data is a dietary diversity score (DDS). DDS counts the number of different food groups consumed over a given period of time (in our case, the 7-day recall period) and has become a widely used and straightforward-to-construct indicator for dietary analysis (FAO, 2011; Sibhatu and Qaim, 2018). Depending on the intention, different food group classifications can be used to construct the DDS. We use a classification with nine food groups as recommended for the women's dietary diversity score (FAO, 2011), namely (1) starchy staples; (2) dark green leafy vegetables; (3) other vitamin-A rich fruits and vegetables; (4) other fruits and vegetables; (5) organ meat; (6) meat and fish; (7) eggs; (8) legumes, nuts and seeds; (9) milk and milk products. A higher DDS score is an indicator of higher dietary diversity.

One disadvantage of DDS is that it counts food groups whenever a food item belonging to the group was consumed, even if the quantity consumed was very small. However, certain minimum quantities are needed in order to prevent nutritional deficiencies. Therefore, in addition to DDS, we calculate the quantities of calories and certain micronutrients consumed by sample households. For micronutrients, we concentrate on vitamin A, iron, and zinc, because deficiencies in these nutrients are widespread in many developing countries with severe adverse health implications (Development Initiatives, 2018). This is also true in Jambi. While calorie undernutrition is no longer considered a major problem, low dietary quality and micronutrient deficiencies are still widespread in Jambi (Dinas Kesehatan Jambi, 2016). We used food composition tables for Indonesia (Berger et al., 2013) supplemented by international references (e.g., USDA, 2016) to convert the food quantities consumed to calorie and micronutrient consumption. The 7-day quantities were converted to daily values and divided by the number of male adult equivalents (AE) living in each household to allow comparison across households of different size.

4.3. Measuring other key variables

Beyond nutrition, other key variables in our analysis are household income, gendered labor time and employment, and several other socioeconomic controls. We proxy household income by annual household expenditures, including the combined value of all foods and non-

[1] While the attrition rate of 6% is relatively low, we tested for possible attrition bias by running a probit model with an attrition dummy as dependent and several socioeconomic variables observed in 2012 (oil palm cultivation, farm size, education, living standard, etc.) as independent variables. Results are shown in Table A1 in the Online Appendix. None of the socioeconomic variables is significant, except for age of the household head. Older farmers were somewhat more likely to drop out due to death or disease. This does not lead to bias in our sample, as the replacement of old farmers is according to the normal generational cycle.

food goods and services consumed by household members. This is a common approach in the development economics literature because expenditures are usually a more precise indicator of household living standard than income (Deaton, 1997). Annual expenditures are expressed in Indonesian Rupiah (IDR) per AE.

Female and male labor time are captured for the entire farm and also separately for rubber and oil palm as the main agricultural enterprises. In the survey, labor input questions for the family and paid laborers were asked for the last 12 months. In this analysis, we only consider the number of hours worked by female and male household members. For off-farm activities, we do not have data on the number of hours worked, but we know from the survey responses who was employed (or self-employed) in off-farm activities during the last 12 months. We use this information to create dummy variables for female and male off-farm employment.

Socioeconomic controls that we use in the regression models include farm size (measured in hectares), household size (female and male adults and children), age and educational levels of male and female adults (years of schooling), ethnicity (dummy for the autochthonous Melayu population), and market distance (measured in km), among others.

4.4. Statistical analysis

We start the analysis by comparing descriptive statistics between different groups of households. Farm households in Jambi either grow rubber, or oil palm, or both, which is why we subdivide the sample into these three groups for the descriptive comparisons. We compare household expenditures, nutrition and dietary indicators, on-farm labor time, and off-farm employment between these three groups to get a first impression of the potential effects of oil palm cultivation.

In addition to the descriptive comparisons, we run the regression models described above to test the research hypotheses. We use two dummy variables to characterize oil palm cultivation: one for households that only cultivate oil palm, and the other for households that cultivate oil palm in addition to rubber. Hence, the reference group is households that only cultivate rubber. The models include observations from both survey rounds (2012 and 2015) and are estimated with random effects panel estimators.

To reduce possible issues of endogeneity of oil palm cultivation, we also tried fixed effects estimators, but these did not result in efficient estimates due to the small variation in oil palm cultivation within households between 2012 and 2015. As an alternative robustness check, we run models where the outcome variables in 2015 are regressed on oil palm cultivation and other explanatory variables in 2012. This approach does not eliminate endogeneity, but it reduces possible issues of reverse causality. That oil palm cultivation improves farm household living standards was shown with the same data from Jambi and instrumental variable models by Euler et al. (2017) and Krishna et al., (2017b). Due to different outcome variables in this study, we were not able to identify valid instruments for oil palm cultivation.[2] Therefore, the estimates reported here should be interpreted as associations, not as causal effects.

5. Results and discussion

5.1. Household expenditures and dietary quality with and without oil palm

Table 1 shows descriptive statistics for the three groups of farm households, namely those with only rubber (column 1), with only oil palm (column 2), and with oil palm and rubber combined (column 3). Households with only rubber and only oil palm have similar farm sizes, whereas households that cultivate both crops have significantly larger farms. As expected, households with oil palm cultivation are significantly wealthier (higher household consumption expenditures) than households that only grow rubber. Table 1 also shows significant differences between the groups in terms of the dietary indicators. Households that cultivate oil palm have higher dietary diversity and higher calorie and micronutrient consumption than households that only cultivate rubber.

5.2. Labor allocation with and without oil palm

Table 2 compares household labor input in oil palm and rubber. On average, the household labor input is 80% lower in oil palm than rubber.[3] This large difference is due to quite different production and harvesting processes between the two crops. Rubber trees are usually tapped every day, so labor input is constantly required. Male and female household members are both involved in rubber cultivation and tapping. In contrast, harvesting in oil palm fields is conducted only once every 2 weeks. Manually harvesting the heavy oil palm fruit bunches is physically demanding and, therefore, often carried out by male laborers.

In order to analyze whether the lower family labor requirement in oil palm is associated with a higher likelihood of off-farm employment, we compare off-farm employment rates between households with and without oil palm cultivation in Fig. 2. Typical off-farm activities in the study region include employment in agriculture, processing, construction, transport, and education, or self-employment in trade and handicrafts. The likelihood of off-farm employment is significantly higher in households that only cultivate oil palm than in households that only cultivate rubber. The difference is not significant when households that only grow rubber are compared with households that cultivate both crops. However, this comparison is not very meaningful as households cultivating both crops have a larger landholding size (Table 1).

Fig. 2 reveals that most of the differences in off-farm employment are due to higher male employment rates in oil palm-cultivating households. For women, small differences are observed, but these are not statistically significant. In general, women are much less likely to have off-farm employment than men, which is not surprising in the local context. In rural Indonesia, due to human capital and cultural constraints, women have limited access to lucrative types of off-farm employment (Elmhirst et al., 2017; Schaner and Das, 2016; Williams, 1990). Especially in poor households, women often work as unskilled laborers in agriculture, or they pursue irregular activities in the informal sector.

Table 3 analyzes possible links between off-farm employment and nutrition. When comparing households with and without off-farm employment, most of the dietary indicators are not significantly different (columns 1 and 2). Strikingly, however, the analysis in columns (3) and (4) shows that households with female off-farm employment have significantly better dietary quality than households where only male household members are employed. This gendered pattern could be

[2] None of the determinants of oil palm cultivation satisfied the exlusion restriction for the nutrition, expenditure, and gendered employment variables. As indicated by Kubitza and Krishna (2020), broadly-defined outcome variables, such as nutrition or dietary diversity, are often influenced by a large number of observed and unobserved factors, so that it can be difficult to identify valid instruments.

[3] In this study, we only look at household labor. Many of the farm households in our sample additionally employ paid laborers on their rubber and oil palm plots. Previous research with the same data showed that oil palm is generally less labor-intensive than rubber, reducing both household labor and paid labor employed per ha of land (Euler et al., 2017).

Table 1
Expenditures and dietary quality by farm household type.

	(1)	(2)	(3)
	Only rubber	Only oil palm	Oil palm and rubber
	(n = 833)	(n = 194)	(n = 323)
Average size of farm (ha)	3.52 (5.06)	3.39 (3.12)	8.83*** (13.15)
Household expenditure (million IDR/AE/year)[a]	13.01 (16.75)	15.65*** (10.88)	18.86*** (17.45)
Dietary diversity score (0–9)	6.56 (1.27)	6.97*** (1.01)	7.00*** (1.21)
Calories (kcal/AE/day)	2793.60 (1312.04)	3114.73*** (1344.07)	3425.93*** (1825.84)
Iron (mg/AE/day)	17.29 (11.80)	20.75*** (11.49)	22.03*** (15.44)
Zinc (mg/AE/day)	9.93 (4.71)	11.56*** (5.78)	12.31*** (7.45)
Vitamin A (μg/AE/day)	941.52 (1557.37)	1132.84 (1454.13)	1350.17*** (1998.66)

Notes: Mean values for the pooled sample, including the 2012 and 2015 survey rounds, are shown with standard deviations in parentheses.
[a] Expenditures in 2015 were deflated by using the consumer price index for Indonesia to make values comparable across survey rounds (in 2015, 1 US$ was equivalent to IDR 13,401).
*** Mean values are significantly different from those in column (1) at the 1% level.

Table 2
Household labor input in oil palm and rubber.

	Labor time in oil palm (hours/ha/year)	Labor time in rubber (hours/ha/year)
Total household labor	157.09 (260.80)	822.94*** (1063.58)
Female household labor	24.75 (68.31)	249.24*** (446.59)
Male household labor	132.34 (235.06)	573.70*** (808.91)
Number of observations	505	1158

Notes: Mean values for the pooled sample, including the 2012 and 2015 survey rounds, are shown with standard deviations in parentheses.
*** Mean values are significantly different at the 1% level.

and the two oil palm dummies (oil palm only, oil palm plus rubber) as the main explanatory variables. We estimate separate models for the different nutrition indicators. For the model with the dietary diversity score (DDS) as the dependent variable, we use a linear specification.[4] For the calorie and micronutrient models, we use a log-transformation of the dependent variables to achieve a more symmetric distribution and a better model fit.

In the models shown in Table 4, oil palm cultivation is positively and significantly associated with better nutrition and dietary quality, also after controlling for other relevant factors. Households that only cultivate oil palm consume 0.36 more food groups than households that only cultivate rubber (reference group). Similarly, the consumption of calories is around 10% higher, and the consumption of vitamin A, zinc, and iron is 32%, 12%, and 19% higher, respectively, in oil palm cultivating households.[5]

As a robustness check, we ran the same models as cross-section

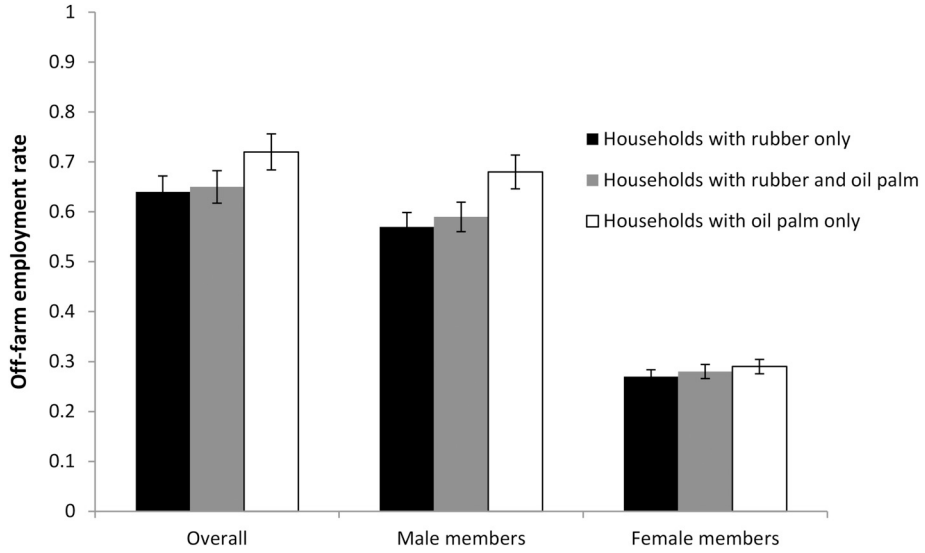

Fig. 2. Gendered off-farm employment in households with and without oil palm.
Note: Mean rates are shown with standard error bars.

related to women with own cash income from off-farm activities having greater financial autonomy within the household, which was also shown to lead to better family nutrition in other contexts (Taridala et al., 2010; Chiputwa and Qaim, 2016).

5.3. Associations between oil palm cultivation and nutrition

We now use the regression models described above to analyze associations between oil palm cultivation and nutrition while controlling for potentially confounding factors. Table 4 shows estimates of the model in eq. (1), with the nutrition indicators as dependent variables

[4] We also tried a Poisson specification to better account for the fact that DDS is a count variable. The results were similar. However, the data do not satisfy the equi-dispersion assumption of the Poisson model.
[5] The percentage effect of dummy variables in log-linear models is calculated as $(e^{coefficient} - 1) \times 100$.

Table 3
Dietary quality in households with and without off-farm employment.

	All households		Only with off-farm employment	
	(1)	(2)	(3)	(4)
	Without off-farm employment	With off-farm employment	Only male employment	At least one female employed
Dietary diversity score (0–9)	6.57 (1.22)	6.80*** (1.24)	6.67 (1.28)	7.00*** (1.16)
Calories (kcal/AE/day)	2981.18 (1520.53)	2963.04 (1434.54)	2837.45 (1251.61)	3133.61*** (1637.17)
Iron (mg/AE/day)	19.27 (12.98)	18.54 (12.61)	17.35 (10.74)	20.16*** (14.63)
Zinc (mg/AE(day)	10.76 (6.24)	10.61 (5.35)	10.18 (4.44)	11.2*** (6.34)
Vitamin A (μg/AE/day)	966.62 (1502.71)	1101.73 (1718.937)	944.41 (1426.11)	1315.37*** (2033.33)
Number of observations	482	922	531	391

Notes: Mean values for the pooled sample, including the 2012 and 2015 survey rounds, are shown with standard deviations in parentheses.
*** Mean values between columns (1) and (2) and between columns (3) and (4) are significantly different at the 1% level.

Table 4
Associations between oil palm cultivation and nutrition.

	DDS	Calories (log)	Vit. A (log)	Zinc (log)	Iron (log)
Oil palm only (dummy)	0.357*** (0.108)	0.094*** (0.030)	0.278*** (0.102)	0.111*** (0.028)	0.173*** (0.049)
Oil palm plus rubber (dummy)	0.305*** (0.093)	0.130*** (0.033)	0.251*** (0.062)	0.135*** (0.032)	0.181*** (0.036)
Total land size (ha)	0.007 (0.004)	0.008*** (0.003)	0.013*** (0.005)	0.007*** (0.003)	0.008** (0.003)
Female-headed household (dummy)	−0.316* (0.168)	0.017 (0.065)	−0.208 (0.158)	−0.012 (0.063)	0.026 (0.085)
Number of adult women in the household	0.085 (0.052)	−0.069*** (0.015)	−0.056 (0.051)	−0.054*** (0.017)	−0.085*** (0.025)
Number of adult men in the household	0.047 (0.039)	−0.046*** (0.017)	−0.052 (0.035)	−0.044*** (0.015)	−0.014 (0.022)
Number of children in the household	0.022 (0.041)	−0.072*** (0.011)	−0.080** (0.035)	−0.051*** (0.011)	−0.069*** (0.019)
Mean education of adult women (years)	0.044*** (0.014)	0.014*** (0.004)	0.040*** (0.011)	0.011** (0.005)	0.020*** (0.005)
Mean education of adult men (years)	0.038*** (0.013)	0.005 (0.004)	0.035*** (0.012)	0.001 (0.005)	0.010* (0.006)
Mean age of adult women	−0.005 (0.004)	0.001 (0.001)	−2.45e-1 (0.003)	3.41e-1 (0.002)	−0.001 (0.002)
Mean age of adult men	−0.001 (0.005)	0.002* (0.001)	0.005 (0.004)	−8.71e-6 (0.001)	0.003 (0.002)
Access to formal credit (dummy)	−0.04 (0.08)	0.044* (0.025)	0.008 (0.056)	0.043 (0.028)	0.034 (0.038)
Melayu (dummy)	−0.271*** (0.072)	−0.027 (0.023)	−0.118* (0.063)	−0.071*** (0.023)	−0.117*** (0.038)
Non-random village (dummy)	0.375*** (0.128)	0.081** (0.034)	0.199*** (0.076)	0.071*** (0.021)	0.067 (0.049)
Distance to market (km)	0.004 (0.006)	2.79e-1 (0.001)	0.008* (0.004)	−0.001 (0.002)	0.003 (0.003)
Survey round 2015 (dummy)	0.033 (0.064)	−0.101*** (0.027)	−0.159*** (0.051)	−0.059* (0.032)	−0.138*** (0.034)
Constant	6.015*** (0.305)	7.872*** (0.066)	5.779*** (0.231)	2.354*** (0.070)	2.666*** (0.109)
R-squared	0.105	0.177	0.107	0.129	0.129
Chi^2	256.526	273.906	269.644	295.427	244.226
Number of observations	1362	1362	1362	1362	1362

Notes: Coefficient estimates of random effects panel models are shown with standard errors in parentheses.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

specifications using 2015 values for the outcome variables and 2012 values for the explanatory variables to reduce possible issues of reverse causality. Also in these alternative specifications, oil palm cultivation has positive and significant coefficients in all models (Table A2 in the Online Appendix). These results support our first and overarching hypothesis that oil palm cultivation is positively associated with household nutrition and dietary quality.

In terms of the control variables in Table 4, total land size and education are positively associated with nutrition, as one would expect. Interesting to see is that women's education has a larger positive association with dietary quality than men's education, which underlines the vital role of women for family nutrition and health. The autochthonous Melayu population has lower dietary quality than the immigrants from Java that make up the largest share of the reference group. This may be related to differences in culture and dietary habits. However, the dietary differences between the ethnicities are probably also a reflection of differences in lifestyle and socioeconomic status. Javanese households have higher average incomes; many of them were supported through the government's transmigration program, as discussed above.[6] Finally, the dummy for the 2015 survey round has significantly negative coefficients in most of the models in Table 4, implying that the dietary situation was worse in 2015 than in 2012. This reflects the stark decline of international prices for rubber and palm oil between 2012 and 2015, leading to lower incomes for producers of these crops (Kubitza et al., 2018b).

5.4. Testing the income mechanism

We hypothesized that at least some of the positive association between oil palm cultivation and nutrition is channeled through the income mechanism. The descriptive comparisons in Table 1 suggested that oil palm cultivation contributes to higher household expenditures, our proxy of household income, or living standard. Positive living standard effects of oil palm cultivation in Jambi were also shown more formally by Euler et al. (2017) and Kubitza et al., (2018b). What has not

[6] We also ran alternative regressions, using a dummy variable for transmigrant villages instead of the Melayu dummy and an additional oil palm-transmigrant interaction term. These alternative specifications are shown in Table A3 in the Online Appendix. Oil palm cultivation remains positive and significant in all models. Likewise, the transmigrant village dummy is significantly positive in most of the models, whereas the interaction term is not significant in any of the models. These additional results suggest that the association between oil palm cultivation and nutrition as such is not affected by transmigration status or ethnicity.

Table 5
Association between household expenditures and nutrition.

	DDS	Calorie (log)	Vit. A (log)	Zinc (log)	Iron (log)
Expenditures (log, IDR)	0.748*** (0.067)	0.453*** (0.021)	0.733*** (0.065)	0.453*** (0.021)	0.571*** (0.027)
Total land size (ha)	−0.007*** (0.003)	−0.001 (0.001)	−0.001 (0.002)	−0.001 (0.001)	−0.003** (0.001)
Female-headed household (dummy)	−0.250 (0.163)	0.080* (0.041)	−0.130 (0.134)	0.048 (0.039)	0.105 (0.066)
Number of adult women in the household	0.142*** (0.049)	−0.032** (0.012)	−0.005 (0.044)	−0.016 (0.015)	−0.041** (0.020)
Number of adult men in the household	0.097** (0.041)	−0.019 (0.013)	−0.005 (0.032)	−0.015 (0.012)	0.028* (0.017)
Number of children in the household	0.102** (0.041)	−0.023*** (0.008)	−0.002 (0.036)	−0.001 (0.008)	−0.007 (0.015)
Mean education of adult women (years)	0.022* (0.013)	0.001 (0.003)	0.018 (0.011)	−0.002 (0.004)	0.004 (0.005)
Mean education of adult men (year)	0.028** (0.013)	−0.002 (0.003)	0.024** (0.011)	−0.006 (0.004)	0.002 (0.005)
Mean age of adult women	−0.007* (0.004)	4.216e-4 (0.001)	−0.002 (0.003)	−4.358e-4 (0.001)	−0.002 (0.002)
Mean age of adult men	−0.001 (0.005)	0.002* (0.001)	0.005 (0.003)	4.97e-5 (0.001)	0.003 (0.002)
Female off-farm employment (dummy)	0.144** (0.066)	0.039* (0.023)	0.150** (0.061)	0.024 (0.021)	0.057** (0.028)
Male off-farm employment (dummy)	−0.070 (0.068)	−0.021 (0.021)	−0.049 (0.060)	−0.027 (0.024)	−0.072** (0.032)
Female on-farm work (hours/year)	−6.51e-5 (5.94e-5)	−1.33e-5 (1.77e-5)	−9.61e−5** (4.59e-5)	-5.16e-06 (1.86e-5)	−8.55e-06 (2.32e-5)
Male on-farm work (hours/year)	−9.10e-06 (3.6e-5)	1.28e-5 (9.16e-6)	4.66e-06 (3.3e-5)	5.54e-06 (1.09e-5)	−2.65e-06 (1.28e-5)
Access to formal credit (dummy)	−0.061 (0.080)	0.014 (0.022)	−0.028 (0.056)	0.017 (0.024)	0.007 (0.032)
Melayu (dummy)	−0.249*** (0.063)	−0.002 (0.016)	−0.091* (0.053)	−0.048*** (0.018)	−0.092*** (0.031)
Non-random village (dummy)	0.316** (0.124)	0.042 (0.027)	0.136* (0.072)	0.035** (0.016)	0.023 (0.045)
Distance to market (km)	0.006 (0.006)	0.002 (0.001)	0.010** (0.004)	0.001 (0.002)	0.005** (0.003)
Survey round 2015 (dummy)	0.121** (0.059)	−0.046** (0.019)	−0.070 (0.050)	−0.004 (0.025)	−0.066** (0.029)
Constant	4.359*** (0.394)	6.804*** (0.090)	4.132*** (0.296)	1.293*** (0.096)	1.372*** (0.141)
R-squared	0.184	0.454	0.221	0.376	0.338
Chi^2	432.632	1877.656	950.956	1579.276	1682.851
Number of observations	1362	1362	1362	1362	1362

Notes: Coefficient estimates of random effects panel models are shown with standard errors in parentheses.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

been shown so far is that higher household expenditures are indeed associated with better diets and nutrition in the local context. This is confirmed in Table 5 with the nutrition indicators as dependent and household expenditures as explanatory variables.

We express household expenditures in log-terms so we have double-log specifications for the calorie and micronutrient models. The results in Table 5 suggest that a 1% increase in household expenditures is associated with a 0.45% increase in calorie consumption, a 0.73% increase in vitamin A consumption, a 0.45% increase in zinc consumption, and a 0.57% increase in iron consumption. Positive and significant expenditure elasticities of calorie and nutrient consumption are also found in alternative cross-section specifications with 2015 values for the outcome variables and 2012 values for the explanatory variables (Table A4 in the Online Appendix).

5.5. Testing the gender mechanism

We now test whether oil palm cultivation is associated with nutrition also through the mechanism of changing gender roles, especially through more off-farm employment. In the first step, we test whether oil palm cultivation is associated with a lower amount of female and male household labor used in on-farm activities. As female and male labor hours are not independent within a farm household, we use a seemingly unrelated regression (SUR) framework. Results are shown in columns (1) and (2) of Table 6. Adding oil palm to rubber such that both crops are cultivated on the farm does not seem to influence household labor use, which is plausible because the rubber still has to be harvested regularly. However, households cultivating oil palm as the only crop use significantly less household labor (406 fewer female hours and 768 fewer male hours per year).

Associations between oil palm cultivation and off-farm employment of female and male household members are shown in columns (3) and (4) of Table 6. For male household members, the probability of off-farm employment is 65 percentage points higher when the household cultivates oil palm instead of rubber. This is very plausible given the lower on-farm family labor requirements in oil palm. Strikingly, however, for female household members, the likelihood of off-farm employment is not significantly associated with oil palm cultivation, despite the lower on-farm requirements for female labor. As mentioned, this may be due to human capital and cultural restrictions for women to pursue off-farm work. Another reason could be the positive income effect of oil palm cultivation: with a sufficient family income, women may not have to pursue off-farm work, which often involves low-paid activities in the local setting. In any case, the hypothesis that oil palm cultivation is associated with more female off-farm employment has to be rejected.[7]

Interesting additional insights on what contributes to more female off-farm employment can be gained when taking a closer look at the control variables in column (3) of Table 6. The likelihood of female off-farm employment is positively associated with the number of adult women living in the household and their mean education level, which is plausible. Better education improves the access to more lucrative off-farm jobs. Interestingly, the likelihood of female off-farm employment is also higher with the mean education level of male adults in the household. A possible explanation is that better-educated men are less restricted by cultural norms and more supportive of developments towards gender equity.

Oil palm-cultivating households do not have a higher likelihood of female off-farm employment in general. Nevertheless, it is interesting to test whether female off-farm work as such has any association with household nutrition and diets. The results in Table A6 in the Online Appendix confirm that it has. Female off-farm employment is positively and significantly associated with nutrition and dietary quality. One could argue that this is just an income effect because female off-farm employment is associated with higher household incomes. However, as the results in Table 5 show, the association between female off-farm employment and nutrition remains positive and significant also after

[7] In cross-section models with 2015 values for the dependent variables and 2012 values for the explanatory variables we actually find a significantly positive association between oil palm cultivation and female off-farm employment (Table A5 in the Online Appendix). As mentioned, rubber and palm oil prices were low in 2015. The results suggest that female labor market responses to such price shocks may possibly be easier in households that only cultivate oil palm, due to the lower on-farm female labor requirements.

Table 6
Associations between oil palm cultivation and household labor allocation by gender.

	On-farm work (hours/year)		Off-farm employment (dummy)	
	(1)	(2)	(3)	(4)
	Female labor	Male labor	Female employment	Male employment
Oil palm only (dummy)	−405.839*** (39.949)	−768.086*** (67.384)	0.145 (0.236)	0.650*** (0.248)
Oil palm plus rubber (dummy)	−29.911 (34.309)	44.467 (57.286)	−0.049 (0.204)	0.083 (0.201)
Total land size (ha)	−2.455 (1.789)	3.684 (3.003)	−0.013 (0.012)	−0.005 (0.011)
Female-headed household (dummy)	−40.183 (71.997)	−52.084 (118.632)	0.658* (0.389)	0.322 (0.408)
Number of adult women in the household	51.128** (22.286)	56.986 (36.713)	0.490*** (0.127)	0.103 (0.128)
Number of adult men in the household	12.033 (19.224)	190.364*** (31.673)	0.096 (0.113)	0.490*** (0.121)
Number of children in the household	18.956 (13.983)	−3.412 (23.281)	0.111 (0.084)	0.075 (0.085)
Mean education of adult women (years)	−1.820 (5.158)	28.170*** (8.546)	0.065** (0.031)	0.024 (0.031)
Mean education of adult men (years)	1.267 (5.078)	−16.501* (8.430)	0.057* (0.031)	0.055* (0.030)
Mean age of adult women	6.606*** (1.680)	11.385*** (2.761)	−0.003 (0.010)	−0.032*** (0.010)
Mean age of adult men	0.385 (1.550)	5.366** (2.553)	−0.001 (0.010)	−0.027*** (0.010)
Access to formal credit (dummy)	84.651*** (30.328)	47.819 (49.865)	0.185 (0.169)	0.305* (0.172)
Melayu (dummy)	−40.319 (28.100)	−193.650*** (47.677)	−0.128 (0.166)	0.196 (0.164)
Non-random village (dummy)	38.152 (40.541)	300.675*** (69.577)	0.418* (0.233)	0.298 (0.240)
Distance to market (km)	−0.080 (1.975)	1.557 (3.299)	−1.174e-4 (0.012)	0.005 (0.011)
Survey round 2015 (dummy)	127.893*** (25.990)	−80.317** (40.621)	0.573*** (0.143)	0.713*** (0.141)
Number of observations	1362	1362	1362	1362

Notes: Coefficient estimates of random effects panel models are shown with standard errors in parentheses. The models in columns (1) and (2) were estimated with a SUR estimator. The models in columns (3) and (4) were estimated with a logit estimator; coefficients can be interpreted as marginal effects.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

controlling for total household expenditures. Moreover, unlike female off-farm employment, male off-farm employment is not positively associated with nutrition, neither with nor without controlling for total household expenditures (Tables 5 and A6).

6. Conclusion

The massive expansion of oil palm in many tropical regions is damaging for the environment and is often also perceived as unfavorable for food security and nutrition. However, relationships between oil palm expansion and nutrition have hardly been analyzed up till now. In this study, we used panel data from smallholder farm households in Indonesia to address this research gap. The results suggest that oil palm cultivation is positively and significantly associated with nutrition and dietary quality, also after controlling for possible confounding factors.

We also analyzed the underlying mechanisms. Food crop production in the study area is very limited regardless of whether or not the farms are involved in oil palm cultivation. Farm households obtain almost all of their food from the market; subsistence does not play a significant role in this context. The association between oil palm cultivation and nutrition is primarily channeled through household income gains. Oil palm is more profitable than the cultivation of alternative crops, and the additional income improves households' economic access to nutritious foods from the market.

Another mechanism that we analyzed is a potential change in intra-household gender roles through oil palm cultivation. Oil palm is less labor-intensive than alternative crops so that less household labor is required for on-farm work. The household labor saved could be used for more off-farm economic activities and additional income generation. Off-farm employment of female household members could increase female financial autonomy, which might have positive effects on household nutrition. Our results show that oil palm cultivation is associated with lower on-farm labor time of both male and female household members. However, a positive association between oil palm cultivation and off-farm employment was only found for male and not for female members. Despite the female labor savings on the farm, there seem to be human capital and cultural constraints that prevent women from participating in more lucrative off-farm employment. A certain fraction of the women works in off-farm activities, and our estimates demonstrate that female off-farm employment is indeed positively associated with family nutrition, even after controlling for total household income. However, this seems to be unrelated to oil palm cultivation. Factors that are positively associated with female off-farm employment are female and male education, among others.

We conclude that oil palm cultivation is positively associated with food security and nutrition and that this association is primarily channeled through positive income effects. This does not mean that further oil palm expansion is desirable, because the environmental costs must not be ignored. Furthermore, not all households are able to cultivate oil palm due to capital constraints, which may lead to rising economic inequality over time. However, many smallholder farmers benefit economically and nutritionally, a finding that needs to be kept in mind when designing policies for more sustainable land use.

In closing, two limitations of this research should be mentioned. First, the results are specific to the study region in Indonesia. Land-use change towards oil palm and other cash crops may have less favorable effects on diets and nutrition in locations where food markets are not well developed, and subsistence still plays a more crucial role. Second, the estimates should be interpreted as associations and not as causal effects. Even though we used panel data and carried out robustness checks to deal with possible concerns about reverse causality, endogeneity issues cannot be ruled out completely. The fact that the empirical results are plausible also from a theory perspective is re-assuring. Nevertheless, further research with longer-term data from various geographical contexts is needed to further enhance our understanding of the multifaceted linkages between land-use change, nutrition, and gender roles.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.forpol.2020.102245.

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