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

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Georg-August-Universität Göttingen
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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 socioeconomic implications. In Indonesia, oil palm cultivation is rapidly expanding at the expense of more traditional agricultural crops 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 influences nutrition through changing income, gender roles, and other possible mechanisms. 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 has positive effects on different indicators of nutrition and dietary quality. These effects are primarily channeled through income gains that improve smallholders' access to nutritious foods from the market. Oil palm requires less family labor than traditional crops, so a switch to oil palm could potentially free 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. Independent of oil palm cultivation, female off-farm employment has positive nutrition effects, even after controlling for total household income.

Keywords: oil palm, smallholder livelihoods, gender roles, female empowerment, nutrition, dietary quality

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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 agricultural crops and forest land is particularly noteworthy (Feintrenie et al. 2010; Gatto et al. 2015; Byerlee et al. 2016; Euler et al. 2016). 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 (Obidzinski et al. 2012; Austin et al. 2015; Marlier et al. 2015; Teuscher et al. 2016). There are also various social concerns, often related to land tenure conflicts (Marti 2008). 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; Hidayat et al. 2018). On the other hand, the oil palm boom has positive effects, as it contributes to economic growth, employment generation, poverty reduction, and broader rural development (Susila 2004; Zen et al. 2006; Rist et al. 2010; Bou Dib et al. 2018).

In Indonesia, oil palm is not only cultivated on large company plantations; around 40% of the palm oil is produced by smallholder farmers (Euler et al. 2016). These farmers benefit economically, because oil palm is more profitable than the production of food crops and more traditional cash crops like rubber (Euler et al. 2017; Kubitza et al. 2018). Beyond profits and income, effects of oil palm cultivation on other social dimensions of household welfare – such as food security, nutrition, or gender equity – have hardly been analyzed up till now. Oil palm may potentially threaten food security, as most of the palm oil production is used for non-food purposes, which may lead to lower production and rising prices of food commodities (Cassman and Liska 2007; Sheil et al. 2009; Li 2015). On the other hand, oil palm cultivation may also improve food security through income gains and thus better economic access to food and dietary quality.

Here, we analyze the effects of oil palm cultivation by smallholder farmers on household nutrition. 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 research hypotheses related to impacts and impact mechanisms. The empirical analysis uses two rounds of household-level panel data collected in Jambi Province on the island of Sumatra, one of the hotspots of Indonesia's recent oil palm boom.

2. Conceptual framework

2.1 Possible impact mechanisms

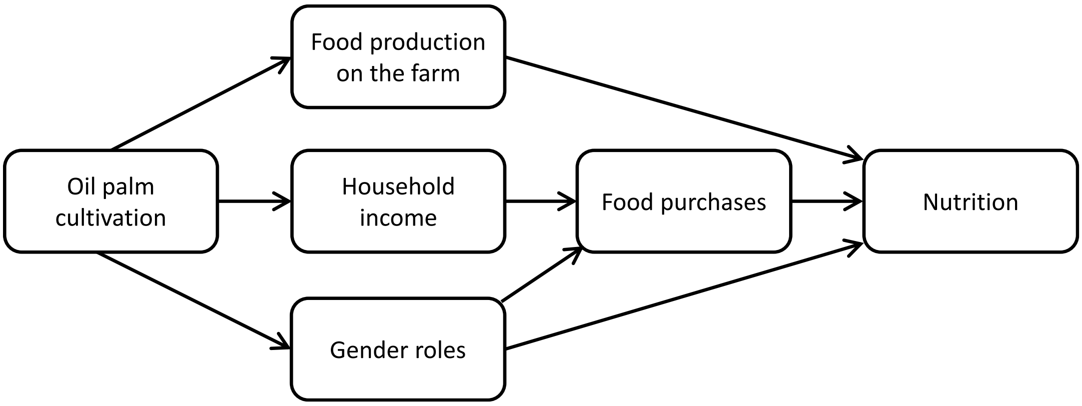

Figure 1. Possible mechanisms of how oil palm cultivation can affect nutrition

We want to analyze the effects of oil palm cultivation by smallholder farmers on farm household nutrition. These effects may be channeled through various mechanisms, as shown in Figure 1. A first mechanism is through food production on farm. Often smallholder farm households are subsistence-oriented, meaning that much or their food consumption comes from own production. In subsistence-oriented settings, the types of crops grown on the farm directly affect household diets and nutrition (Jones 2017). When household resources are limited, the production 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 farm household nutrition (Li 2015).

A second mechanism is through income effects of oil palm cultivation. Several studies with data from Indonesia show that farm households can earn significantly more when they are engaged in own oil palm cultivation (Rist et al. 2010; Euler et al. 2017; Krishna et al. 2017b; Kubitza et al. 2018). The additional cash income can improve households' access to food and dietary quality from the market, which would imply a positive partial effect on nutrition. Euler et al. (2017) showed that oil palm cultivation is associated with higher calorie consumption in small farm households, but further details of dietary quality were not addressed in previous research.

A third mechanism is related to the possibility of changing gender roles within the household. 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; Djurfeldt et al. 2017; Tavenner and Crane 2018). Loss in female autonomy may entail a negative partial effect on household nutrition, as women tend to have a stronger emphasis than men on family health and nutrition (Hoddinott and Haddad 1995; Taridala et al. 2010; Malapit and Quisumbing 2015). However, beyond possible shifts in the control of crop income, gender roles may also change through the re-allocation of other household resources (Theis et al. 2018; Lecoutere and Jassogne 2019). Oil palm is known to be more capital-intensive but less labor-intensive than many other 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. Female off-farm employment could increase women's financial autonomy and thus lead to a positive partial effect on nutrition (Amugsi et al. 2016; Van den Broeck and Maertens 2017; Stevano et al. 2018). Concrete research hypotheses related to these mechanisms are developed in the next subsection.

2.2 Research hypotheses

The first and overarching hypothesis that we want to test is that oil palm cultivation by smallholder farmers improves 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 own 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 the estimate for α_1. A positive and significant estimate for α_1 would lend support to the first hypothesis.

We develop additional hypotheses to analyze the possible impact mechanisms (Figure 1). The mechanism through possible changes in own food production on oil palm cultivating farms is relevant in general, but does not apply to the particular context in Jambi Province, where our empirical study is located. Food crop production in Jambi was very low even before the oil palm area started to expand in the early-1990s. For the last few decades, the most widely grown agricultural crop in Jambi was rubber (Gatto et al. 2015), which is a pure cash crop itself. Oil palm plantations have partly replaced rubber plantations, or they were established on fallow areas and forest land (Drescher et al. 2016; Clough et al. 2016). Substitution of oil palm for food crop production was hardly observed. 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). Hence, we do not develop and test a hypothesis related to the food production and subsistence mechanism.

Concerning the income mechanism, previous studies showed that oil palm cultivation contributes to significant income gains in Indonesia's small farm sector (Euler et al. 2017; Kubitza et al. 2018). We build on these previous results but additionally want to test the hypothesis that the income gains lead to better nutrition and improved 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 leads to 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 also for the income from rubber, as both crops are cash commodities. As mentioned, food crop production is limited in Jambi, even on farms that are not involved in oil palm cultivation. However, related to a possible re-allocation of labor time, we test the hypothesis that oil palm cultivation reduces the amount of household labor involved in farming, compared to households that mainly or only cultivate rubber. As we want to understand gendered effects, we differentiate between male and female labor and estimate 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 a next step, and related to a possible reduction in labor time on the farm, we test the hypothesis that oil palm cultivation contributes to more off-farm employment through estimating:

$$FOF_i = \theta_0 + \theta_1 OP_i + \theta_2 Z_i + \varepsilon_i \quad (5)$$
$$MOF_i = \vartheta_0 + \vartheta_1 OP_i + \vartheta_2 Z_i + \varepsilon_i \quad (6)$$

where FOF_i and MOF_i denote female and male off-farm employment, respectively. A positive θ_1 and $\vartheta_1$value would indicate that oil palm cultivation increase female and male off-farm employment, respectively.

Whether or not off-farm employment contributes to improved nutrition is analyzed with:

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

Off-farm employment of female household members would increase female financial autonomy and could thus have a positive effect on nutrition and dietary quality. This hypothesis would be supported by a positive estimate for ρ_1.

3. Materials and methods

3.1 Farm household survey

We surveyed farm households in Jambi Province on the island of Sumatra, Indonesia. The main land uses in Jambi are rubber, oil palm, and forest (Gatto et al. 2015). In spite of the rapid increase in the area cultivated with oil palm, rubber remains the dominant crop grown by most of the smallholder farm households in Jambi (Krishna et al. 2017b).

Our survey was implemented in two rounds, namely in 2012 and in 2015. Sample farm households were selected 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. Five villages were added purposively to cover specific areas where other project activities were ongoing (Drescher et al. 2016). In the regression models we control for non-randomly selected villages to avoid any possible bias. Finally, in each of the 45 villages we randomly selected 6-25 farm households, depending on the village size. Thus, we obtained a sample of 701 farm households in 2012. For the 2015 round, the same households were included, but due to attrition, 6% of the sample (41 households) had to be replaced. In the analysis, we use the unbalanced panel with observations from both survey rounds. A small fraction of the observations with missing values for some of the important variables had to be excluded.

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.

3.2 Measuring nutrition

Nutrition can be measured in a number of ways, including through 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 common tools to analyze diets and nutrition (Pingali and Ricketts 2014; 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 usually strongly correlated with individual-level indicators (Sununtnasuk and Fiedler 2017; Fongar et al. 2018). 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. Variation in consumption is typically related to agricultural seasons, especially in subsistence-oriented farm households. But, as mentioned, farm households in Jambi purchase almost all of their food from the market. Rubber and oil palm are both harvested all the year around, 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 diet and nutrition 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 simple to construct indicator in dietary analysis (FAO 2011; Jones 2017; Sibhatu and Qaim 2018). Depending on the intention, different food group classifications can be used to construct the DDS. We use a classification with 9 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 and better dietary quality.

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. But certain minimum quantities are needed in order to prevent nutritional deficiencies. Therefore, in addition to DDS, we also calculate the quantities of calories and certain micronutrients consumed by the sample households. For the micronutrients, we concentrate on vitamin A, iron, and zinc, because deficiencies in these nutrients are widespread in many developing countries with severe negative health implications (Bhutta et al. 2013; IFPRI 2017). This is also true in Jambi. While calorie undernutrition is not considered a major problem in Jambi anymore, low dietary quality and micronutrient deficiencies are still commonplace (Dinas Kesehatan Jambi 2016). We used food composition tables for Indonesia (Berger et al. 2013) supplemented by international references (USDA 2016) to convert the food quantities consumed to levels of 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.

3.3 Measuring other key variables

Beyond nutrition, other key variables used in our analysis are household income, gendered labor time and employment, and several other variables used as socioeconomic controls in the different regression models. We proxy household income by annual household expenditures, including the value of all foods and non-food goods and services combined. This is a common approach in the development economics literature, because expenditures are usually a more precise indicator of living standard than income (Deaton 1997). Annual expenditures are expressed in Indonesian Rupiah (IDR) per AE.

Female and male labor time is 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 family and hired laborers were asked for the last 12 months for all of the agricultural operations. 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 who of the female and male household members 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 ha), household size (in terms of female and male adults and children), age and educational levels of male and female adults (measured in years of schooling), ethnicity (a dummy for the autochthonous Melayu population), and market distance (measured in km), among others. Most of the non-Melayu people in Jambi are immigrants from Java, many of whom came to Jambi as part of the governments' transmigration program (Gatto et al. 2017).

3.4 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 crops, 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 that were described above to test the research hypotheses on nutrition effects of oil palm cultivation and impact mechanisms. 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 is households that only cultivate rubber. All models include observations from both survey rounds (2012 and 2015) and are estimated with random effects panel estimators. 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 during the short period of time covered by the two survey rounds.

4. Results and discussion

4.1 Expenditures and dietary quality with and without oil palm cultivation

Table 1. Expenditures and dietary quality by farm household type

	(1) Only rubber (n=833)	(2) Only oil palm (n=194)	(3) Oil palm and rubber (n=323)
Average size of farm (ha)	3.52	3.39	8.83***
	(5.06)	(3.12)	(13.15)
Household expenditure (million IDR/AE/year) [a]	13.01	15.65***	18.86***
	(16.75)	(10.88)	(17.45)
Dietary diversity score (0-9)	6.56	6.97***	7.00***
	(1.27)	(1.01)	(1.21)
Calories (kcal/AE/day)	2793.60	3114.73***	3425.93***
	(1312.04)	(1344.07)	(1825.84)
Iron (mg/AE/day)	17.29	20.75***	22.03***
	(11.80)	(11.49)	(15.44)
Zinc (mg/AE/day)	9.93	11.56***	12.31***
	(4.71)	(5.78)	(7.45)
Vitamin A (µg/AE/day)	941.52	1132.84	1350.17***
	(1557.37)	(1454.13)	(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 were deflated by using the consumer price index for Indonesia to make values comparable across survey rounds (1 US$ = IDR 13,401). *** Mean values are significantly different from those in column (1) at the 1% level.

Table 1 shows descriptive statistics for the three groups of farm households, namely those with only rubber (columns 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 areas than the other two groups. As expected, households with oil palm cultivation are significantly richer (higher household consumption expenditures) than households that only grow rubber. This is line with earlier research that also found income gains through oil palm cultivation among Indonesian smallholders (Kubitza et al. 2018). Table 1 also shows significant differences between the groups in terms of the nutrition and dietary indicators. Households that cultivate oil palm have higher dietary diversity and higher calorie and micronutrient consumption than households that only cultivate rubber.

Table 2 compares household labor input in oil palm and rubber. Previous research showed that oil palm is much less labor-intensive than rubber (Feintrenie et al. 2010; Euler et al. 2017). This is confirmed in our data. On average, the household labor input is 80% lower in oil palm than in rubber. This big difference is due to quite different production and harvesting processes between the two crops. Rubber trees are usually tapped every day, so that a constant labor input is required. Male and female household members are both involved in rubber cultivation and tapping. In contrast, harvesting in oil palm fields is conducted only every two weeks. Manually harvesting the heavy oil palm fruit bunches is physically demanding, and is often carried out by male laborers. The strong physical requirements are also the main reason why female household members are hardly involved in oil palm cultivation.

4.2 Labor allocation with and without oil palm cultivation

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	822.94***
	(260.80)	(1063.58)
Female household labor	24.75	249.24***
	(68.31)	(446.59)
Male household labor	132.34	573.70***
	(235.06)	(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.

In order to analyze whether lower household labor use in agriculture through a switch from rubber to oil palm leads to a higher likelihood of off-farm employment, we compare off-farm employment rates between households with and without oil palm cultivation in Figure 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 comparing household that only grow rubber with households that cultivate both crops. However, this latter comparison is not very meaningful as households that cultivate both crops have much larger farm sizes on average (Table 1).

The gendered analysis in Figure 2 reveals that most of the differences in off-farm employment rates between rubber and oil palm cultivating households are due to higher employment rates among male household members. 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 cultural context. In Indonesia, women were traditionally discouraged to work outside the household and they may require permission to do so from a man (Rammohan and Johar 2009; Schaner and Das 2016; Elmhirst et al. 2017).

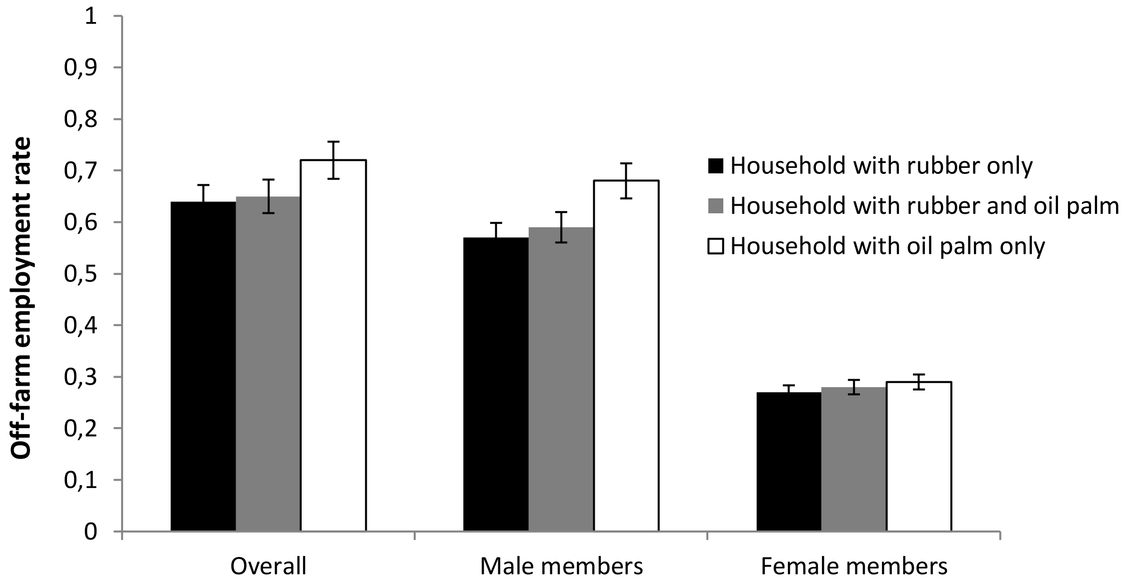

Figure 2. Gendered off-farm employment in households with and without oil palm

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

	All households		Only with off-farm employment	
	(1) Without off-farm employment	(2) With off-farm employment	(3) Only male employment	(4) At least one female employed
Dietary diversity score (0-9)	6.57	6.80***	6.67	7.00***
	(1.22)	(1.24)	(1.28)	(1.16)
Calories (kcal/AE/day)	2981.18	2963.04	2837.45	3133.61***
	(1520.53)	(1434.54)	(1251.61)	(1637.17)
Iron (mg/AE/day)	19.27	18.54	17.35	20.16***
	(12.98)	(12.61)	(10.74)	(14.63)
Zinc (mg/AE(day)	10.76	10.61	10.18	11.2***
	(6.24)	(5.35)	(4.44)	(6.34)
Vitamin A (µg/AE/day)	966.62	1101.73	944.41	1315.37***
	(1502.71)	(1718.937)	(1426.11)	(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 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 gendered analysis in columns (3) and (4) shows those households with female off-farm employment have significantly better dietary quality than households where only male household members are employed. This supports the hypothesis that female off-farm employment contributes to women's financial autonomy and household expenditures that are more geared towards family nutrition and health.

4.3 Effects of oil palm cultivation on nutrition

We now use the regression models described above to analyze the effects of oil palm cultivation on nutrition while controlling for potentially confounding factors. Table 4 shows estimates of the model in equation (1) with nutrition indicators as dependent variables 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 dependent variable, we use a linear specification.[1] For the calorie and micronutrient models, we used a log-transformation of the dependent variables to achieve a more symmetric distribution and a better model fit.

In all models in Table 4, the two oil palm dummies have significantly positive effects, implying that oil pam cultivation improves nutrition and dietary quality also after controlling for other relevant factors. Interpreting results for the oil palm only dummy, oil palm cultivation increases household dietary diversity by 0.36 food groups, the consumption of calories by 9.8%, of vitamin A by 32.0%, of zinc by 11.7%, and of iron by 18.9%.[2] These are quite large effects that clearly support our first and overarching hypothesis.

In terms of the control variables in Table 4, total land size and education of the adult members of the household have positive effects on nutrition, as one would expect. Interesting to see is that women's education has larger positive effects on dietary quality than men's education, which underlines the important role of women's empowerment for family nutrition and health. Household size in terms of the number of male and female adults and children produces negative coefficients. On the one hand, larger households may find it more difficult to adequately nourish all household members. On the other hand, larger households tend to have positive economies of scale in food preparation and consumption with lower quantities wasted. This means that lower gross consumption quantities do not necessarily result in lower actual intakes per household member.

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. Javanese households have higher average incomes; many of them were supported through the government's transmigration program, which involved subsidized credits and public infrastructure investments (Gatto et al. 2017).

2012. This reflects the considerable drops in international prices for rubber and palm oil between 2012 and 2015 leading to lower incomes for farmers producing these crops (Kubitza et al. 2018).

Table 4. Effects of oil palm cultivation on nutrition indicators

Variables	DDS	Calories (log)	Vit. A (log)	Zinc (log)	Iron (log)
Oil palm only (dummy)	0.357***	0.094***	0.278***	0.111***	0.173***
	(0.108)	(0.030)	(0.102)	(0.028)	(0.049)
Oil palm plus rubber	0.305***	0.130***	0.251***	0.135***	0.181***
(dummy)	(0.093)	(0.033)	(0.062)	(0.032)	(0.036)
Total land size (ha)	0.007	0.008***	0.013***	0.007***	0.008**
	(0.004)	(0.003)	(0.005)	(0.003)	(0.003)
Female-headed (dummy)	-0.316*	0.017	-0.208	-0.012	0.026
	(0.168)	(0.065)	(0.158)	(0.063)	(0.085)
Number of adult women	0.085	-0.069***	-0.056	-0.054***	-0.085***
	(0.052)	(0.015)	(0.051)	(0.017)	(0.025)
Number of adult men	0.047	-0.046***	-0.052	-0.044***	-0.014
	(0.039)	(0.017)	(0.035)	(0.015)	(0.022)
Number of children	0.022	-0.072***	-0.080**	-0.051***	-0.069***
	(0.041)	(0.011)	(0.035)	(0.011)	(0.019)
Mean education of adult	0.044***	0.014***	0.040***	0.011**	0.020***
women (years)	(0.014)	(0.004)	(0.011)	(0.005)	(0.005)
Mean education of adult	0.038***	0.005	0.035***	0.001	0.010*
men (years)	(0.013)	(0.004)	(0.012)	(0.005)	(0.006)
Mean age of adult	-0.005	0.001	-2.45e-1	3.41e-1	-0.001
women	(0.004)	(0.001)	(0.003)	(0.002)	(0.002)
Mean age of adult men	-0.001	0.002*	0.005	-8.71e-6	0.003
	(0.005)	(0.001)	(0.004)	(0.001)	(0.002)
Access to formal credit	-0.04	0.044*	0.008	0.043	0.034
(dummy)	(0.08)	(0.025)	(0.056)	(0.028)	(0.038)
Melayu (dummy)	-0.271***	-0.027	-0.118*	-0.071***	-0.117***
	(0.072)	(0.023)	(0.063)	(0.023)	(0.038)
Non-random village	0.375***	0.081**	0.199***	0.071***	0.067
(dummy)	(0.128)	(0.034)	(0.076)	(0.021)	(0.049)
Distance to market (km)	0.004	2.79e-1	0.008*	-0.001	0.003
	(0.006)	(0.001)	(0.004)	(0.002)	(0.003)
Survey round 2015	0.033	-0.101***	-0.159***	-0.059*	-0.138***
(dummy)	(0.064)	(0.027)	(0.051)	(0.032)	(0.034)
Constant	6.015***	7.872***	5.779***	2.354***	2.666***
	(0.305)	(0.066)	(0.231)	(0.070)	(0.109)
R-squared	0.105	0.177	0.107	0.129	0.129
Chi2	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 the 10%, 5%, and 1% level, respectively.

4.4 Testing the income mechanism

Table 5. Effects of household expenditures on nutrition indicators

Variables	DDS	Calorie (log)	Vit. A (log)	Zinc (log)	Iron (log)
Expenditures (log)	0.748***	0.453***	0.733***	0.453***	0.571***
	(0.067)	(0.021)	(0.065)	(0.021)	(0.027)
Total land size (ha)	-0.007***	-0.001	-0.001	-0.001	-0.003**
	(0.003)	(0.001)	(0.002)	(0.001)	(0.001)
Female-headed (dummy)	-0.250	0.080*	-0.130	0.048	0.105
	(0.163)	(0.041)	(0.134)	(0.039)	(0.066)
Number of adult women	0.142***	-0.032**	-0.005	-0.016	-0.041**
	(0.049)	(0.012)	(0.044)	(0.015)	(0.020)
Number of adult men	0.097**	-0.019	-0.005	-0.015	0.028*
	(0.041)	(0.013)	(0.032)	(0.012)	(0.017)
Number of children	0.102**	-0.023***	-0.002	-0.001	-0.007
	(0.041)	(0.008)	(0.036)	(0.008)	(0.015)
Mean education of adult	0.022*	0.001	0.018	-0.002	0.004
women (years)	(0.013)	(0.003)	(0.011)	(0.004)	(0.005)
Mean education of adult	0.028**	-0.002	0.024**	-0.006	0.002
men (year)	(0.013)	(0.003)	(0.011)	(0.004)	(0.005)
Mean age of adult	-0.007*	4.216e-4	-0.002	-4.358e-4	-0.002
women	(0.004)	(0.001)	(0.003)	(0.001)	(0.002)
Mean age of adult men	-0.001	0.002*	0.005	4.97e-5	0.003
	(0.005)	(0.001)	(0.003)	(0.001)	(0.002)
Female off-farm	0.144**	0.039*	0.150**	0.024	0.057**
employment (dummy)	(0.066)	(0.023)	(0.061)	(0.021)	(0.028)
Male off-farm	-0.070	-0.021	-0.049	-0.027	-0.072**
employment (dummy)	(0.068)	(0.021)	(0.060)	(0.024)	(0.032)
Female on-farm work	-6.51e-5	-1.33e-5	-9.61e-5**	-5.16e-06	-8.55e-06
(hours/year)	(5.94e-5)	(1.77e-5)	(4.59e-5)	(1.86e-5)	(2.32e-5)
Male on-farm work	-9.10e-06	1.28e-5	4.66e-06	5.54e-06	-2.65e-06
(hours/year)	(3.6e-5)	(9.16e-6)	(3.3e-5)	(1.09e-5)	(1.28e-5)
Access to formal credit	-0.061	0.014	-0.028	0.017	0.007
(dummy)	(0.080)	(0.022)	(0.056)	(0.024)	(0.032)
Melayu (dummy)	-0.249***	-0.002	-0.091*	-0.048***	-0.092***
	(0.063)	(0.016)	(0.053)	(0.018)	(0.031)
Non-random village	0.316**	0.042	0.136*	0.035**	0.023
(dummy)	(0.124)	(0.027)	(0.072)	(0.016)	(0.045)
Distance to market (km)	0.006	0.002	0.010**	0.001	0.005**
	(0.006)	(0.001)	(0.004)	(0.002)	(0.003)
Survey round 2015	0.121**	-0.046**	-0.070	-0.004	-0.066**
(dummy)	(0.059)	(0.019)	(0.050)	(0.025)	(0.029)
Constant	4.359***	6.804***	4.132***	1.293***	1.372***
	(0.394)	(0.090)	(0.296)	(0.096)	(0.141)
R-squared	0.184	0.454	0.221	0.376	0.338
Chi2	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 the 10%, 5%, and 1% level, respectively.

We hypothesized that at least some of the positive nutrition effects of oil palm cultivation are 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.

4.5 Testing the gender mechanism

Table 6. Effects of oil palm cultivation on household labor allocation by gender

	On-farm work (hours/year)		Off-farm employment (dummy)	
Variables	(1) Female labor	(2) Male labor	(3) Female employment	(4) 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 (dummy)	-40.183 (71.997)	-52.084 (118.632)	0.658* (0.389)	0.322 (0.408)
Number of adult women	51.128** (22.286)	56.986 (36.713)	0.490*** (0.127)	0.103 (0.128)
Number of adult men	12.033 (19.224)	190.364*** (31.673)	0.096 (0.113)	0.490*** (0.121)
Number of children	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 random-effects SUR estimator. The models in columns (3) and (4) were estimated with a logit model; the coefficients shown can be interpreted as marginal effects. *, **, *** significant at the 10%, 5%, and 1% level, respectively.

Positive expenditure effects of oil palm cultivation in Jambi were also shown more formally by Kubitza et al. (2018). What has not been shown so far is that higher household expenditures really contribute to better diets and nutrition. 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 that we have double-log specifications for the calorie and micronutrient models. A one percent gain in total household expenditures increases calorie consumption by 0.45%, vitamin A consumption by 0.73%, zinc consumption by 0.45%, and iron consumption by 0.57%.

We now test whether oil palm cultivation affects nutrition also through the mechanism of changing gender roles, especially an increase in female financial autonomy through more off-farm employment. In a first step, we test whether oil palm cultivation reduces the amount of household labor used in on-farm activities by estimating models with female and male farm labor time as dependent and the two oil palm dummies as explanatory variables. As female and male labor hours used on the farm are not independent, we employ the seemingly unrelated regression (SUR) technique to estimate these two equations while accounting for possible error term correlation. 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 affect household labor use. This is plausible because the rubber still has to be tapped every morning. However, cultivating oil palm as the only crop reduces household labor time on the farm significantly. Female and male farm work is reduced by 406 and 768 hours per year, respectively.

The effects of oil palm cultivation on 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 large on-farm labor savings through switching from rubber to oil palm cultivation. Strikingly, however, for female household members the likelihood of off-farm employment does not increase significantly through oil palm cultivation, in spite of a considerable reduction in female labor time on the farm. This may be due to cultural restrictions for women to pursue off-farm work. Other constraints may also play a role. In any case, the hypothesis that oil palm cultivation contributes to more female off-farm employment and thus higher female financial autonomy has to be rejected.

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 increases with the number of adult women living in the household and their mean education level, which is very plausible. Better education improves the access to more lucrative off-farm jobs. In addition, better female education improves the bargaining position of women in the household, for instance to get permission from male household members to work outside the household. Interestingly, the likelihood of female off-farm employment also increases 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 equality (McDavid 1988; Rammohan and Johar 2009). In female-headed households, women can decide more freely to pursue off-farm employment, which is underlined by the positive and significant coefficient for female household head.

In spite of the fact that oil palm cultivation does not seem to increase the likelihood of female off-farm employment, it is interesting to test whether female off-farm work has any effect on household nutrition and diets. The results in Table 7 confirm that it has. Female off-farm employment increases dietary diversity by 0.22 food groups, calorie consumption by 8.5%, vitamin A consumption by 25.0%, zinc consumption by 7.0%, and iron consumption by 11.6%. One could argue that this is just an income (expenditure) effect, because female off-farm employment contributes to higher household incomes (expenditures). However, the effects of female off-farm employment on nutrition remain positive and significant also after controlling for total household expenditures (Table 5). Moreover, unlike female employment, male off-farm employment does not seem to influence nutrition significantly (Table 7). These results underline the positive role of female financial autonomy for nutrition and dietary quality.

Table 7. Effects of female and male labor allocation on nutrition indicators

Variables	DDS	Calories (log)	Vit. A (log)	Zinc (log)	Iron (log)
Female off-farm employment (dummy)	0.218***	0.082***	0.223***	0.068***	0.110***
	(0.075)	(0.029)	(0.068)	(0.024)	(0.033)
Male off-farm employment (dummy)	-0.025	0.009	-0.007	0.001	-0.034
	(0.071)	(0.026)	(0.062)	(0.028)	(0.036)
Female on-farm work (hours/year)	-7.68e-5	-2.02e-5	-1.11e-4**	-1.19e-5	-1.7e-5
	(6.35e-5)	(2.11e-5)	(5.1e-5)	(2.32e-5)	(2.91e-5)
Male on-farm work (hours/year)	-1.20e-6	1.7e-5	1.16e-5	9.54e-6	2.86e-6
	(4.08e-5)	(1.31e-5)	(3.87e-5)	(1.48e-5)	(1.78e-5)
Total land size (ha)	0.010**	0.009***	0.016***	0.009***	0.010***
	(0.004)	(0.003)	(0.005)	(0.003)	(0.003)
Female-headed (dummy)	-0.384**	-0.005	-0.265	-0.036	-0.011
	(0.170)	(0.063)	(0.163)	(0.060)	(0.077)
Number of adult women	0.062	-0.079***	-0.076	-0.063***	-0.098***
	(0.052)	(0.017)	(0.05)	(0.018)	(0.026)
Number of adult men	0.052	-0.047***	-0.052	-0.043***	-0.009
	(0.041)	(0.017)	(0.037)	(0.016)	(0.021)
Number of children	0.022	-0.072***	-0.080**	-0.050***	-0.068***
	(0.043)	(0.011)	(0.037)	(0.010)	(0.019)
Mean education of adult women (years)	0.038***	0.011***	0.034***	0.009*	0.017***
	(0.014)	(0.004)	(0.011)	(0.005)	(0.005)
Mean education of adult men (years)	0.038***	0.005	0.034***	0.001	0.011*
	(0.013)	(0.004)	(0.012)	(0.005)	(0.006)
Mean age of adult women	-0.006	0.001	-0.001	-2.78e-1	-0.002
	(0.004)	(0.001)	(0.003)	(0.002)	(0.002)
Mean age of adult men	0.000	0.002**	0.005	4.66e-01	0.003*
	(0.005)	(0.001)	(0.004)	(0.001)	(0.002)
Access to formal credit (dummy)	0.007	0.059**	0.046	0.062**	0.061
	(0.082)	(0.026)	(0.057)	(0.030)	(0.039)
Melayu (dummy)	-0.299***	-0.032	-0.139**	-0.078***	-0.129***
	(0.071)	(0.023)	(0.057)	(0.023)	(0.039)
Non-random village (dummy)	0.381***	0.082*	0.200***	0.075***	0.074
	(0.114)	(0.042)	(0.069)	(0.028)	(0.057)
Distance to market (km)	0.002	-4.39e-01	0.006	-0.002	0.002
	(0.006)	(0.002)	(0.004)	(0.002)	(0.003)
Survey round 2015 (dummy)	0.022	-0.107***	-0.168***	-0.065*	-0.143***
	(0.068)	(0.029)	(0.055)	(0.034)	(0.037)
Constant	6.204***	7.911***	5.933***	2.405***	2.768***
	(0.338)	(0.073)	(0.242)	(0.075)	(0.128)
R-squared	0.098	0.170	0.108	0.116	0.117
Chi2	344.093	258.313	228.944	227.535	192.019
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 the 10%, 5%, and 1% level, respectively

5. Conclusion

The massive expansion of oil palm in many tropical regions is damaging for the environment and is often also perceived as negative for food security and nutrition. However, effects of oil palm expansion on food security and nutrition have hardly been analyzed till now. In this study, we have used panel data from smallholder farm households in Indonesia to analyze the effects of oil palm cultivation on nutrition and dietary quality. Regression models have shown that a switch from traditional crops – such as rubber – to oil palm results in higher dietary diversity and higher household consumption of calories and micronutrients. These results suggest that oil palm cultivation improves food security and dietary quality in rural Indonesia.

We have 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. Most of the positive nutrition effects of oil palm cultivation are channeled through the income mechanism. Oil palm is more profitable than the cultivation of alternative crops, so that a switch to oil palm contributes to higher household incomes and better 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 rubber and alternative crops, so that household labor can be saved. This household labor could be used for more off-farm economic activities. Off-farm employment of female household members could increase female financial autonomy, which might have positive effects for household nutrition. Our results have shown that a switch to oil palm reduces on-farm labor time of male and female household members. At the same time, we have observed a significant increase in the likelihood of off-farm employment for male household members, but not for female household members. In spite of the on-farm labor savings, there seem to be cultural constraints that prevent women from increasing their off-farm employment. A certain fraction of the women do work in off-farm activities, and our estimates have demonstrated that this has positive effects on household diets and nutrition, even after controlling for total household income. But these effects are not related to oil palm cultivation. Factors that increase the likelihood of female off-farm employment are female and male education, among others. Education does not only improve women's access to off-farm jobs but also helps to raise their status and bargaining position within the household.

We conclude that oil palm cultivation has positive effects for food security and nutrition in rural Indonesia, and that these effects are primarily channeled through the income mechanism. This does not mean that further oil palm expansion is desirable, because the environmental costs must not be ignored. But, clearly, smallholder income growth matters for nutritional improvements, a finding that needs to be kept in mind when designing policies for more sustainable land use. Furthermore, our results emphasize the important role of women empowerment for improving food and nutrition security.

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 possibly have less positive effects on diets and nutrition in locations where food markets are less developed and subsistence still plays a more important role. Second, the exact magnitude of the model estimates should be interpreted with caution. Even though we used panel data, which has clear advantages over cross-section data, a certain bias due to unobserved heterogeneity 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 better 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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NOTES

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[1] We also tried a Poisson specification to better account for the fact that DDS is a count variable. The results were very similar. However, the data do not satisfy the equi-dispersion assumption of the Poisson model.

[2] The percentage effect of dummy variables in log-linear models is calculated as $\left(e^{coefficient} - 1\right) \times 100$.g