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Agrarian change, livelihood dynamics and welfare outcomes: Evidence from plantation crop farmers in Indonesia

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ABSTRACT

In the tropical belt of Africa, Asia, and the Americas, smallholder farming is undergoing a significant transformation from subsistence-oriented to highly specialized and market-oriented plantation systems. While understanding the transition of livelihoods of plantation farm households over time is an important development goal, available empirical evidence is scant. This study provides the first quantitative evidence on the dynamics, transitions, and determinants of livelihood strategies linked to the crop choices of commercial farm households in the tropics. We use three-wave panel data of oil palm and rubber farmers from Indonesia for the empirics. Particular emphasis is placed on the trade-offs smallholders face in growing these two crops. Employing the dynamic livelihood strategy framework and Latent Markov Model estimations, we reveal that even highly specialized farm households pursue diversified livelihood strategies, and they actively switch between the identified strategies. Over time, significant changes are observed in the composition of strategies, which continue to be dominated by oil palm-oriented and off-farm-based activities. *Inter alia*, climate anomalies and a decline in oil palm and rubber prices influence the dynamics and trajectories of the livelihood strategies. We also find that a larger farm size possibly hinders households' labor allocation to more remunerative off-farm activities, implying that possessing a larger farm-land alone may not suffice for improving farmers' wellbeing. We conclude by discussing the generalizability of our findings and providing implications for future research and policymaking.

1. Introduction

In the tropical belt of Africa, Asia, and the Americas, smallholder farmers are moving away from subsistence-oriented to market-oriented plantation systems. Farmers are particularly abandoning traditional crops, clearing out tropical rainforests, and converting them to high-value and export-friendly cash crop monocultures like cacao, rubber, and oil palm (Byerlee et al., 2017; Byerlee and Viswanathan, 2018; Drescher et al., 2016; Qaim et al., 2020). Unlike subsistence-oriented farmers, plantation crop farmers are highly integrated into global crop markets (Grass et al., 2020; Kubitza et al., 2019; Qaim et al., 2020; Sibhatu, 2019). At the same time, plantation farmers' capability to adapt to new cropping systems—in response to external shocks—is severely limited because of costly establishments and several growing periods of the crops they grow. Thus, those farmers' sole dependency on such crops for their livelihoods and employment makes them particularly vulnerable to deterrent factors such as unstable world market prices, pest and disease infestation, and climate shocks (Kubitza et al., 2018b; Stiegler et al., 2019). To support such farmers along successful livelihood pathways and design policy measures that foster long-term livelihood and agricultural sustainability, it is paramount to understand which combination of activities and what underlying factors determine their livelihood strategy choices and trajectories over time.

Studies investigating the dynamics of agrarian livelihood strategies generally report that farm households actively move across livelihood strategies and welfare levels and find a variety of assets such as access to finance, social networks, infrastructure, or education to be enabling or constraining factors of varying intensities and scales (Jiao et al., 2017; van den Berg, 2010; Walelign, 2017; Zhang et al., 2019). However, the focus of these studies has been limited to traditional peasant environments only. To the best of our knowledge, this study is the first to quantitatively examine the dynamics of livelihood strategies of market-oriented smallholders *over time,* including the dynamics of plantation crop choice, namely, between rubber and oil palm. These

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perennial crops have significantly different agronomic properties, notably in terms of labor use (Kubitza et al., 2018a). This study aims to contribute to the extant literature by answering three interlinked questions. (1) What are the characteristics and trajectories of livelihood strategies linked to plantation crop choice? (2) Which of the pursued livelihood strategies provides better welfare outcomes? (3) What are the determinants of these livelihood strategy choices and trajectories?

To answer these questions, we use three-wave survey data of smallholder farmers operating in the Jambi province of Indonesia—a global hotspot of plantation crops (Drescher et al., 2016; Euler et al., 2017). Many of Jambi's smallholders have abandoned traditional crops and agroforestry systems to take up rubber and oil palm farming (Grass et al., 2020; Qaim et al., 2020). As stated earlier, these two plantation crops have substantial productivity differences regarding return on labor and land (Clough et al., 2016). Agronomically, cultivating rubber is much more labor-intensive than cultivating oil palm. Shifting toward oil palm cultivation has enabled smallholders to expand their farmland and allocate more labor to off-farm activities (Euler et al., 2017; Krishna et al., 2017a; Kubitza et al., 2018a; Mehraban et al., 2021). Thus, our study also consider the dynamics of smallholders' crop choices and examines how crop production trade-offs are linked to livelihood strategy compositions.

The conceptual framework of our study is based on the Dynamic Household Livelihood Strategy Framework (DHLS) (Ellis, 2000; Jansen et al., 2006; Nielsen et al., 2013; Scoones, 1998, 2015). Employing DHLS allows us to systematically analyze livelihood strategies and their relationships with welfare outcomes by considering various asset types such as human, financial, social, physical, and natural capital (Scoones, 1998). We investigate livelihood strategies by studying activity choice variables and applying a Latent Markov Model estimation. Additionally, we run regression models to understand the relationship between capital asset variables and livelihood strategies and assess the underlying factors that drive the related dynamics and trajectories. Interestingly, our dataset includes information collected before, during, and after the El Niño event of 2015 (Stiegler et al., 2019). Our study period also coincides with a considerable decline in the prices of oil palm and rubber, both locally and globally (Kubitza et al., 2018a). As we shall describe below, these critical weather shocks and price crises have provided us a rare opportunity to further examine how such external factors drive the dynamics of livelihood strategies in plantation farm households.

2. Background and context of the study

The households that we examine in this study – in the context of livelihood strategies and agrarian changes – are rubber and oil palm farmers. And understanding the ecological and socioeconomic functions of the two crops is vital for the later analysis. Hence, in this section, we briefly compare their historical development, current state, and trade-offs in the study area. We also briefly explain the DHLS before presenting the data and the empirical approaches used in our study.

2.1. Land-use change in Jambi

Jambi province is located in the central-eastern part of Sumatra island. The province comprises extensive tropical lowland areas historically covered by rainforests (Drescher et al., 2016). As the humid tropical climatic condition is highly conducive to plantation crops, the province has for long been affected by forest exploitation, first by the extraction of timber and other agroforestry products, then by the cultivation of plantation crops (mostly rubber), and recently through the expansion of oil palm monoculture (Andaya, 1993; Clough et al., 2016; Drescher et al., 2016). Some forest reserves in the province are rich in biodiversity and home to several endangered wildlife species, including the Sumatran orangutan, tiger, and elephant (Luskin et al., 2014; Sibhatu, 2019).

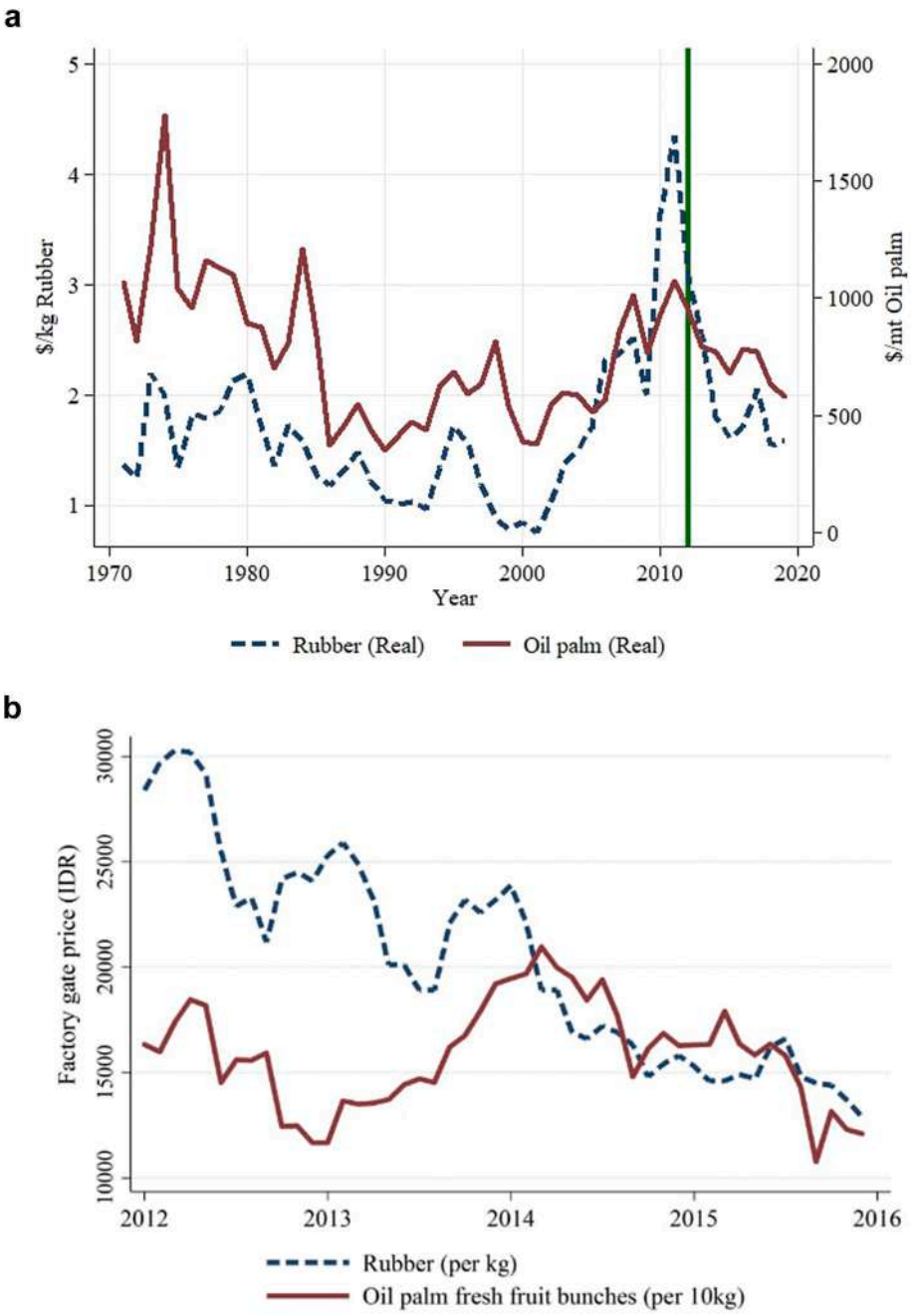
The expansion of plantation crops in Jambi and other areas of Indonesia was reinforced by the issue of commercial logging concessions and the transmigration program in the second half of the 20th century. The latter was aimed at voluntarily relocating families from overpopulated islands to underpopulated ones by offering land, credit, and technical support for agricultural production (McCarthy and Cramb, 2009). Before oil palm cultivation became important, in the late 1980s, transmigrants were supported in the cultivation of rice and rubber (Krishna et al., 2017b). Now, rubber and oil palm remain the most important crops and income sources for rural people in Jambi (Euler et al., 2017; Kubitza et al., 2018a; Sibhatu, 2019). While government-supported programs were stopped at the beginning of the 21st century, farm households continue to adopt and cultivate oil palm independently and sporadically without the support of the government or private sector (Euler et al., 2017; Gatto et al., 2017). Consequently, today, the number of independent farmers outnumbers the supported smallholders (Schwarze et al., 2015).

2.2. Trade-offs in smallholder oil palm and rubber cultivation

Rubber and oil palm are among the few industrial crops substantially produced by smallholder farmers globally. Both take several years to harvest after planting (rubber: nine years; oil palm: four years). Their cultivation, especially that of oil palm, is very capital intensive. High economic-ecological trade-offs further characterize the two perennial crops. While harvested biomass is higher for oil palm than for rubber, oil palm's relationship with ecological factors such as biodiversity, genetic diversity, nutrient retention, soil processes, and stability in climatic conditions is negative (Clough et al., 2016). Labor use is substantially higher in rubber plantations, as rubber trees have to be tapped approximately five times a week, whereas oil palm fruit bunches need to be collected only once in two weeks (Clough et al., 2016). These differences in agricultural management practices result in differing productivity outcomes per unit of labor and land. The cultivation of oil palm is associated with higher returns on labor, but rubber is found to yield a higher return on land as input (Clough et al., 2016). Consequently, depending on the access to capital, land, or proximity to commercial centers, oil palm cultivation might save family labor that can be allocated to other agricultural or non-agricultural (off- and on-farm) activities or allow the farmers to expand their land (Clough et al., 2016; Euler et al., 2017; Krishna et al., 2017b; Schwarze et al., 2015). In the absence of these external factors or if a household has access to surplus family labor, rubber cultivation can still prove to be the better strategy (Euler et al., 2017).

As stated, due to more extended growing periods and costly planting, oil palm and rubber farmers cannot easily switch between production systems in response to external pressures and shocks, as is often observed in traditional peasant contexts (Jiao et al., 2017; Zhang et al., 2019). Farm households in Jambi faced two significant external impacts during our study period: a significant price drop and the 2015 El Niño event. Fig. 1 displays the global and local price movements for rubber and oil palm. The prices of both crops have been substantially fluctuating in the past 50 years. As shown in panel B in Fig. 1, the prices in Jambi follow international price trends. Between 2012 and 2016, rubber and oil prices plummeted significantly, exposing farm households in Jambi to significant declines in their on-farm income during the period (especially for rubber-oriented farmers).

The 2015 El Niño event is ranked as the worst episode of weather shocks in the past two decades; it caused severe droughts, widespread fires and smoke emissions, and it increased temperature in the tropical lowland areas geographically closer to seas and oceans (Field et al., 2016; Solander et al., 2020; Stiegler et al., 2019). While there is little empirical evidence evaluating the impact of the 2015 El Niño event in Jambi, the province was one of the worst affected areas globally (Stiegler et al., 2019). Hence, we expect farmers to make substantial changes to their livelihood strategies to compensate for the loss of their incomes from the price falls and adapt to the climate shocks.



Notes: Rubber price data from Gabungan Perusahaan Karet Indonesia (GAPKINDO), Jambi. Oil palm fresh fruit bunch price data from Dinas Perkebunan, Jambi.

Fig. 1. Price movement of rubber and oil palm: global (a) and local (b). *Note:* Prices are deflated to the 2010 base year. Source: a - authors' representation of data obtained from World Bank (2020). b – obtained from Kubitza et al. (2018a) with permission.

2.3. The dynamic livelihood strategy framework (DHLS)

We employ the DHLS as the framework for our empirical analysis (Jansen et al., 2006; Jiao et al., 2017; Nielsen et al., 2013). The DHLS framework has two interlinked components: the "context" and the "subject" (Fig. 2). As depicted in the upper panel of Fig. 2, the context refers to the external environment in which a subject operates, including natural forces (such as weather anomalies) and human forces (such as changes in global market prices or the implementation of policies and programs) (Winters et al., 2001). In our example, the world market prices of oil palm and rubber might influence the pattern of consumption and investment of households. At the same time, the 2015 El Niño event might negatively affect oil palm and rubber harvests.

The "subject"—we are the first to use this term in the extant literature—can be individuals or groups of people (lower panel of Fig. 2). In this study, the subjects are plantation crop households, whose livelihoods comprise three components: the first component includes the productive assets smallholders typically allocate to income-generating activities—labor and land. The ability to use these assets effectively is strongly dependent on the underlying capital structure, which can be

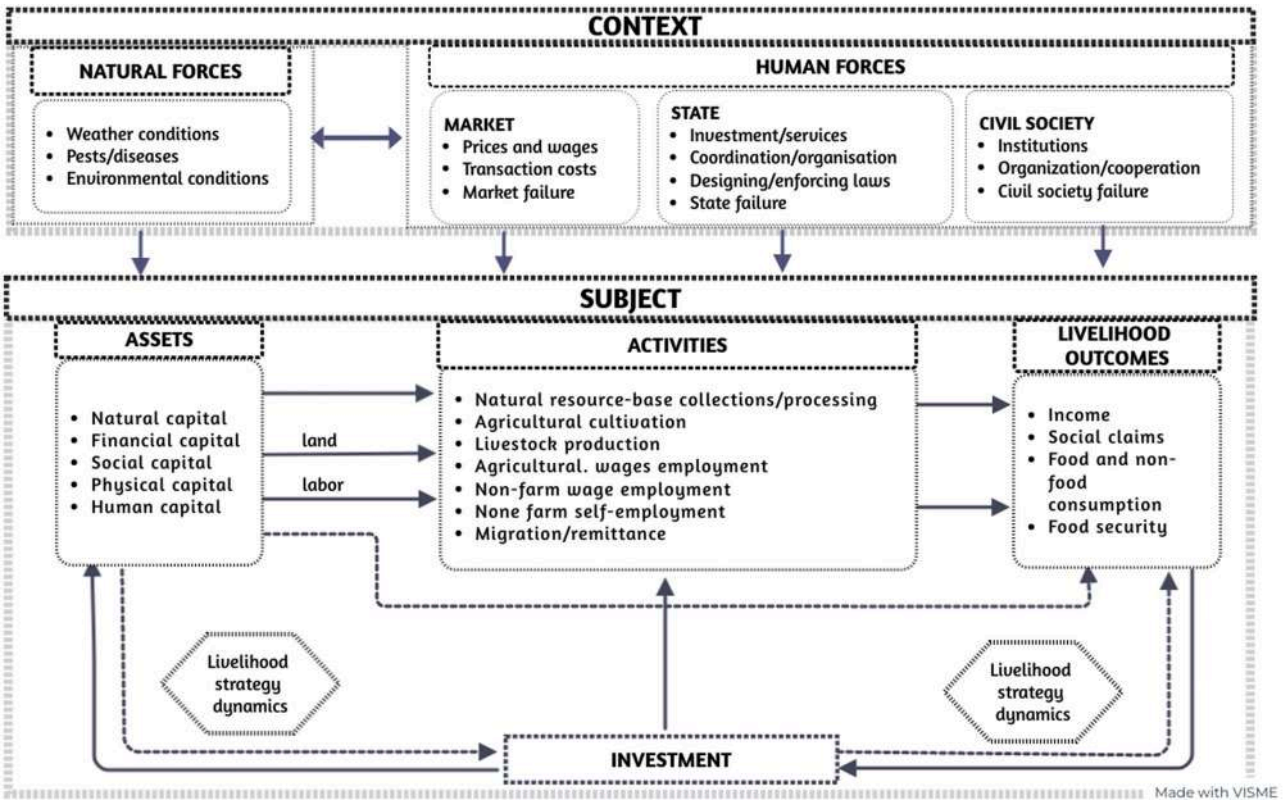


Fig. 2. The dynamic household livelihood strategy framework, with modification after Winters et al. (2001), Nielsen et al. (2013) and Jiao et al. (2017).

tangible (resources and stores) or intangible (claims and access). The second refers to the activities pursued by using these productive assets. The last component concerns the resultant livelihood outcomes, including monetary income, food and non-food consumption, and social claims (Jiao et al., 2017; Nielsen et al., 2013; Winters et al., 2001). How households can achieve their desired outcomes is considered a multi-dimensional and dynamic process, and upward and downward mobility are possible over time (Nielsen et al., 2013).

3. Materials and methods

3.1. The farm household survey

The data for this study were collected as part of the CRC990/EFForTS investigating ecological and socioeconomic changes associated with the transformation of lowland rainforest into agricultural systems in three survey rounds: 2012, 2015, and 2018 (Drescher et al., 2016). To ensure spatial diversity and randomness, a multistage sampling procedure was applied for household selection, leading to data stratification at the regency, district, and village levels. First, five regencies—Sarolangun, Batanghari, Muaro Jambi, Tebo, and Bungo—comprising the lowland areas affected by the oil palm expansion were purposely chosen. Within these five regencies, 40 villages were randomly selected in 2012, from which 600 households were randomly sampled. An additional 80 households were selected randomly from five selected villages for study collaboration with other projects (Drescher et al., 2016). This increased the overall sample size to 680. The same households were revisited in 2015 and 2018, respectively. The attrition rate between 2012 and 2018 was only 7%. A few observations were further dropped because of missing information for key variables. We also excluded a few observations because their mean total annual consumption expenditure (TACE) over all of the periods exceeded three standard deviations of the mean value, and their set of socioeconomic and farm characteristics was significantly different from that of other farmers. Our final analysis is based on data concerning 580 households (1740 observations). The data were collected each year between August and December through face-to-face interviews and structured questionnaires. The survey questions sought detailed information on cropping activities, demographic characteristics, asset endowments, on- and off-farm wage employment, and consumption (Euler et al., 2016, 2017; Krishna et al., 2017a).

3.2. Empirical analysis

Our empirical analysis follows two steps. First, we identify the livelihood strategies and examine how households transition among their livelihood trajectories over time. Thereafter, we investigate the factors influencing the choices and transitions of households' livelihood strategies.

3.2.1. Models to identify and analyze livelihood strategies and trajectories

To identify the livelihood strategies, we utilize the Latent Markov Model (LMM, also known as hidden Markov models (Bartolucci et al., 2013; Jiao et al., 2017). LMM provides a higher degree of flexibility than other model-based clustering techniques by allowing units of observations to move between the latent profiles in different periods (Bartolucci et al., 2013). This method also enables testing and finding an optimal number of clusters instead of relying on *ad hoc* procedures that becomes necessary in other clustering approaches (Nielsen et al., 2013). When applying the LMM to the DHLS, the subjects (households) are perceived to be divided into certain unobservable latent livelihood portfolios (strategies), where the composition of livelihood strategies diverge. The subjects belonging to the same later profile mean that they utilize the same livelihood strategies, and over time, they may switch between strategies. Households are assigned to a given strategy for which their posterior membership probability is the largest, which minimizes the number of assignment errors and within-cluster variations (Bakk et al., 2013). Following Vermunt and Magidson (2016a), the LMM, under the

assumption of local independence among all the activity variables x_{it} for household i, with the covariates excluded, has the following form:

$$P(x_i) = \sum_{y_0=1}^{K} \sum_{y_1=1}^{K} \sum_{y_2=1}^{K} P(y_0) \prod_{t=1}^{T_i} P(y_t \mid y_{t-1}) \prod_{t=0}^{T_i} P(x_{it} \mid y_t) \quad (1)$$

where the vector collecting the activities of all households at all of the time points is denoted by x_i. y_t represented the latent states (i.e., livelihood strategies at time t) that run from 0 to T_i (i.e., $x_0 = 2012$; $x_1 = 2015$; and $x_2 = 2018$). Three sets of probabilities are included in the model: $P(y_0)$ is the initial state probabilities, $P(y_t|y_{t-1})$ the transition probabilities, and $P(x_{it}|y_t)$ the distribution of indicators or the response probabilities. Hence, the only covariate included in the model and allowed to influence state transitions, but not initial probabilities, is time (t). The initial state and the transition probabilities are modeled using standard logit regression models (Vermunt and Magidson, 2013). The LMM estimations are normalized between 0 and 1. The analysis is conducted in Latent GOLD 5.1 (Vermunt and Magidson, 2016a, 2016b). Supplementary Part A provides additional explanations and results for the main assumptions underlying the LMM.

3.2.2. Models to analyze determinants of livelihood strategy choices and mobility

Our objective is also to assess the determinants of the households' likelihood of belonging to a specific livelihood strategy. We use two regression models to estimate the factors determining the livelihood strategy choices. In the first model, the livelihood strategies are subjected to discrete choice modeling using a multinomial logit regression model (MLM), based on the random utility maximization theory of a household's livelihood choice:

$$U_{ij} = \beta Z_{ij} + e_{ij} \quad (2)$$

where U_{ij} is the utility of ith household from jth livelihood strategy, Z_{ij} represents the explanatory variables (household's capital composition), β is a set of parameters, and e_{ij} is a random error term. Under the assumption of utility maximization, the probability that household i chooses livelihood strategy j is specified as:

$$P(y_{it} = j \mid z_{it}) = \frac{\exp(z_{it}\beta j)}{\sum_{k=0}^{m} \exp(z_{it}\beta j)} \quad (3)$$

The estimated coefficients of the independent variables are interpreted as factors that increase or decrease the probability of being part of a particular livelihood strategy (Cameron and Trivedi, 2005; Wooldridge, 2010).

The second model employed is an ordered logit model (OLM), which we use to identify covariates affecting livelihood strategy transitions. Stochastic dominance analysis is applied to rank livelihood strategies (Nielsen et al., 2013; Jiao et al., 2017; Zhang et al., 2019). Unlike previous literature on livelihood dynamics which used total income, here, we use total annual consumption expenditure (TACE) from 2012 until 2018. If a household moved from a more remunerative livelihood state in the previous year to a less remunerative one in the current year (2012–2015; 2015–2018), it is categorized as downward-moving (DM). If a household remained in the same livelihood state, it is marked as non-moving (NM). And if a household moved from a less remunerative livelihood state to a more remunerative one, it is defined as upward-moving (UM). The livelihood movement categories take discrete and ordered values 1, 2, and 3 for DM, NM, and UM, respectively. The MLM and OLM models are estimated using STATA 16.0 (StataCorp, 2019).

According to Cameron and Trivedi (2005), the underlying response model can be determined from the unobserved latent variable M_i measuring the livelihood transition (DM, NM, and UM):

$$M_i^* = \theta_{Z_{it}} + \gamma_{y_{it-1}} + u_i;\ M_i = j \text{ if } c_{j-1} < j < c_j \quad (4)$$

$i = 1, 2, \ldots, N$; $j = 1, 2, 3$ where the cut-off points c_1, c_2, and c_3 for each category are unknown z_{it} is the vector of capital assets, y_{it-1} is the lagged livelihood states, θ and γ are the parameters of interest and u_i is the error term with a logistic distribution. The probability of outcome j occurring given the independent variable can then be defined as:

$$P(M_{it} = j \mid y_{it-1}, z_{it}) = F(c_j - \theta z_{it} - \gamma y_{it-1}) - F(c_{j-1} - \theta z_i - \gamma y_{it-1}) \quad (5)$$

Letting the ordered response j have s categories, then $c_0 = -\infty$, $c_j - 1 = j$, $c_s = \infty$. F is the cumulative distribution function (c.d.f.) of u_i and $F_j = 1/(1 - exp(-c_j - z_{it}\theta - \gamma y_{it-1}))$.

At this point, it must be emphasized that the analysis aimed to uncover significant associations between livelihood strategies, welfare, and capital assets. However, the applied empirical approach of this study by no means allowed a direct test of any causal links.

3.3. Choice of variables

In this study, the activity variables account for households' allocation of their productive assets — land and labor. In the empirical analysis, they are the latent state indicators. Most households in Jambi allocate their land to rubber and oil palm (Krishna et al., 2017b; Kubitza et al., 2018b, 2019). Table 1 shows the returns on labor and land of the crops. Generally, cultivating oil palm is more profitable per unit of labor than cultivating rubber, but less per unit of land. In 2015, due to a substantial fall in world market prices, rubber producers' return on land and labor declined drastically, while the decile for oil palm producers was less pronounced. In our sample, the real prices for rubber fell by approximately 50% from 2012 to 2015, compared to a decline of about 20% for oil palm. For both these crops, the prices remained relatively stable until 2018 (Supplementary Figure A1). The comparatively large slump in productivity for both crops in 2015 can also be linked to the 2015 El Niño event. Consequently, the share of land under production allocated to both rubber and oil palm is included to assess their influence in shaping the livelihood strategies of the farmers.

Labor allocation is a direct measure of how households invest their time in three broad activities—own-farm activities, off-farm business activities, and on- and off-farm wage employment. Previous studies have used agricultural input costs (e.g., costs of seeds, fertilizers, and hired labor) as a proxy for engagement in self-employed activities because information about the allocation of households' labor hours to off-farm

Table 1
Labor and Land Productivity of Oil palm and Rubber.

Survey Rounds	N	Oil palm	N	Rubber
		Labor productivity ['000 IDR/hour]		
2012	126	63.090*** (65.607)	307	19.120*** (14.956)
2015	179	30.603*** (33.837)	348	8.243*** (6.683)
2018	149	47.821*** (127.988)	299	10.896*** (13.267)
		Land productivity ['000 IDR/ha/year]		
2012	126	11215.34*** (9261.276)	308	15900.39*** (11700.81)
2015	179	6969.179*** (6399.46)	343	8358.151*** (5441.898)
2018	153	7165.277*** (8162.962)	305	11225.74*** (13682.48)

Note: Mean values with standard errors are in parenthesis are provided. N – number of observations. The 1st and 99th percentile of the observations are trimmed. Monetary values are deflated to the 2012 base year. Statistical significance was estimated using the Kruskal-Wallis equality of populations rank test comparing the variables across the two crops. *** denotes significance level at the 1% level. IDR – Indonesian Rupiah.

business activities was not captured in their data (Jiao et al., 2017). However, using agricultural input cost as a proxy for time allocation does not enable differentiation between agricultural and non-agricultural self-employment. In this study, the time allocated to non-farm-related own business activities measured through the hours worked in own-business per month can be used. For off-farm wage employment, the involvement in agricultural and non-agricultural (forestry, manufacturing, services, and others) wage labor is differentiated. Also, the share of the external workforce hired for cropping activities is included. Disentangling family and hiring on-farm labor are vital, as employing external workforce frees the time of the respective household members to engage in off-farm activities (Díaz-Montenegro et al., 2018; Jansen et al., 2006).

Remittances, pensions, livestock holding, firewood, and fishing, on average, made up less than 1% of the total income of our sampled households. Unlike previous research, such activity variables are, therefore, not included in our estimation.

A set of covariates is assumed to influence a household's livelihood choices. The covariates represent various capital types that a household can possess that impact the effectiveness of productive assets. We identified the covariates based on the DHLS and data availability. In the analysis, all of the labor variables and the TACE are adjusted to adult equivalent units (AEU), following the OECD measure (Besharov and Couch, 2012). Table 2 indicates the covariates that we include in our estimation models. Supplementary Tables A3, A4, and A5 report the descriptive statistics of all covariates. Finally, following Nielsen et al. (2013), activity and key asset variables are tested for correlation in order to exclude those with statistically significant correlations (at a 5% level) of 0.6 or above (Supplementary Table A6).

4. Results

4.1. Livelihood strategies

Table 3 presents the results of the LMM estimation. Based on the activity variables, eight statistically meaningful livelihood strategies (LS) are identified. The LS names reflect the most prominent activity variables and their composition. Supplementary Table A7 further reports the mean capital assets and consumption expenditure composition of each LS. Bonferroni pairwise tests are used to statistically compare the respective livelihood profiles and their activity variables (Supplementary Table A8).

As shown in Table 3, LS1 (Rubber Farmers) is the largest group, representing nearly 28% of the sample households. The highest share of their income is derived from rubber produced solely with family labor (Supplementary Figure A2). Farmers in LS2 (Rubber Farmers & Non-Agricultural Diversifiers) also cultivate rubber alone and rely solely on family labor but diversify their income through wage labor in the non-agricultural sector and own-business activities. LS3 (Oil palm Farmers) represents households allocating the largest share of their land to oil palm cultivation. Farmers in LS4 (Mixed Farmers & Non-Agricultural Wage Laborers) divide their land almost equally between oil palm and rubber. On average, 42% of the on-farm agricultural activities are conducted with hired labor, and off-farm income diversification relies almost entirely on wage labor in the non-agricultural sector. With about 18%, it is the second-largest group. Farmers in LS5 (Diversifiers) cultivate rubber and oil palm, and rely only on the family workforce and pursue diverse off-farm activities. The degree of activity diversification in LS6 (Intense Mixed Farmers & Diversifiers) is comparable with LS5. The main difference between the two strategies is that in LS6, more than

Table 2
Activity, capital, and outcome variables.

Variables	Description
Activity Variables	
Oil palm	Area under oil palm/Total Area under Oil palm and rubber
Rubber	Area under rubber/Total Area under oil palm and rubber
Hired Labor	Hired labor/Total labor used for on-farm activities
Wage Labor Agriculture	Total months of all family members working as wage laborers in agriculture (AEU)
Wage Labor Non-Agriculture	Total months of all family members working as a wage laborer in a non-agricultural sector (AEU)
Own Business	Hours worked per month in own business (AEU)
Capital Variables	
Human Capital	
Education	Highest number of years of education (all HH members)
Dependency Ratio	Ratio of Active/Inactive HH members ($\geq$ 15 and$\leq$65)
Male Ratio	Men in working-age/Women in working age
Transmigrant	Transmigrant household (=1)
Ethnicity: Melayu	Household belongs to Melayu ethnicity (=1)
Physical Capital	
Transport	Household owns car or jeep/truck (=1)
Market distance	Distance to closest market (kilometer)
Road distance	Mean distance from plots to a road (meter)
Contract	Village level contract with oil palm company (dummy)
Financial Capital	
Formal Credit	Credit from a formal institution (=1)
Wealth Index	Index of ownership of protective assets
Transfer	Government financial transfer received last year (Dummy)
Social Capital	
Cooperative	Member in village organization with a productive purpose (=1)
Relative	Relative cultivated same crop before starting farm (=1)
Natural Capital	
Farm size	Total area of farm (ha)
Certificate	Area under systematic land title/Total farm size
Altitude	Altitude of residence (meter)
Shock	Household experienced natural shock in the last 12 months (natural disasters, crop pests, droughts, floods, late rain)
Outcome Variable	
TACE	Total annual consumption expenditure (AEU; '000 Rupiah)

Notes: TACE - total household annual consumption expenditure; AEU – Adult equivalent unit.

Table 3
Mean activity values for each of the eight livelihood strategies (LS).

Activity variables	LS1	LS2	LS3	LS4	LS5	LS6	LS7	LS8
	Rubber Farmers	Rubber Farmers & Non-Agricultural Diversifiers	Oil palm Farmers	Mixed Farmers & Non-Agricultural Wage Laborers	Diversifiers	Intense Mixed Farmers & Diversifiers	Entrepreneurs	Off-Farm Diversifiers
Oilpalm (Share)	0.00	0.00	0.64	0.45	0.31	0.43	0.43	0.00
	(0.00)	(0.00)	(0.34)	(0.41)	(0.40)	(0.43)	(0.36)	(0.00)
Rubber (Share)	1.00	1.00	0.36	0.55	0.69	0.57	0.57	0.00
	(0.00)	(0.00)	(0.34)	(0.41)	(0.40)	(0.43)	(0.36)	(0.00)
Hired Labor	0.00	0.00	0.00	0.42	0.00	0.54	0.40	0.00
	(0.00)	(0.00)	(0.00)	(0.38)	(0.00)	(0.33)	(0.40)	(0.00)
WL Agriculture	2.21	0.00	2.29	0.00	4.41	3.62	0.00	2.84
	(3.54)	(0.00)	(3.56)	(0.00)	(2.86)	(3.35)	(0.00)	(3.60)
WL Non-Agriculture	0.00	4.09	0.00	3.70	3.16	3.15	0.00	2.12
	(0.00)	(3.80)	(0.00)	(4.10)	(2.76)	(3.37)	(0.00)	(2.77)
Own Business	0.06	30.53	0.05	0.04	34.53	47.68	101.47	36.06
	(0.41)	(57.59)	(0.38)	(0.30)	(47.65)	(73.00)	(99.39)	(73.71)
HH 2012 (No./(%))	192 (33.10)	90 (15.52)	95 (16.38)	100 (17.24)	26 (4.48)	28 (4.83)	49 (8.45)	0 (0.00)
HH 2015 (No./(%))	160 (27.59)	102 (17.59)	64 (11.03)	111 (19.14)	63 (10.86)	30 (5.17)	46 (7.93)	4 (0.69)
HH 2018 (No./(%))	143 (24.66)	79 (13.62)	97 (16.72)	105 (18.10)	51 (8.79)	28 (4.83)	54 (9.31)	23 (3.97)
Pooled (No./(%))	495 (28.45)	271 (15.57)	256 (14.71)	316 (18.16)	140 (8.05)	86 (4.94)	149 (8.56)	27 (1.55)

Notes: Standard errors are in parenthesis.

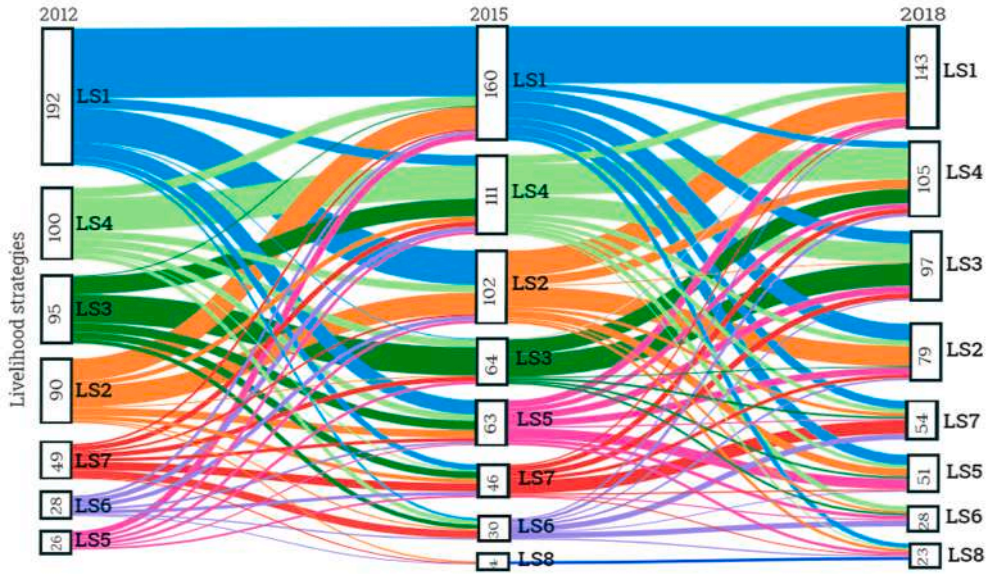


Fig. 3. Livelihood strategy transition matrix (2012-2015-2018). Note: Results of the Chi-squared test (Pearson X2 (14) = 68.61, P = 0.000).
Notes: LS1 = Rubber Farmers; LS2 = Rubber Farmers & Non-Agricultural Diversifiers; LS3 = Oil palm Farmers; LS4 = Mixed Farmers & Non-Agricultural Wage Laborers; LS5 = Diversifiers; LS6 = Intense Mixed Farmers & Diversifiers; LS7 = Entrepreneurs; LS8 = Off-Farm Diversifiers.

50% of the on-farm agricultural activities are carried out by hired labor. Farmers in LS7 (Entrepreneurs) cultivate rubber and oil palm and diversify their off-farm activities by allocating their time to self-employment activities. Similar to LS6, they employ hired labor in their plantations. LS8 (Off-Farm Diversifiers) is the smallest group and appeared for the first time in 2015. Households in this strategy seem to abandon rubber and oil palm cultivation and derive their income from agricultural and non-agricultural wage employments and own business activities.

4.2. Trajectories and transitions of livelihood strategies

Fig. 3 illustrates trajectories and changes in the composition of the livelihood strategies for each survey wave. The width of the flowing lines from each year's column portrays the observation size. LS1, Rubber farmers, remains the most prevalent livelihood strategy during the study period. However, with nearly 25% abandoning the strategy, it also faces the highest outflow. Between 2012 and 2015, corresponding to the El Niño event and the decline of rubber prices, the strategies that faced the highest decline are the agriculturally specialized ones (LS1 and L3). Most of the households that left LS1 in 2015 switched to LS2 or LS5, indicating that they kept to their agricultural production portfolio, but started allocating more labor time to off-farm activities, especially non-agricultural wage employment. Considering the entire study period, it can be observed that L5 and LS8, the most off-farm diversified portfolios, recorded the highest growth.

LS5, the diversifiers, clocked a 100% increase in the study period. About 4% of the smallholders stopped cultivating oil palm or rubber during the study period and adopted the new strategy LS8, Off-Farm Diversifiers. All livelihood strategies that involve oil palm farming also grew. The only strategies that faced higher out-movement than in-movement are LS1 and LS2, the rubber-focused ones. Overall, the findings reveal a change of livelihood strategies to more oil palm-oriented cultivation patterns and off-farm diversified livelihood

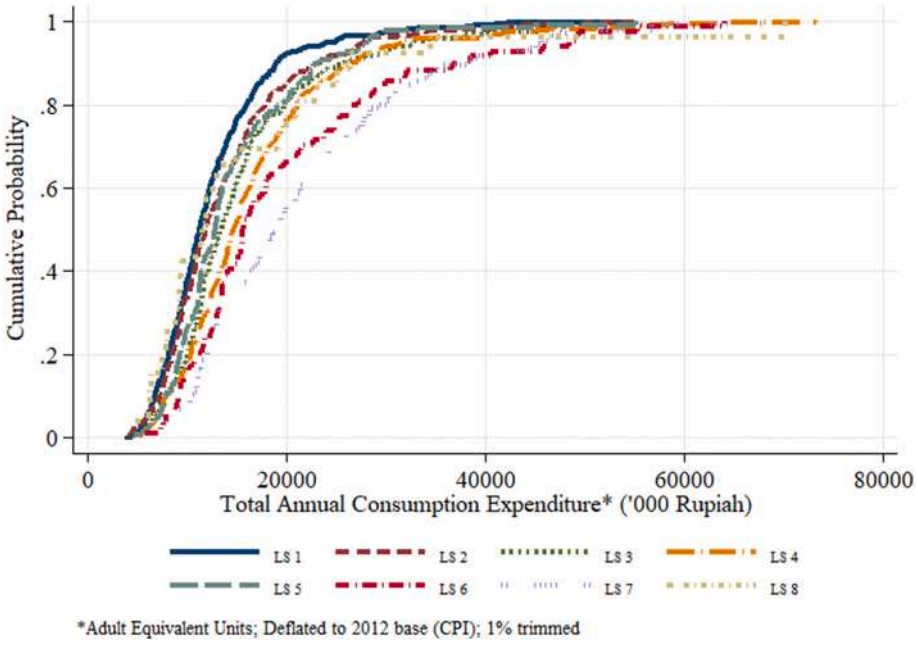


Fig. 4. Cumulative density distribution of TACE by livelihood strategies.
Notes: LS1 = Rubber Farmers; LS2 = Rubber Farmers & Non-Agricultural Diversifiers; LS3 = Oil palm Farmers; LS4 = Mixed Farmers & Non-Agricultural Wage Laborers; LS5 = Diversifiers; LS6 = Intense Mixed Farmers & Diversifiers; LS7 = Entrepreneurs; LS8 = Off-farm Diversifiers.

portfolios. (Please refer to Supplementary Figure A3 for the exact number of movements in and out of livelihood strategies and Table A9 for detailed statistical test results).

4.3. Livelihood outcomes of different profiles

The cumulative density curves of TACE over the whole study period follow the pattern depicted in Fig. 4. Across all periods, similar patterns in curve distribution is observed, and the mean TACE does not change significantly in most livelihood strategies (Supplementary Table A10). Therefore, a figure combining the three study waves is presented. LS1 and LS2, the strategies involving only rubber cultivation, are the least remunerative, followed by LS5—the Diversifiers, and the most oil-palm-dominated livelihood strategy LS3 the Oil palm Farmers. The strategies that employ hired labor on their plots, LS6 and LS7, recorded the highest consumption expenditure. The cumulative density curve of TACE of the latter lies below the curves of the other strategies for nearly every possible expenditure level.

Conversely, LS1 (rubber-only farmers) is the stochastically inferior strategy. The results are further confirmed by Bonferroni pairwise TACE tests between the eight strategies (Supplementary Table A11). The tests confirm that the strategies dominated by oil palm cultivation and on- and off-farm wage employment yield statistically better livelihood outcomes than the rubber-based strategies. Moreover, all livelihood strategies, except LS6, perform statistically worse than LS7 in terms of TACE. Fifty percent of the households in LS7 are in the top consumption quintiles, with less than 10% of them belong to the lowest quintile (Supplementary Figure A4). Accordingly, livelihood strategies are ranked in the following order from the highest to the lowest outcome: LS7, LS6, LS4, LS3, LS5, LS2, and LS1. For off-farm diversifiers (LS8), an exact rank order can not be assigned, as it appeared in 2015 for the first time.

4.4. Determinants of livelihood strategy choice and transitions

4.4.1. Determinants of household livelihood strategies

Table 4 presents the results of the MLM regression. The coefficients reported in Table 4 indicate a relative influence compared to pursuing a strategy of agricultural intensification based on rubber and family labor. The least remunerative livelihood strategy, LS1, is the base category.

Higher education levels are associated with livelihood strategies involving wage employment and own-business activities. Predictably, the values for being a transmigrant household are significant and positively associated with almost all livelihood strategies involving oil palm cultivation. Residing closer to the markets seems to encourage oil palm specialization or stimulate the pursuit of entrepreneurial livelihood strategies, compared to LS1. This finding corroborates that of Santika et al. (2019), who report that villages with better market access benefit more from oil palm expansion than their counterparts in remote areas. The positive association of ownership of a transport vehicle with livelihood strategies, including off-farm activity diversification, indicates a relationship with market access. Owning a car is particularly crucial in Jambi, as farmers use cars to transport fresh oil palm fruit bunches that should be treated within 24 h of harvest. Larger farm size is positively associated with livelihood strategies that include oil palm cultivation, instead of Rubber alone (LS1). The geographical location in terms of altitude plays a significant role in influencing livelihood choice. Households residing at lower altitudes are much more likely to adopt livelihood strategies with oil palm cultivation, which is plausible because oil palm grows better at lower altitudes. As a robustness check, we rerun the MLM regression for livelihood strategy choices, this time only from 2015, with lagged livelihood strategies included. The results are reported in Supplementary Table A12. Generally, the results are consistent with those reported in Table 4.

4.4.2. Determinants of household upward and downward livelihood movements

Our OLM estimation aims at further examining the specific capital variables that influence households' livelihood trajectories to more (UM) or less (DM) remunerative livelihood strategies or to stay in the same strategy (NM) over the study periods of 2012–2015 and 2015–2018. Comparing the mean differences of TACE between households in UM, NM, or DM trajectories reveals that the households that are DM report, on average, 0.75 M IDR less consumption expenditure compared to the previous year, those that are NM increase their consumption expenditure by 0.11 M IDR on average, and those that are UM

Table 4
Multinomial logit regression results for determinants of livelihood strategies (LS).

	LS2 Rubber Farmers & Non-Agricultural Diversifiers		LS3 Oil palm Farmers		LS4 Mixed Farmers & Non-Agricultural Wage Laborers		LS5 Diversifiers		LS6 Intense Mixed Farmers & Diversifiers		LS7 Entrepreneurs		LS8 Off-Farm Diversifiers	
	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.
Education	0.129***	0.025	0.001	0.025	0.094***	0.024	0.155***	0.033	0.109***	0.038	−0.011	0.031	0.097	0.073
Dependency Ratio	0.236	0.182	0.286	0.190	0.199	0.177	−0.004	0.244	0.008	0.293	0.020	0.238	−0.511	0.563
Male ratio	−0.131	0.110	0.016	0.115	−0.387***	0.115	−0.061	0.135	−0.480**	0.192	−0.266*	0.152	−0.471	0.357
Transmigrant	−0.149	0.319	0.882***	0.278	0.881***	0.265	0.375	0.351	0.983**	0.389	0.490	0.343	−14.359	1031.976
Ethnicity: Melayu	0.435**	0.177	0.022	0.194	0.389**	0.183	0.325	0.231	0.263	0.294	0.061	0.239	0.177	0.497
Transport	0.789**	0.345	−0.213	0.399	0.699**	0.323	1.244***	0.379	1.415***	0.386	2.081***	0.329	2.912***	0.706
Distance road	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Distance market	0.015	0.012	−0.041***	0.015	−0.016	0.013	−0.020	0.018	−0.018	0.022	−0.044**	0.020	−0.080	0.048
Contract	0.028*	0.015	0.093***	0.013	0.073***	0.013	0.067***	0.016	0.063***	0.019	0.059***	0.016	0.109***	0.033
Formal credit	0.633***	0.187	0.571***	0.192	0.425**	0.183	0.867***	0.227	1.074***	0.266	0.726***	0.228	−0.510	0.727
Wealth index	0.276**	0.108	0.155	0.116	0.397***	0.107	0.342**	0.136	0.484***	0.169	0.432***	0.142	−0.187	0.337
Transfer	0.173	0.183	−0.003	0.202	0.233	0.186	0.593***	0.221	0.388	0.301	−0.121	0.281	1.313***	0.465
Cooperative	−0.447*	0.231	0.423**	0.205	0.120	0.200	−0.167	0.266	0.149	0.301	0.144	0.262	0.368	0.579
Crop relative	−0.118	0.165	−0.058	0.180	0.033	0.165	0.048	0.208	0.129	0.261	0.264	0.218	0.051	0.473
Farmsize	−0.035	0.030	0.125***	0.025	0.141***	0.023	−0.147***	0.046	0.131***	0.026	0.140***	0.023	−1.316***	0.262
Share certicate	−0.395	0.257	−0.011	0.263	0.208	0.243	−0.208	0.304	−0.003	0.381	0.326	0.313	−0.524	0.708
Altitude (m)	0.000	0.003	−0.019***	0.004	−0.014***	0.003	−0.012***	0.004	−0.013***	0.005	−0.019***	0.004	−0.023**	0.010
Constant	−2.686***	0.421	−1.002**	0.425	−2.372***	0.415	−2.877***	0.572	−4.091***	0.700	−1.974***	0.532	−0.036	1.191

Notes: Observations = 1740; Log Likelihood = −2829.077; Pseudo R^2 = 0.128; LR χ^2 = 833.776; Prob = 0.000. *, **, *** denote significance level at the 10%, 5%, and 1% level, respectively.

Table 5
Ordered logit model estimation of LS movements, including lagged LS.

	All		Downward Moving		Not moving		Upward Moving	
	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.	Coef.	St. Err.
LS2-1	−2.615***	0.203	0.359***	0.025	0.058***	0.013	−0.416***	0.027
LS3-1	0.059	0.204	−0.008	0.028	−0.001	0.004	0.009	0.032
LS4-1	−2.100***	0.196	0.288***	0.027	0.046***	0.009	−0.334***	0.026
LS5-1	−4.315***	0.319	0.592***	0.033	0.095***	0.024	−0.687***	0.047
LS6-1	0.076	0.328	−0.010	0.045	−0.002	0.007	0.012	0.052
LS7-1	−3.308***	0.279	0.454***	0.033	0.073***	0.017	−0.527***	0.040
Education	0.053***	0.018	−0.007***	0.002	−0.001**	0.000	0.009***	0.003
Dependency ratio	−0.011	0.138	0.001	0.019	0.000	0.003	−0.002	0.022
Male ratio	−0.150*	0.086	0.021*	0.012	0.003*	0.002	−0.024*	0.014
Transmigrant	0.069	0.199	−0.009	0.027	−0.002	0.004	0.011	0.032
Ethnicity: Melayu	0.265*	0.142	−0.036*	0.019	−0.006*	0.003	0.042*	0.023
Transport	0.829***	0.215	−0.114***	0.029	−0.018***	0.006	0.132***	0.034
Road distance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Market distance	0.013	0.012	−0.002	0.002	0.000	0.000	0.002	0.002
Contract	0.009	0.009	−0.001	0.001	0.000	0.000	0.001	0.001
Formal credit	0.342**	0.133	−0.047**	0.018	−0.008**	0.003	0.054***	0.021
Wealth index	0.143	0.088	−0.020	0.012	−0.003	0.002	0.023	0.014
Transfer	0.144	0.139	−0.020	0.019	−0.003	0.003	0.023	0.022
Cooperative	−0.252*	0.148	0.035*	0.020	0.006	0.003	−0.040*	0.024
Relative	0.073	0.128	−0.010	0.018	−0.002	0.003	0.012	0.020
Farmsize	−0.024**	0.012	0.003**	0.002	0.001*	0.000	−0.004**	0.002
Certificate	−0.203	0.181	0.028	0.025	0.004	0.004	−0.032	0.029
Altitude (m)	−0.001	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Natural shock	0.086	0.125	−0.012	0.017	−0.002	0.003	0.014	0.020

Notes: Observations = 1133; Log Likelihood = −966.834; Pseudo R^2 = 0.213; LR χ^2 = 524.271; Prob = 0.000. *, **, *** denote significance level at the 10%, 5%, and 1% level, respectively; LSX -1 with X = 2, …,7 are the lagged livelihood;. LS1 = Rubber Farmers; LS2 = Rubber Farmers & Non-Agricultural Diversifiers; LS3 = Oil Palm Farmers; LS4 = Mixed Farmers & Non-Agricultural Wage Laborers; LS5 = Diversifiers; LS6 = Intense Mixed Farmers & Diversifiers; LS7 = Entrepreneurs; LS8 = Off-Farm Diversifiers.

increase their consumption by 0.67 M IDR, on average. Households belonging to LS8 are excluded since no clear rank assignment is possible.

The results of the OLM analysis presented in Table 5 indicate that except LS6, all livelihood strategies that include some form of off-farm income diversification in the previous year are negatively associated with UM, compared to LS1. For LS3 and LS6, there is no significant difference in movement patterns against LS1. Having a higher education level, belonging to the Melayu ethnicity, owning a car, and having access to formal credit are positively associated with upward mobility and seem to protect households from dropping to lower remunerative strategies. Counterintuitively, the results indicate a negative relationship between cooperative membership and farm size with upward mobility. A robustness check with a subgroup analysis in which households that cultivated only rubber at the beginning of the study period in 2012 supports this finding (Supplementary Table A13). The share of land on which a household holds a certificate is also negatively associated with upward mobility. This is not surprising because cooperatives and certified large farm areas may encourage farmers to allocate household labor to their farms. Finally, the positive relationship between the receipt of transfer income and upward livelihood mobility could indicate the effectiveness of the respective programs, particularly during price and climate shocks.

We would like to reiterate that caution is required when establishing causal relationships. Associations of education, the wealth index, or transport, for example, with livelihood strategy choice and mobility, can be both directional as they could be the result instead of the cause of livelihood strategy choice and the models do not allow controlling for that.

5. Discussions and conclusions

Relying on a three-wave survey conducted between 2012 and 2018, this study has systematically analyzed the livelihood dynamics of oil palm and rubber farm households in Jambi province in Indonesia. Using the DHLS as our conceptual framework, we have examined livelihood dynamics by using activity choice variables and estimating an LMM. We have also used regression models to understand the relationship between capital asset variables and livelihood strategies and assess the underlying factors that drive farmers' livelihood trajectories.

Our findings show that the sample household utilize eight significantly different livelihood strategies, which are characterized by various intensities and scales of on- and off-farm agricultural activities. A detailed consideration of differences in on-farm cultivation compositions contributes significantly to understanding housheold livelihoods. We find that smallholders in the study region face certain opposing conditions and trade-offs between rubber and oil palm cultivation. For example, while rubber has a higher return to land, oil palm generally benefits from lower labor requirements. Oil palm-oriented smallholders are found to have a more off-farm diversified activity portfolio than their rubber-oriented counterparts (Chrisendo et al., 2020; Kubitza et al., 2019; Mehraban et al., 2021).

Further, we find that the livelihood strategies of plantation farm households in our sample are highly dynamic. Only one-third of the examined households persisted with the same livelihood strategy. At the same time, transitions occur to both higher and lower remunerative strategies, illustrating that rural households react to factors that constrain or enable their actions (Ellis, 2000; Scoones, 2015; Winters et al., 2001). Our findings also show that changes in livelihoods are locally and temporally mediated. Probably in response to the El Niño event and the global decline in the price of rubber and oil palm, specialized agricultural strategies face the highest outflow, and those that include more off-farm activities recorded the highest inflow in the short-term (2012–2015). When considering a longer timeframe (2012–2018), the composition of livelihood strategies is marked by a substantial decline in rubber-dominated strategies in favor of those that include oil palm cultivation and off-farm activities. This indicates that plantation crop farmers seem to apply short-term coping strategies. However, given their farming characteristics, risk-mitigation and resilience enhancing strategies can be adopted in the long term by adjusting their crop portfolio. Hence, the analysis of livelihood dynamics in those farm households requires a careful assessment of the individual contexts across various timeframes.

Interestingly, we discover that a new livelihood strategy emerged during the El Niño event in 2015. Specifically, some households abandoned rubber and oil palm cultivation completely, to derive their livelihood from agricultural and non-agricultural wage employment. Emergence of a new strategy has not been reported in previous studies conducted in the traditional peasant context (Jiao et al., 2017; Nielsen et al., 2013; van den Berg, 2010; Walelign et al., 2015; Zhang et al., 2019). Such households' emergence might be worrying in our study context because they belong to the autochthonous ethnic groups, which are historically and institutionally disadvantaged (Murray Li, 2018). Notably, those households own smaller farm size and receive more transfer money. They also reside at lower altitudes where oil palm cultivation continues to expand and in villages where contracts with oil palm companies are more prevalent. Unfortunately, our dataset does not indicate whether these households sold their land due to debts and were thus forced to become laborers, or had identified off-farm activities to be more remunerative than rubber and oil palm cultivation. Concurrently, an increasing number of households are allocated to livelihood strategies in which on-farm activities rely on the hired workforce. Although the average area under cultivation in these clusters is the largest, the share of crop income is relatively low, compared to the off-farm activities. This pinpoints to management systems that might be characterized as "shareholder" schemes— farmers turn their holding into a form of financial capital by contributing little or no family labor time, a development already observed in Malaysia (Cramb and McCarthy, 2018).

Our results further indicate a significant association of livelihood strategy choices with livelihood outcomes. Livelihood strategies involving own-business activities, oil palm cultivation, and off-farm wage employment are the stochastically lucrative strategies, while those that rely on family labor and rubber cultivation are the least remunerative. This is also in line with the general literature on rural households' livelihoods that found a positive relationship between off-farm activity diversification and better livelihood outcomes (Alemayehu et al., 2018; Ansoms and McKay, 2010; Brown et al., 2006; Díaz-Montenegro et al., 2018).

Moreover, our analysis provides strong evidence that capital endowments constrain or enable livelihood strategy choices. Several factors determine households' transition to more remunerative livelihood strategies and create new opportunities beyond farming, including higher educational attainment, access to formal credit, owning transport vehicles, higher wealth index, conducive agroecological environments, and better market and rural infrastructure. These factors become particularly prevalent in more remunerative oil palm-specialized and off-farm-based livelihood strategies. The effects of political instruments like the transmigration program are evident in the composition of livelihood strategies until today. Transmigrants are significantly more often found in oil-palm-based livelihood portfolios. Yet, the effects can be seen only in the initial structure of livelihood profiles, rather than in their mobility. Transmigrants appear to have an initial advantage, but other factors seem to be more determinantal in improving livelihoods.

Finally, our results also indicate that larger farm size is negatively associated with upward livelihood mobility. A similar relationship between farm-land area and livelihood mobility was found by Zhang et al. (2019). There could be two principal explanations for this counter-intuitive discovery. First, the concentration of resources on on-farm agricultural activities might bias a household's assessment of the utility it could derive from off-farm labor allocation. Second, the larger the farm size, the more family labor might be taken up by on-farm activities, and the more restricted the households are in off-farm labor diversification. This seems to apply above all to the labor-intensive rubber plantations, as the subgroup analysis of rubber producers alone further reveals a negative relationship between upward mobility and the share of titled land and cooperative membership.

In conclusion, we state two important limitations of our study that should help future research. First, while measuring livelihood outcomes with expenditures rather than using income has some advantages, it cannot fully consider people's actual motives. Livelihood choices could also be adopted for reasons other than purely economic goals. Thus, it is crucial to explore in future research what farm households had hoped to do and why and whether they could achieve their goals with the particular strategies they pursued. Second, to estimate the determinants of livelihood strategy choice, the difficulty lies in capturing causality directions. Though certain clear associations can be detected, our estimation strategies do not allow for causal inference and address issues that could arise from reverse causality between TACE and capital endowments and livelihood strategies. This should be considered when extrapolating our findings.

Credit author statement

Marlene Kühling: Conceptualization, Methodology, Formal analysis, Writing – original draft preparation, Writing- Reviewing and Editing, **Zulkifli Alamsyah:** Data curation, Writing – original draft preparation, Writing- Reviewing and Editing, **Kibrom T. Sibhatu:** Conceptualization, Data curation, Methodology, Formal analysis, Writing – original draft preparation, Writing- Reviewing and Editing, Project administration.

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2022.114864.

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