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## Oil Palm Boom and Land–Use Dynamics in Indonesia

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The Role of Policies and Socioeconomic Factors

Marcel Gatto, Meike Wollni and Matin Qaim

EFForTS discussion paper series

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Georg-August-Universität Göttingen

Johann-Friedrich-Blumenbach Institut für Zoologie und Anthropologie, Fakultät für Biologie und Psychologie

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**Keywords:** Oil palm, land-use change, deforestation, socioeconomic factors, Indonesia, government policy

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# Oil Palm Boom and Land-Use Dynamics in Indonesia: The Role of Policies and Socioeconomic Factors

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## **Abstract**

We investigate land-use dynamics in Jambi, Sumatra, one of the hotspots of Indonesia's recent oil palm boom. Data from a structured village survey are used to analyze the role of socioeconomic and policy factors. Oil palm is partly grown on large plantations, but smallholders are also involved significantly. We find that, in spite of significant oil palm expansion, rubber remains the dominant crop. Most of the oil palm growth takes place on previous fallow and rubber land. Oil palm has not been a major driver of deforestation. Much of the forest in Jambi was cleared more than 20 years ago, and rubber was an established cash crop long before the oil palm boom started. However, oil palm growth occurs in locations with ongoing logging activities, so indirect effects on deforestation are likely. The government's transmigration program of the 1980s and 1990s was instrumental for the start and spread of oil palm in Jambi. Some autochthonous villages have adopted oil palm, but adoption started later compared to migrants from Java, and it happens at a slower pace. While the transmigration program benefited many of the participating families, it has contributed to the risk of unequal socioeconomic developments in Jambi.

**Keywords:** Oil palm, land-use change, deforestation, socioeconomic factors, Indonesia, government policy

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## 1 Introduction

In the past four decades tropical lowland regions in many parts of the world have experienced major land-use changes. The forest area declined significantly, while the area used for agricultural production increased. In Southeast Asia in particular, the land under oil palm was expanded considerably. In Indonesia, which is now the largest palm oil producer worldwide, the oil palm area increased from 0.7 million ha in 1990 to 6.5 million ha in 2012 (FAO, 2014). Globally, the oil palm expansion is driven by rising demand for vegetable oil used for human consumption, biofuel, and as an ingredient in the cosmetics industry (McCarthy, 2010). While oil palm has caused an economic boom in the producing regions, it has also attracted criticism on environmental and social grounds. Oil palm expansion is often held responsible for deforestation, biodiversity loss, increased greenhouse gas emissions, and conflicts over land rights between oil palm companies and local communities (Curran et al., 2004; Fitzherbert et al., 2008; Koh and Wilcove, 2008; Rist et al., 2010; Wilcove and Koh, 2010; Feintrenie et al. 2010a; Koh et al., 2011; Wicke et al., 2011; Carlson et al., 2012; Margono et al., 2012; Obidzinski et al., 2013; Dewi et al., 2013; Wheeler et al., 2013). However, oil palm is not only grown on large-scale plantations. Local smallholder farmers themselves are increasingly involved as well. In Indonesia, the active involvement of smallholder farmers in oil palm cultivation is part of an official government policy (Larson, 1997).

What are the drivers of the oil palm expansion and related other land-use changes at the local level? Why are the trends more pronounced in certain locations than in others? Addressing such questions could help adjust policies aimed at avoiding undesirable outcomes, but related research is scant (Nesheim et al., 2014). Several studies have analyzed land-use changes in oil palm hotspots using satellite images (Hansen et al., 2009; Koh et al., 2011; Carlson et al., 2012; Margono et al., 2012). However, while satellite images for different points in time provide reliable information about the types of land-use changes, they cannot explain why these changes occurred. In other words, the socioeconomic and policy drivers remain unclear. Regional policies in particular are expected to play an important role for land-use changes. In Indonesia, for instance, the government has implemented the so-called transmigration program since the 1980s in which people from Java were relocated to Sumatra and other less densely populated islands and supported in oil palm cultivation and other economic activities (Larson, 1996; Fearnside, 1997).

In this paper, we address this knowledge gap and analyze the types and determinants of land-use changes in Indonesia. The concrete study region is the province of Jambi on the island of Sumatra, where the expansion of oil palm has been very rapid over the last 30 years. Other important land-use systems in Jambi include rubber and forest. We use data from a survey of randomly selected villages to explain land use at a certain point in time through land use in previous time periods and a set of socioeconomic and policy factors. We account for likely correlation between different land-use equations by using a seemingly unrelated regression (SUR) approach.

The remainder of this paper is structured as follows. We start with providing some background of Jambi and the Indonesian government's transmigration program. After that,

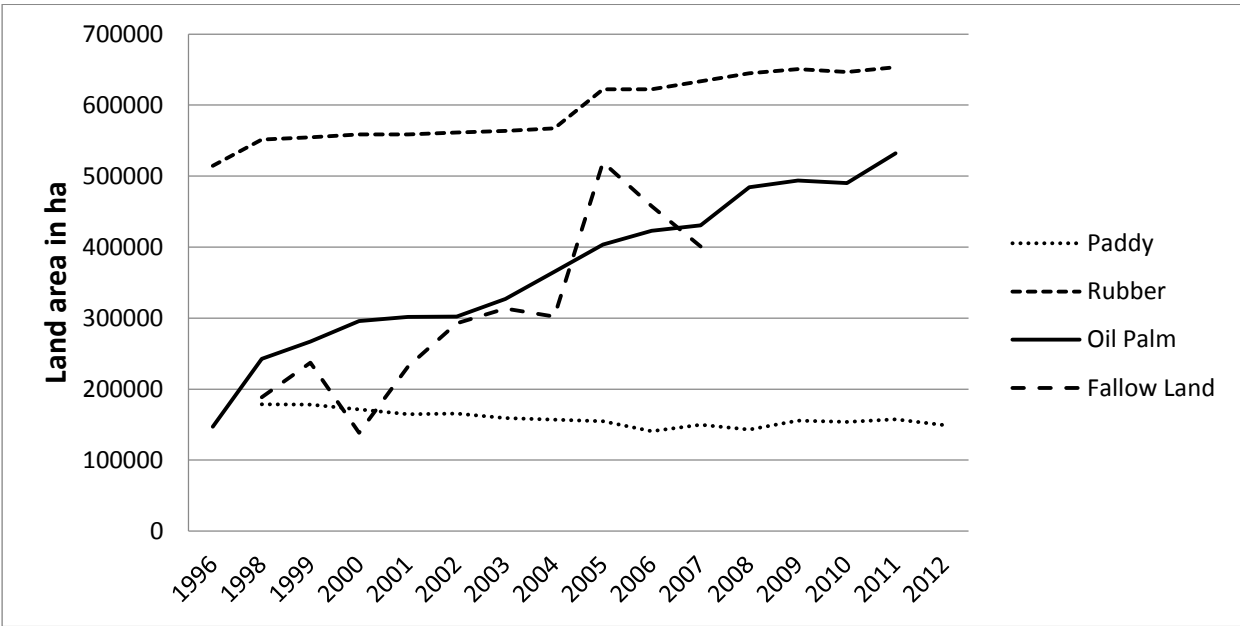
the village survey and the statistical approach are described, before the estimation results are presented and discussed. The last section draws conclusions.

## 2 Background

### 2.1 Land-use in Jambi Province

Located in central Sumatra, the province of Jambi has increasingly become a hotspot of oil palm cultivation during recent decades. The area under oil palm in Jambi almost quadrupled from 150,000 ha in 1996 to 550,000 ha in 2011 (Figure 1). During the same period, the area under rubber increased by only 27%, from 510,000 to 650,000 ha. Despite this rapid expansion of oil palm, rubber remains the dominant crop in Jambi. We also observe a considerable increase in fallow land. Fallow land is locally often referred to as ‘sleeping land’, because households and communities keep this land with the intention of some future use. Fallow land is either over-logged forest or unproductive plantation land. Paddy cultivation is only observed in some pockets of Jambi with a declining trend. Forest land is not shown in Figure 1, because the official statistics have various definitions and subcategories that do not provide a consistent picture. Regardless of the exact numbers, it is clear that the forest area in Jambi declined significantly over the last decades when the land for agricultural use expanded (Margono et al., 2012; Villamor et al., 2014). While the mountainous regions in south-western Jambi still hold large natural forests, the remaining forest cover in the lowlands is small and nowadays largely confined to two national parks and a protected area. In addition, villages in the lowlands have shrinking patches of secondary forest at various levels of degradation.

**Figure 1: Land-use change in Jambi Province between 1996 and 2012**



Source: BPS (2012).



## 2.2 Transmigration program

We expect that the government's transmigration program played an important role in shaping land-use changes in Jambi. As part of this program, families from Java's densely populated areas were relocated to the so-called 'Outer Islands' Sumatra, Kalimantan, and Papua. Apart from a spatial-political rationale of Suharto's New Order Regime in achieving unity across the various ethnicities (Elmhirst, 1999), the transmigration program facilitated the government's efforts to spur economic development in rural areas. At the beginning of the program, in the early-1980s, transmigrants were allocated rice fields in their new homes mainly for subsistence farming. Later, transmigrants also received government support to cultivate rubber as a cash crop. From the late-1980s, the Indonesian government changed the focus and started to develop the oil palm sector. This took place when the first 'oil palm transmigrants' arrived in Jambi through fully government-sponsored schemes. These oil palm transmigrants were placed into newly established settlements next to large government-managed oil palm estates. Participants were allocated a piece of oil palm land (usually 2-3 ha per family) at the periphery – the *plasma* – of the estate. Likewise, agricultural inputs and extension services were provided by the government through a loan system (Fearnside, 1997). After loan repayment, transmigrant families could obtain a formal title for their piece of land (Murdiyarso et al., 2002). At the core of the plantation area – the *inti* – an oil palm mill was established, allowing the processing of the fresh fruit bunches within a short period after harvest. Such inti-plasma systems are often referred to as nucleus estate and smallholder (NES) schemes. Similar NES schemes for oil palm were soon also established with the involvement of private companies under strict contractual conditions. In exchange for land concessions and access to subsidized capital provided by the state, private companies had to guarantee the involvement of smallholder transmigrants, and sometimes also autochthonous communities. However, autochthonous communities started to be involved in oil palm schemes significantly later. For many of them, rubber is still the most important crop (Hauser-Schäublin and Steinebach, 2014).

The NES schemes that were established in the 1980s and 1990s largely remained in place until now, although the overall conditions have changed. Due to the large costs and the fall of the Suharto Regime, the government gradually backed out. Today, the oil palm sector in Jambi is dominated by private companies and smallholder farmers. The post-Suharto government implemented a decentralization process, shifting decision making power to local authorities. Companies that wish to establish new oil palm plantations now have to negotiate directly with local communities over access to land (Larson, 1996; McCarthy, 2010). Such contracts are often similar to NES schemes, because communities that provide part of their land for plantation establishment may request loans and other support from companies for own oil palm cultivation. However, most autochthonous communities do not hold formally recognized titles for their land (Barkmann et al., 2010). Hence, conflicts over land rights and contractual details are commonplace. In this respect, transmigrants who received a formally recognized land title after loan repayment have a clear advantage over the autochthonous population. Autochthonous people can also apply for formal land titles, but the administrative procedure is costly and time-consuming (Thorburn, 2004).

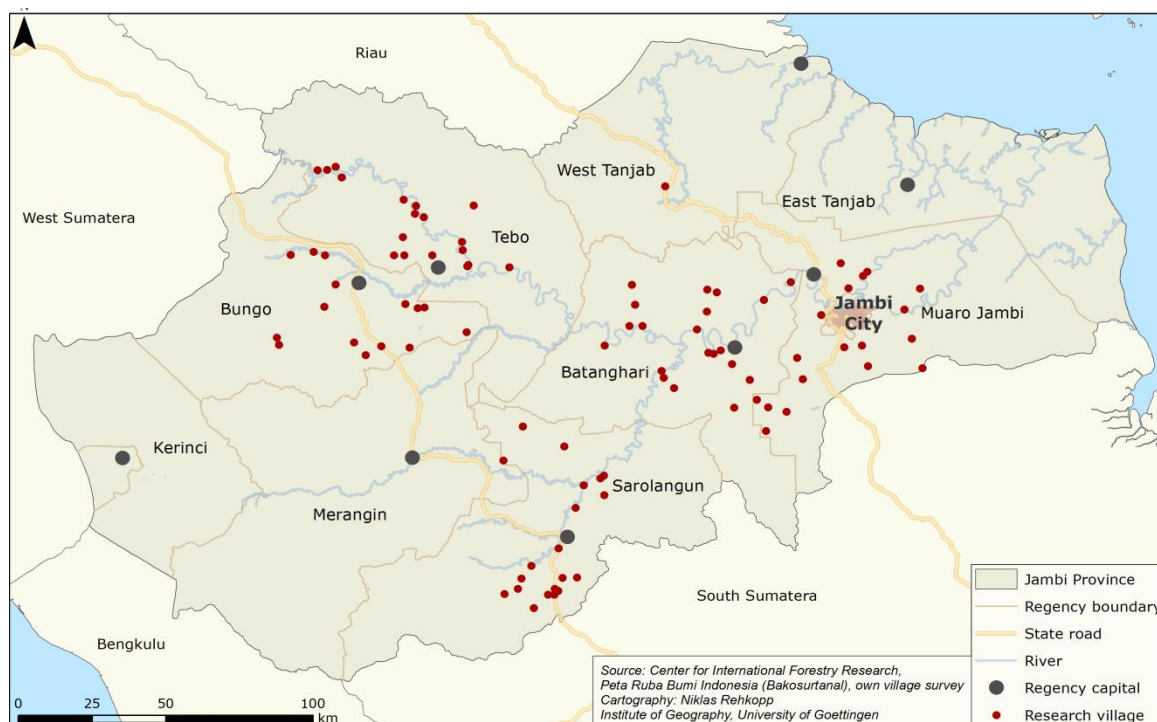
Oil palm development in Jambi was initiated by the government transmigration program and later continued through contracts between private companies and smallholder farmers. In addition to these contracts, an increasing number of smallholders have recently started to cultivate oil palm independently. In some cases, these are farmers whose initial contracts expired. Other independent oil palm growers never had a contract, but could access the required capital and knowledge through other channels. In our analysis, we are particularly interested to analyze recent land-use changes and possible differences between migrants and autochthonous people.

### 3 Materials and Methods

#### 3.1 Village survey

We carried out a village survey in the lowland regions of Jambi Province that have been most affected by land-use changes over the last few decades. The five major lowland districts in Jambi are Muaro Jambi, Batang Hari, Sarolangun, Tebo, and Bungo. In each of these five districts, five sub-districts were randomly selected. For all these 25 sub-districts we compiled complete lists of villages using data from the Indonesian national village census (PODES). From these lists, we randomly sampled four villages in each sub-district, resulting in a total of 100 villages. Due to logistical problems, two of these villages could not be reached; the other 98 villages were visited for detailed data collection through interviews with the village leadership. The locations of these 98 sample villages are shown in the map in Figure 2.

**Figure 2: Map of Jambi Province with sample villages**



Data collection took place from September to December 2012. A structured questionnaire was designed for this purpose. Interviews were carried out in the local language by enumerators from Jambi University. These enumerators were trained intensively and supervised in the field by the researchers. Before visiting the villages, we made appointments with the village head explaining the purpose of the study and asking for cooperation. All village heads agreed to participate in the interviews. In addition, other village officials, such as the village secretary, the village district leader, and elderly villagers, were invited to participate in the interviews to increase information accuracy, especially for data related to past. These group interviews were held in the house of the village head or his/her office and lasted for three to four hours in each village. In most villages, statistical data about the population, land use, land titles, and related details are kept as hard copy or digital files, which facilitated the process of filling in the questionnaire considerably.

The data collected include a breakdown of the total village area by land-use systems. The village area comprises the land that village households use individually as well as communal areas and land leased out to companies. The three major land-use systems in Jambi's lowlands are rubber, oil palm, and forest. Furthermore, villages have varying areas of fallow land. For rubber in particular, different production intensities are observed, ranging from extensive agroforestry systems (sometimes referred to as 'jungle rubber') to intensively cultivated rubber plantations. As boundaries are fluid, we do not differentiate further between production intensities. We recorded the land-use data for 2012, as well as for 2002 and 1992, thus covering changes over a period of 20 years. For the same points in time we also captured village socioeconomic data, such as population structure, infrastructure conditions, and types of institutions. Furthermore, we asked the group of respondents for estimates on the share of village households owning certain assets and using particular technologies. These data are used in the statistical analysis as explained below.

### 3.2 Modeling land-use dynamics

We want to understand how land use in the lowlands of Jambi changed during the last 20 years and what factors contributed to these changes. To model land-use dynamics, we specified the following system of equations:

$$OP_{vt} = \alpha_1 + \beta_1 2012_v + \gamma_1' LU_{vt-10} + \delta_1 L_{vt} + \rho_1' S_{vt-10} + \varepsilon_{1v} + \mu_{1vt}, \quad (1)$$

$$RU_{vt} = \alpha_2 + \beta_2 2012_v + \gamma_2' LU_{vt-10} + \delta_2 L_{vt} + \rho_2' S_{vt-10} + \varepsilon_{2v} + \mu_{2vt} \quad (2)$$

$$FO_{vt} = \alpha_3 + \beta_3 2012_v + \gamma_3' LU_{vt-10} + \delta_3 L_{vt} + \rho_3' S_{vt-10} + \varepsilon_{3v} + \mu_{3vt} \quad (3)$$

where  $OP_{vt}$  is the oil palm area,  $RU_{vt}$  the rubber area, and  $FO_{vt}$  the forest area in village  $v$  at time  $t$ , all expressed in ha.  $LU_{vt-10}$  is a vector of land-use systems in the same village 10 years earlier.  $L_{vt}$  is the total area in village  $v$  at time  $t$ , which we include on the right-hand side to control for villages of different land size.  $S_{vt-10}$  is a vector of village-level

socioeconomic variables; to avoid endogeneity we use lagged values for time period  $t - 10$ .  $\varepsilon$  captures the time-invariant unobserved factors in each equation that may affect land-use. To control for such unobserved factors, we include village fixed effects.  $\mu_{vt}$  in each equation is the idiosyncratic error term that changes over time and across villages. Time  $t$  includes the observations for 2002 and 2012. To control for a time trend, we include a year dummy for 2012. Accordingly,  $t - 10$  includes the observations for 1992 and 2002.

The vector of lagged land-use systems ( $LU_{vt-10}$ ) includes oil palm, rubber, forest, and fallow land, all expressed in ha. The estimated coefficients for these land-use variables ( $\gamma'$ ) help us to identify land-use trends. For instance, a positive and significant coefficient for the lagged forest area in the oil palm equation would suggest that the oil palm expansion contributes directly to deforestation. A positive and significant coefficient for the lagged oil palm area in the oil palm equation would suggest a path-dependency towards specialization at the village level.

In terms of socioeconomic variables as part of vector  $S_{vt-10}$ , we build on the land-use change and deforestation literature (e.g., Lambin et al., 2003; Mitsuda and Ito, 2011). We use village characteristics such as population density, distance to road, share of households with formal land titles, and share of households using certain types of technologies such as mineral fertilizers. Furthermore, wealth may play an important role for land-use change decisions, such as switching towards oil palm (Feintrenie et al., 2010b). We constructed a wealth index at the village level, building on data on the percentage of households owning assets such as cars, television, fridges, and mobile phones. The wealth index was calculated using principle component analysis, as described in Sahn and Stifel (2003). It is normalized in the 0-1 range, with higher values representing higher village-level wealth.

In this model, equations (1) to (3) are not independent. When total land is limited, land-use change decisions from one system to another are made simultaneously. We therefore estimate this system of equations with the seemingly unrelated regression (SUR) approach. The SUR model produces consistent estimates also when there is error term correlation (Cameron and Trivedi, 2009, p.162). The Breusch-Pagan test is used to test for error term correlation. We estimate the SUR model with a feasible generalized least squares estimator, which requires the equations not to have identical sets of regressors (Cameron and Trivedi, 2009, p.163). We therefore exclude individual variables from  $LU_{vt-10}$  in equations (2) and (3).

### *3.3 Modeling the role of migration and ethnicity*

In addition to other socioeconomic factors, we are also interested to better understand the role of migration. As discussed above, transmigrants from Java were the first smallholders to start oil palm cultivation in Jambi. We use a transmigrant dummy for villages that were initiated as part of the government's transmigration program. Moreover, we use a dummy for villages that were started by spontaneous migrants. Spontaneous migrants may also be from Java, or from other parts of Sumatra, who came to Jambi without being part of the transmigration program. The reference group consists of villages with no migrational background. In more

detail, these were founded by Jambi's autochthonous people, mainly the Melayu Jambi. Overall, the dummies refer to the migrational background<sup>2</sup> of the majority of inhabitants in each village.

Nowadays, most villages in Jambi comprise a mixture of ethnicities due to marriages and additional migration. To capture the possible role of ethnical composition for land-use changes, we use a variable measuring the population share of the dominant ethnicity in a particular village.

The two migration dummies (spontaneous migration and transmigration) are closely correlated with the village fixed effects, leading to collinearity problems in estimation. Hence, we first estimate a model with village fixed effects but without migration dummies. In a second specification, we include the migration dummies and exclude the village fixed effects. In additional specifications, we test whether spontaneous migration and transmigration also affect the coefficients of the other variables by interacting with  $LU_{vt-10}$  and  $S_{vt-10}$ . For instance, it might be possible that the availability of forest land affects oil palm expansion differently in autochthonous and migrant villages. Similarly, the role of wealth or land titles for land-use change decisions may differ by migrational background. Including all possible interaction terms in one specification would inflate the standard errors due to low degrees of freedom. We therefore use a sequence of additional specifications, including different groups of interaction terms always along with the other control variables.

## 4 Results and Discussion

### 4.1 Descriptive statistics

Table 1 shows descriptive statistics for our sample of villages for the three time periods 1992, 2002, and 2012. Of the 98 villages for which we had collected data in 2012, 8 villages had to be dropped for the following reasons. In five cases, the villages had recently emerged through separation from another village; for these five villages, we could collect data for 2012 but not for the previous time periods. In three other cases, we had to deal with missing data and stark outliers for some of the variables. We therefore remain with 90 village observations for 2012. These 90 villages include a few that were newly founded during the last 20 years (e.g., through a new transmigration settlement), which is also the reason why the numbers of observations are somewhat smaller in 1992 and 2002. When villages were newly founded and did not emerge through separation from another village, we decided to keep them in order not to further reduce the sample size.

On average, in 2012 villages had a total land area of 4558 ha, of which 51% was covered with rubber (Table 1). This underlines that rubber is still the dominant agricultural crop in Jambi. The rest of the village land is under secondary forest (17%), fallow (15%), oil palm (12%),

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<sup>2</sup>As explained, migrational background has a clear ethnical component. In example, transmigrants mainly consist of Sudanese and Javanese people, jointly originating from Java. In contrast, villages with no migrational background are dominated by Melayu Jambi. We emphasize this because our analysis will not be restricted to migrational backgrounds of villages but also expands on ethnical differences.

and other uses (5%), including residential areas and food crops. However, land use changed considerably over the last 20 years. In particular, the oil palm area has increased almost tenfold since 1992, while the forested area declined significantly. The fallow area and the land under rubber did not change much in size, although nowadays rubber is often cultivated more intensively than 20 years ago. That the average fallow land did hardly change since 1992 does not mean that exactly the same pieces of land are still fallow 20 years later. As mentioned, fallow land is either over-logged forest or unproductive plantation land; it is therefore a temporary state available for new land-use decisions by individual households or the village community.

Table 1 also shows other village characteristics. In 2012, 58% of the sample villages were autochthonous, 25% were transmigrant, and 17% were spontaneous migrant villages. As expected, the proportion of transmigrant villages increased somewhat over time with new settlements being established under the government program. The data on population density suggest significant population growth over the 20-year period. Furthermore, the use of agricultural technology (chemical fertilizer) and mean wealth levels have significantly increased, and infrastructure conditions have improved since 1992.

**Table 1.** Village-level descriptive statistics

	Mean (std. dev.)					
	1992		2002		2012	
	N= 72		N=76		N=90	
<i>Land-use variables</i>						
Oil palm (ha)	61.5	(225.67)	269.09	(543.52)	565.78	(780.75)
Rubber (ha)	2387.65	(6821.96)	2435.63	(6753.58)	2334.12	(6254.25)
Forest (ha)	1417.49	(2615.41)	866.05	(1978.17)	779.11	(1872.04)
Fallow (ha)	660.13	(1155.75)	669.26	(1157.21)	662.61	(1137.99)
Total land (ha)	5057.72	(7640.09)	4889.79	(7417.02)	4558.11	(6951.48)
<i>Migration dummies</i>						
Autochthonous village (d)	0.611	(0.491)	0.592	(0.495)	0.578	(0.497)
Spontaneous migrant village (d)	0.167	(0.375)	0.158	(0.367)	0.167	(0.375)
Transmigrant village (d)	0.222	(0.418)	0.251	(0.436)	0.256	(0.439)
<i>Socioeconomic variables</i>						
Population density (pop/ha)	0.486	(0.565)	0.761	(0.818)	1.006	(1.039)
Distance to road (km)	4.244	(14.31)	2.181	(7.351)	1.266	(5.427)
Chemical fertilizer (share of households)	0.186	(0.342)	0.328	(0.381)	0.496	(0.366)
Wealth index	0.151	(0.163)	0.479	(0.291)	0.724	(0.131)
Dominant ethnicity (share of households)	0.762	(0.327)	0.787	(0.273)	0.806	(0.167)
Land title (share of households)	0.213	(0.356)	0.351	(0.393)	0.458	(0.349)

## 4.2 Base model estimation results

Table 2 presents results from estimation of equations (1) to (3). The Breusch-Pagan test statistic shows that the null hypothesis of no error term correlation between the equations has to be rejected. We conclude that the SUR approach is preferred over the ordinary least squares estimator. The number of observations in the regressions is 180, consisting of the 90 villages observed for  $t = 2012$  and  $t = 2002$ , and corresponding lagged time periods for 2002 and 1992. Not all of the villages sampled in 2012 existed in previous periods. When a village did not exist in 2002 or 1992, all variable values for these years were set to zero. To control for possible systematic differences between such new villages and older ones, we additionally include an ‘old village’ dummy, which takes a value of one for all villages that already existed in 1992 and zero otherwise.

We first focus on the left-hand part of Table 2 (columns 1 to 3). The year dummy for 2012 in column (1) suggests that the oil palm area increased significantly, on average by 502 ha per village during the 2002-2012 period. For rubber (column 2), no such effect is observed. For the forest area (column 3), a negative time trend occurs, which is not statistically significant though. Looking at the role of lagged land-use systems, the results in columns (1) and (2) suggest a path-dependent trend towards specialization. Oil palm cultivation in the past contributes to further expansion of oil palm, while rubber cultivation in the past contributes to further expansion of rubber. However, the positive and significant lagged rubber coefficient in column (1) indicates that there is also some conversion of rubber to oil palm. Such conversion to oil palm is more likely on extensively cultivated agroforestry rubber than on intensive rubber plantations. Furthermore, fallow land in the past contributes significantly to oil palm expansion.

The coefficient for lagged forest land in column (1) is not significantly different from zero, suggesting that the oil palm expansion during the last 10 years did not contribute to deforestation directly. In other words, villagers in Jambi do not clear forest with the immediate intention to use the land for oil palm. This is in line with a study in Papua New Guinea, where Nelson et al. (2013) concluded that deforestation takes place without an explicit intention to grow oil palm in the future. On the other hand, the results in column (3) show that oil palm cultivation and fallow land in the past both contributed to declining forest land at the village level. This points at another path-dependency: more intensive logging and land conversion in the past is associated with more deforestation also in the future. In particular, oil palm expansion occurs in locations with ongoing logging activities, so we conclude that there are indirect effects on deforestation.

Turning to the effect of the socioeconomic variables, we observe that old villages that already existed in 1992 increased the oil palm area significantly less than newly established villages. This should not surprise, because many of the new villages are transmigrant settlements that were initiated as part of an oil palm NES scheme. We further find that higher population density in the village 10 years ago entails less oil palm cultivation today (column 1), whereas the population effect on forest land is insignificant (column 3).

**Table 2.** Land-use equations (SUR model)

	(1)	(2)	(3)	(4)	(5)	(6)
	Oil palm	Rubber	Forest	Oil palm	Rubber	Forest
Year 2012 (d)	501.88*** (85.73)	-8.531 (110.52)	-250.31 (162.94)	224.23*** (81.19)	170.31 (109.93)	-40.18 (158.01)
<i>Land-use variables</i>						
Oil palm <sub>t-10</sub>	0.252*** (0.095)	-0.027 (0.115)	-0.745*** (0.175)	0.951*** (0.092)	-0.184 (0.123)	-0.427** (0.172)
Rubber <sub>t-10</sub>	0.304*** (0.074)	0.457*** (0.108)	.	-0.077*** (0.028)	1.024*** (0.026)	.
Forest <sub>t-10</sub>	0.002 (0.032)	.	0.085 (0.069)	0.015 (0.029)	.	0.522*** (0.037)
Fallow <sub>t-10</sub>	0.359*** (0.081)	-0.194* (0.105)	-0.693*** (0.145)	-0.126*** (0.044)	0.209*** (0.052)	-0.001 (0.067)
Total land <sub>t</sub>	-0.053+ (0.036)	0.255*** (0.047)	0.304*** (0.071)	0.099*** (0.027)	-0.021 (0.024)	0.006 (0.011)
<i>Socioeconomic variables</i>						
Old village (d)	-608.46** (283.15)	-280.62 (368.22)	38.29 (544.39)	8.326 (104.89)	-194.31 (142.94)	-167.38 (205.14)
Population density <sub>t-10</sub> (pop/ha)	-201.92* (118.76)	-57.38 (155.43)	284.37 (224.69)	-59.44 (61.06)	-28.67 (83.06)	-30.81 (119.24)
Distance to road <sub>t-10</sub> (km)	10.68** (4.816)	-6.778 (6.245)	38.394*** (9.332)	-13.51*** (3.569)	0.871 (4.778)	24.58*** (6.969)
Chemical fertilizer <sub>t-10</sub> (share of HH)	-46.03 (144.68)	-169.41 (186.61)	-279.29 (277.29)	-252.65** (101.39)	-14.11 (138.47)	276.25 (195.93)
Wealth index <sub>t-10</sub>	-560.54*** (194.96)	362.87 (253.25)	-23.78 (376.64)	-141.24 (162.89)	-218.15 (222.21)	31.66 (318.62)
Land title <sub>t-10</sub> (share of HH)	176.08 (132.95)	-1.888 (168.45)	88.51 (255.39)	52.42 (108.59)	-114.11 (151.47)	14.42 (217.29)
Dominant ethnicity <sub>t-10</sub> (share of HH)	-237.97 (-238.07)	-56.73 (-300.53)	536.13 (446.86)	-92.13 (111.05)	-41.65 (153.17)	-96.08 (220.57)
Spontaneous migrant village (d)	.	.	.	62.76 (100.66)	-389.45*** (137.57)	-318.55* (191.85)
Transmigrant village (d)	.	.	.	287.53*** (106.57)	-42.89 (145.68)	-283.45 (203.51)
Constant	-646.19* (387.19)	-168.45 (502.89)	396.27 (746.53)	94.84 (120.84)	183.31 (183.54)	181.65 (225.73)
Village fixed effects	YES	YES	YES	NO	NO	NO
Observations	180	180	180	180	180	180
R <sup>2</sup>	0.87	0.99	0.91	0.58	0.99	0.71
Breusch-Pagan independence test (chi <sup>2</sup> )		51.68***			19.01***	

Notes: Estimation coefficients are shown with standard errors in parentheses. All land-use variables are expressed in ha. HH, households. \*\*\* Significant at the 1% level. \*\* Significant at the 5% level. \* Significant at the 10% level.

This latter effect is interesting, because population pressure has often been identified as a driver of deforestation (e.g., Mertens et al., 2000; Kirby et al., 2006; Mena et al., 2006). However, DeFries et al. (2010) pointed out that urban population growth and associated increases in the demand for agricultural products are probably more important drivers of deforestation than rural population growth.



In terms of infrastructure conditions, distance to an all-season road in the past influences oil palm and forest land today. Each additional km of distance increases the village oil palm area by 10 ha and the forest area by 38 ha. The result for forest area is expected and in line with the literature showing that road infrastructure can contribute to deforestation (Kirby et al., 2006). Yet the effect for oil palm is somewhat surprising. Conventionally, one would expect that better infrastructure contributes to more cash crop cultivation. However, it should be stressed that Jambi has not been a typical forest frontier region over the last 20 years. Much of the pristine forest in Jambi had already been logged before 1992, and rubber was already a major cash crop before the oil palm boom started. Many of the oil palm NES schemes were deliberately established in remoter regions. Hence, the construction of new infrastructure was not the trigger but occurred as part of a centrally planned development process.

Wealth does not have a significant effect for rubber and forest land, but it does play an important role for oil palm expansion. Villages with a larger lagged wealth index increased their oil palm land significantly less than poorer villages. This may be contrary to initial expectations. Establishing new oil palm plantations requires access to capital for the planting material and other inputs and also to bridge the period of 3-5 years before the first fruits can be harvested. However, participants in oil palm NES schemes had access to subsidized loans and other support measures, so that for them limited initial wealth was not a major constraint to start oil palm cultivation. On the other hand, wealthier villages with productive rubber plantations had fewer incentives to switch to oil palm that was brought to Jambi from outside. Cultural differences between the autochthonous Melayu Jambi and the migrants from Java might also have played a role. Such aspects related to migration are analyzed more explicitly in the following.

#### *4.3 Results on the role of migration*

We now analyze the role of migration in more detail by including migration dummies for villages that were started by spontaneous migrants and transmigrants as explanatory variables. Results of this expanded model are shown in columns (4) to (6) of Table 2. Controlling for other factors, transmigrant villages have significantly larger oil palm areas than autochthonous villages that constitute the reference group (column 4). However, the transmigrant dummy has no significant effect on rubber and forest areas (columns 5 and 6). As explained, early transmigrants were supported in rubber cultivation. Spontaneous migrant villages have significantly less rubber than autochthonous villages. They also tend to have less forest land. For spontaneous migrants, who were not allocated any land by the government, clearing forest land is one way of getting access to an own agricultural production base. That the spontaneous migrants focused more on oil palm than rubber is due to the fact that they do not have a rubber-growing tradition and migrated at a time when the oil palm boom had already started in Jambi. Like the transmigrants, many of the spontaneous migrants came from Java, so cultural similarities can be expected. The differences between the two dummies point at important effects of policy support that the transmigrants received and the spontaneous migrants did not.

**Table 3.** Model results with interactions between migration dummies and land-use systems (SUR model)

	(1)	(2)	(3)
	Oil palm	Rubber	Forest
Oilpalm <sub>t-10</sub>	0.188* (0.101)	-0.054 (0.123)	-0.679*** (0.193)
A Spontaneous * oil palm <sub>t-10</sub>	0.189 (0.404)	-0.121 (0.532)	-0.097 (0.798)
Transmigrant * oil palm <sub>t-10</sub>	0.481* (0.291)	0.261 (0.387)	-0.465 (0.572)
Rubber <sub>t-10</sub>	0.231*** (0.077)	0.581*** (0.112)	.
B Spontaneous * rubber <sub>t-10</sub>	0.484*** (0.171)	-0.797*** (0.258)	.
Transmigrant * rubber <sub>t-10</sub>	0.447 (0.421)	-0.648 (0.637)	.
Forest <sub>t-10</sub>	0.003 (0.032)	.	0.083 (0.061)
C Spontaneous * forest <sub>t-10</sub>	-0.404** (0.169)	.	-0.028 (0.326)
Transmigrant * forest <sub>t-10</sub>	0.032 (0.407)	.	-1.317* (0.795)
Fallow <sub>t-10</sub>	0.376*** (0.082)	-0.229** (0.106)	-0.731*** (0.151)
D Spontaneous * fallow <sub>t-10</sub>	-0.243 (0.311)	0.634* (0.401)	0.552 (0.597)
Transmigrant * fallow <sub>t-10</sub>	-0.695 (0.787)	1.259 (1.013)	0.489 (1.522)
Land-use controls	YES	YES	YES
Socioeconomic controls	YES	YES	YES
Village fixed effects	YES	YES	YES
Observations	180	180	180

Notes: Estimation coefficients are shown with standard errors in parentheses. All land use variables are expressed in ha. Parts A, B, C, and D were estimated in separate regressions. All regressions contain a year 2012 dummy and the same land-use and socioeconomic variables as in Table 2; these other variables are not shown here for brevity. \*\*\* Significant at the 1% level. \*\* Significant at the 5% level. \* Significant at the 10% level.

**Table 4.** Model results with interactions between migration dummies and other socioeconomic variables (SUR model)

	(1)	(2)	(3)
	Oil palm	Rubber	Forest
Population density <sub>t-10</sub>	-437.38*** (177.01)	83.75 (231.52)	595.66* (341.31)
A Spontaneous * population density <sub>t-10</sub>	150.15 (260.95)	-244.94 (340.75)	-349.79 (509.12)
Transmigrant * population density <sub>t-10</sub>	446.48** (226.64)	-208.74 (295.53)	-532.04 (442.28)
Distance to road <sub>t-10</sub>	9.747 (6.577)	-12.35 (8.325)	83.52*** (11.63)
B Spontaneous * distance to road <sub>t-10</sub>	-10.54 (22.64)	-45.64* (29.05)	-27.73 (39.95)
Transmigrant * distance to road <sub>t-10</sub>	2.698 (8.669)	14.23 (11.14)	-89.73*** (15.32)
Wealth index <sub>t-10</sub>	-725.22*** (224.93)	604.08** (291.25)	-150.27 (436.54)
C Spontaneous * wealth index <sub>t-10</sub>	326.03 (287.24)	-693.42* (371.05)	284.47 (559.47)
Transmigrant * wealth index <sub>t-10</sub>	329.98 (281.44)	-309.06 (363.47)	228.52 (547.47)
Land titles <sub>t-10</sub>	-1359.02** (601.18)	-188.71 (483.02)	1675.56 (1088.21)
D Spontaneous * land titles <sub>t-10</sub>	1768.16*** (657.96)	611.52 (613.52)	-1510.26 (1223.82)
Transmigrant * land titles <sub>t-10</sub>	1552.54*** (611.01)	136.01 (506.91)	-1682.98 (1115.01)
Land-use controls	YES	YES	YES
Socioeconomic controls	YES	YES	YES
Village fixed effects	YES	YES	YES
Observations	180	180	180

Notes: Estimation coefficients are shown with standard errors in parentheses. All land use variables are expressed in ha. Parts A, B, C, and D were estimated in separate regressions. All regressions contain a year 2012 dummy and the same land-use and socioeconomic variables as in Table 2; these other variables are not shown here for brevity. \*\*\* Significant at the 1% level. \*\* Significant at the 5% level. \* Significant at the 10% level.

The other coefficients of the land-use and socioeconomic variables are also affected, which is largely due to the exclusion of village fixed effects in columns (4) to (6). As explained, the joint inclusion of migration dummies and village fixed effects causes collinearity problems. Differences in the coefficients with and without village fixed effects should not be overinterpreted. Nonetheless, it appears that migration might have more systematic effects on land-use change that cannot be fully captured with the two migration dummies alone. We therefore, interact these dummies with the major land-use and other socioeconomic variables to gain further insights. As described above, we use a sequential approach and estimate the

model separately with different groups of interaction terms included. Results of these additional specifications are shown in Tables 3 and 4.

In Table 3, we analyze in how far the effects of previous land-use variables differ between autochthonous and migrant villages. Part A reveals that each ha of oil palm 10 years ago contributes to 0.19 ha of additional oil palm today (column 1). This effect is smaller than the one observed in column (1) of Table 2; in Table 3 it only refers to autochthonous villages because we now include interaction terms with the two migration dummies. The significant coefficient for the transmigrant interaction shows that the lagged oil palm effect is larger among transmigrants as compared to the base category of autochthonous villages. The combined effect for transmigrant villages is derived as the sum of both coefficients, in this case  $0.19 + 0.48 = 0.67$ . Part B reveals significant differences also in the effect of lagged rubber land on oil palm expansion between autochthonous and migrant villages (column 1). Lagged rubber land has a positive and significant effect in all village types, suggesting significant conversion of rubber to oil palm. But the effect is much stronger in migrant villages, and especially among spontaneous migrants. On the other hand, lagged rubber land contributes to more future rubber only in autochthonous villages (column 2). These results imply that there are path-dependencies that differ by migration background.

Table 4 shows results with interaction terms between the migration dummies and other socioeconomic factors. Part A reveals that higher population density in the past contributes to smaller oil palm areas in autochthonous villages. This is likely related to differences in labor requirements between oil palm and rubber. Rubber cultivation requires continuous labor availability for tapping the trees. In contrast, for oil palm significant labor input is required only in certain intervals for harvesting the ripe fruit bunches. Hence, more densely populated autochthonous villages with higher labor availability have lower incentives to switch to oil palm. The same effect is not observed in migrant villages. For many migrants who never grew rubber, oil palm expansion occurs independently of population density.

Part B of Table 4 shows that lagged road distance has a significantly positive effect on forest land in autochthonous villages, as already discussed above and in line with the deforestation literature (Kirby et al., 2006). However, the same effect is not observed in transmigrant villages where new settlements were deliberately established in remoter areas. Also for wealth effects, we observe notable differences between migrant and autochthonous villages (part C). Above we found that lagged wealth is associated with less oil palm expansion. We now see that this effect only holds for autochthonous villages, where wealth contributes to less oil palm and more rubber land. For the migrant villages, the combined wealth effects are not statistically significant.

Finally, part D of Table 4 reveals interesting results for the role of land titles. A larger lagged share of households with land titles contributes to further oil palm expansion in transmigrant and spontaneous migrant villages. Land titles can be used as collateral and therefore improve households' access to agricultural credit (Feder and Nishio, 1998). While transmigrants in particular received subsidies for oil palm cultivation in the beginning, these subsidized programs ceased. Many successful transmigrants who had repaid their loans and obtained

their land titles have started to establish new independent oil palm plantations more recently. The same holds true for spontaneous migrants who either purchased land or obtained a title through the costly application process. In contrast, in autochthonous villages the lagged share of households with land titles has a negative effect on oil palm cultivation. This negative effect is plausible with some additional information on the local context. As discussed, most autochthonous people have traditional land rights yet without formally recognized titles. While autochthonous households can apply for land titles, many of them have never entered this costly procedure, unless they plan to sell their land. Hence, obtaining land titles can be considered as a strategy of autochthonous people to exit own agricultural production in the medium run, rather than investing in new oil palm plantations. Formal land transactions are increasingly observed in Jambi with autochthonous people as sellers and migrants as buyers.

## **5 Conclusions**

In this article, we have investigated land-use dynamics in the province of Jambi on the island of Sumatra, a tropical lowland region and one of the hotspots of Indonesia's recent oil palm boom. Unlike previous research that relied on satellite images to analyze land-use changes, we have used data from a survey of randomly selected villages, which allowed us to examine the role of socioeconomic and policy factors more explicitly. Through structured interviews with village leaders we collected recall data on land use and a broad set of other village-level variables covering a period of 20 years, from 1992-2012.

The data reveal considerable land-use changes, with a decline in forested land and a rapid expansion of oil palm. In spite of this significant oil palm expansion, rubber remains the dominant crop in Jambi. Oil palm is partly grown on large public sector or private company plantations, but smallholder farmers are also involved to a remarkable extent. While it is often argued that oil palm is the main driver of deforestation, this has not been the case in Jambi in the recent past. Most of the oil palm growth takes place on previous fallow and unproductive rubber land. This land was covered with forest at some point, but it was logged and cleared without the immediate intention to grow oil palm. In this regard, Jambi is not representative of rainforest frontier regions, because much of the forest in Jambi was cleared more than 20 years ago, and rubber was an established cash crop long before the oil palm boom started. However, our data also show that oil palm growth occurs in locations with ongoing logging activities, so that indirect effects on deforestation are likely.

In terms of socioeconomic and policy factors, our results show that the Indonesian government's transmigration program played a key role for the start and spread of oil palm cultivation in Jambi and the significant involvement of smallholder farmers. In the transmigration program, people from densely populated Java were relocated to Sumatra and supported in oil palm cultivation in so-called nucleus-estate and smallholder (NES) schemes. Many of these schemes were established in the 1980s and 1990s in relatively remote areas. This is also the reason why past infrastructure development was not found to be a determinant of oil palm development in the statistical analysis. Although some autochthonous villages in

Jambi are now also growing oil palm, they have started later than the transmigrants and expand their oil palm area at a slower pace.

Our results point at path-dependencies that differ by migrational background. In autochthonous villages, past rubber cultivation is a strong predictor of future rubber cultivation, whereas in transmigrant villages oil palm in the past promotes more oil palm in the future. These divergent paths may be attributable to cultural differences between the Melayu Jambi and the immigrants from Java. Rubber cultivation is a cultural heritage for autochthonous families, but not for the Javanese. Yet the government support provided to the oil palm NES schemes was also instrumental, as the comparison between transmigrant villages with support and spontaneous migrant villages without support suggests. Transmigrants received technical and financial assistance for oil palm cultivation; they were also awarded formal land titles after loan repayment. In contrast, most autochthonous people do not hold formal land titles. Autochthonous people can apply for land certificates, but this involves a costly administrative procedure, which many consider worthwhile only when planning to sell the land afterwards. Field observations suggest that the government-supported oil palm NES schemes were beneficial for many of the transmigrant families. At the same time, the transmigrant program has contributed to the risk of unequal developments between the transmigrant and autochthonous population.

Our results do not allow statements on whether the oil palm expansion in Jambi is good or bad. Such statements would require comprehensive analysis of the economic, social, and environmental impacts, which is beyond the scope of this article. However, our study clearly shows that socioeconomic and policy factors play an important role in explaining land-use trends at the local level. Understanding these factors is an important precondition to design sustainable land-use policies. A concrete policy recommendation is that a more efficient land titling process, providing fair and secure land ownership rights to all ethnicities, could help to avoid undesirable social developments.

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