ELSEVIER
www.elsevier.com/locate/worlddev

World Development Vol. 99, pp. 335–349, 2017
0305-750X/© 2017 The Author(s). Published by Elsevier Ltd.
This is an open access article under the CC BY-NC-ND license
(http://creativecommons.org/licenses/by-nc-nd/4.0/).

http://dx.doi.org/10.1016/j.worlddev.2017.05.018

Land markets, Property rights, and Deforestation: Insights from Indonesia

VIJESH V. KRISHNA [a], CHRISTOPH KUBITZA [a], UNAI PASCUAL [b,c,d] and MATIN QAIM [a,*]

[a] *University of Goettingen, Germany*
[b] *Basque Centre for Climate Change, Leioa, Spain*
[c] *Ikerbasque, Basque Science Foundation, Bilbao, Spain*
[d] *University of Cambridge, UK*

Summary. — We examine the emergence of land markets and their effects on forest land appropriation by farm households in Jambi Province, Sumatra, using micro-level data covering land use and land transactions for a period of more than 20 years (1992–2015). Based on a theoretical model of land acquisition by a heterogeneous farming population, different hypotheses are developed and empirically tested. Farm households involved in forest land appropriation differ from those involved in land market purchases in terms of migration status and other socioeconomic characteristics. In principle, these differences provide opportunities for market-induced deforestation. However, the appropriated forest land is not extensively traded, which we attribute to the lack of *de jure* property right protection and the resulting undervaluation in the market. While the *de facto* property right protection under customary law provides sufficient security within the village community, the sense of external tenure security is low when the land cannot be formally titled. Clearing forests for trading in the land market is, therefore, financially less lucrative for farm households than engaging in own cultivation of plantation crops, such as oil palm and rubber. We conclude that land markets did not have significant effects on deforestation. On the other hand, the emergence of land markets alone has also not been able to deter forest appropriation by local farm households.
© 2017 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Key words — tropical deforestation, property rights, oil palm, rubber, land tenure

1. INTRODUCTION

Population and income growth tend to increase the demand for agricultural land (Hertel, Ramankutty, & Baldos, 2014; Platteau, 1996). In the absence of robust institutions, the resulting land scarcity instigates conversion of forest land, especially in the global South (Bhattarai & Hammig, 2001). Agriculture is one of the most important drivers of deforestation worldwide, becoming a major environmental concern and the target of global policy initiatives (Gibbs *et al.*, 2010; Kissinger, Herold, & De Sy, 2012; Phelps, Carrasco, Webb, Koh, & Pascual, 2013; Pülzl & Rametsteiner, 2002).

While deforestation in developing countries is primarily driven by rising demand for agricultural and forestry products (World Bank, 2007), micro-level determinants and institutional factors, such as the role of land markets, remain under-examined. Farm households in developing countries access land through different pathways, including inheritance and inter-vivo transfers, community membership, appropriation of forest land, market transactions, and occasionally coercive or non-coercive state interventions (de Janvry & Sadoulet, 2001). Increasing land scarcity could potentially lead to a shift from common property to individual property rights regimes with land market transactions becoming more prominent for households to acquire cultivable land (Fitzpatrick, 2006; Platteau, 1996). While some argue that markets could be an efficient mechanism to allocate land to its most productive use (Wallace & Williamson, 2006; Zimmerman & Carter, 1999), others contend that institutional constraints could suppress economically and socially desirable outcomes (Deininger & Jin, 2008; Deininger, Jin, & Nagarajan, 2009; Holden, Otsuka, & Place, 2009).

There exists a large body of literature analyzing the conceptual relationship between land market development and forest conservation (e.g., Barbier, 2001; Bhattarai & Hammig, 2001; Geist & Lambin, 2002). There are also several studies that investigated farm households' participation in land markets in developing countries (e.g., Deininger & Jin, 2008; Deininger, Zegarra, & Lavadenz, 2003; Deininger *et al.*, 2009). However, surprisingly little empirical evidence exists about the effect of land market development on deforestation. This effect is not straightforward to predict, because the emergence of land markets often coincides with the emergence of private property rights, and the effect of private property rights on deforestation itself is not unambiguous (Alston, Libecap, & Schneider, 1996; Araujo, Bonjean, Combes, Motel, & Reis, 2009; Godoy, Kirby, & Wilkie, 2001; Liscow, 2013; Place & Otsuka, 2001). Stronger property rights and tenure security could prompt landholders to discount the future less, thus being more likely to realize long-term benefits of forests as opposed to short-term benefits from land conversion. However, stronger property rights could also increase incentives to invest in productive activities such as cash crops (Fenske, 2011; Grimm & Klasen, 2015; Lawry *et al.*, 2016). A

* We thank Stefan Schwarze, Michael Euler, Marcel Gatto, Yvonne Kunz, and two anonymous referees of this journal for their constructive comments on previous versions of this manuscript, and Hermanto Siregar and Zakky Fathoni for their valuable inputs during the field work in Indonesia. This study was undertaken as part of the research project SFB 990 "Ecological and Socioeconomic Functions of Tropical Lowland Rainforest Transformation Systems, Sumatra (Indonesia)" (EFForTS) funded by the German Research Foundation (DFG). Final revision accepted: May 16, 2017.

recent meta-analysis indicated a negative association between land tenure security and the rate of deforestation (Robinson, Holland, & Naughton-Treves, 2014). But the role of land markets was not explicitly considered. Similarly, while many micro-level empirical studies have attempted to examine the drivers of land-use change across the globe (Meyfroidt, Lambin, Erb, & Hertel, 2013), the potential of land markets — an emerging pathway of importance for farm households to access cultivable land in forest fringes — has not been addressed. We address this research gap by examining different land acquisition options for farm households in Indonesia, and the institutional factors that incentivize selection of market participation as opposed to direct appropriation of forest land.

Indonesia, like many other tropical countries, has experienced a rapid depletion of forest resources in favor of a fast expanding export-oriented agrarian sector (MoF, 2009; Barraclough, 2013; FAO, 2010; Margono *et al.*, 2012). A major share of deforestation is caused by large plantation and mining companies. During 2000–10, companies were responsible for an estimated 88% of the total area deforested in the country, while land conversion by farm households only accounted for 11% (Lee *et al.*, 2014). Nevertheless, the decentralized activities by farm households are much more difficult to monitor and regulate and hence become a critical challenge for forest conservation (Indrarto *et al.*, 2012). Land markets in Indonesia are largely informal, with land transactions often lacking proper documentation and registration. This makes it difficult to generate data on land transactions at meso- and macro-levels.

Here, we use micro-level survey data to examine the links between the emergence of land markets and forest land appropriation, the two major pathways of land acquisition for farm households in Indonesia. We examine determinants of land acquisition through markets *versus* forest land appropriation and possible connections between these two pathways. We also analyze the role of land property rights. We use the term "forest land appropriation" in a broad sense, referring to state-owned forest as well as forest owned by village communities under customary law. Furthermore, we use the term "deforestation" to refer to the act of clearing forest land regardless of land ownership. The term "land market transaction" is used here for any voluntary purchase or sale of land in exchange for money. Land rental agreements are not included, because tenants usually do not make longer-term land-use decisions, such as clearing forest or establishing plantation crops. Most land market transactions involve signing a civil agreement of ownership transfer with village officials as key witnesses; this can occur with or without formal land titles, as is explained in more detail below.

The data for this research were collected in Jambi Province, Sumatra, and include details on land-use changes and land market transactions by local households over a period of more than 20 years (1992–2015). Jambi Province provides a typical example for the deforestation process in Indonesia, as the local land use has undergone significant changes during the last few decades, including the conversion of primary forests to rubber agroforests, and later to intensive rubber and oil palm plantations (Wilcove, Giam, Edwards, Fisher, & Koh, 2013). About 43% of the 2.7 million hectares of primary forest standing in 1990 were lost in the province by 2010 (Margono *et al.*, 2012). While different private and public companies are producing palm oil in Jambi on large landholdings, farm households still dominate much of the rubber sector and are also involved in oil palm cultivation to a significant extent (Euler, Schwarze, Siregar, & Qaim, 2016; Gatto, Wollni, & Qaim, 2015).

The next section provides background information about Indonesia's evolving land governance system and Sumatra's socio-demographic heterogeneity. The conceptual framework is presented in Section 3, leading to concrete hypotheses that are tested empirically in subsequent sections. Data sources and empirical methods are described in Sections 4 and 5. Empirical results are presented and discussed in Section 6, whereas Section 7 concludes.

2. LAND GOVERNANCE IN INDONESIA

(a) *Evolution of land governance since the 1960s*

During the Dutch colonial rule and the early independence era, land governance in Indonesia was based on indigenous customary tenure (*adat*), which varied between different regions of the country (Szczepanski, 2002). One of the most important land governance legislations during the post-independence era was the Basic Agrarian Law (BAL), which was enacted in 1960 and later complemented by a number of other laws, regulations, and decrees (Susanti & Budidarsono, 2014). While the BAL was primarily aimed at unifying the different land laws into a single system, it conditionally recognized customary rights of rural communities. A significant shift in land governance occurred under the "New Order Regime" (1967–98). Specifically, legislations enabling forestry and mining leases were enacted, including the Forestry Law of 1967, which set the framework for forest management for the following three decades. The Forestry Law entailed a disenfranchising of the rural population from forest resources, and *adat* institutions were overlooked (Haverfield, 1999). Around 70% of the country's territory was delegated as state forest land (*kawasan hutan*) under the jurisdiction of the Ministry of Forestry (Indrarto *et al.*, 2012; Susanti & Budidarsono, 2014). *Kawasan hutan* also included many unregistered plots that were already used by local people for agricultural cultivation when the Forestry Law was enacted. The government also did not recognize land rights of farm households over forest plots that were illegally converted after 1967. However, even without formal recognition, local farm households continued to clear forest land for crop production, claiming *de facto* ownership rights (Johnson & Nelson, 2004; Peluso, 2005). There exists a strong conviction by farm households that such *de facto* tenure is secure within the village community (Resosudarmo *et al.*, 2013).

Market transactions of land hardly occurred in many parts of rural Indonesia till the 1980s, partly due to the fact that only a small share of the total land was formally titled. In 1981, the Indonesian government introduced the National Agrarian Operation Project (PRONA), a program to reduce transaction costs involved in land titling. However, by the end of the 20th century only less than 20% of all registrable plots (about 10% in rural areas) had actually been titled (Fitzpatrick, 1997; Slaats, Rajagukguk, Elmiyah, & Safik, 2009). From the early-1990s, the government intensified its efforts to develop a reliable land titling system over non-forest land. PRONA was largely replaced by the Land Administration Project (LAP), financially supported by the World Bank and the Australian Government. The objective of LAP is to title all agrarian land in Indonesia by 2020 (Thorburn, 2004).

At present, two ways of obtaining formal titles are possible for agrarian land: (i) *systematic* titling, where usually a large number of contiguous plots across different users can be registered at a subsidized rate, and (ii) *sporadic* titling, where a

single landholder applies for the title (USAID., 2010). While PRONA primarily covered sporadic titling, LAP aims for systematic titling (Slaats *et al.*, 2009). During the first phase of LAP (1994–2001), about two million plots of land were registered in Indonesia, mostly in West Java (Reerink & van Gelder, 2010). Although systematic titles are generally considered more secure, the application requires significant documentation from land owners and hence the process is often time-consuming. On the other hand, access to formal credit is significantly higher when farm households can use their systematic title as collateral. Although designed as an intermediary step in the process of land certification, sporadic titles are now considered by many farm households as a cheaper substitute that does not require any validation from the National Land Agency (Kunz, Hein, Mardiana, & Faust, 2016).

Customary land rights, which are not easily amenable to individualization and titling, still apply in many parts of Indonesia (Slaats *et al.*, 2009), and could be excluded from the institutional purview of land markets. Further, the state law allows land owners to transfer their ownership rights through civil agreements even without any titles (Lindsey, 1998; USAID, 2010). At present, state *kawasan hutan*, communal *adat* land, and private land co-exist in Indonesia.

(b) *Land acquisition pathways in Sumatra*

Farm households in Indonesia use different pathways of land acquisition. The most common pathways nowadays include inheritance or inter-vivo transfers, forest land appropriation, and purchases in the land market. In Sumatra, an additional form of land acquisition has had major impacts on land governance: the government's transmigration program, which gained momentum in the late-1980s and early-1990s (Susanti & Budidarsono, 2014). Transmigrant families from Java were settled in newly created transmigrant villages in Sumatra in isolation from the autochthonous Melayu population. Transmigrant families were allocated plots of land for crop cultivation, for which they could easily obtain formal land titles (Gatto, Wollni, Asnawi, & Qaim, 2017). While the transmigration program slowed down since the late-1990s, it continues to have important implications for land ownership structures in rural Sumatra. Many of the former transmigrants hold formal land titles, whereas the majority of the autochthonous population has *de facto* land rights under customary law. Customary land rights mostly do not apply to migrants from outside the community, that is, migrants cannot easily establish *de facto* rights unless they have a formal title.

Nowadays, forest land appropriation and market transactions are the two most prevalent pathways of land acquisition in the study area in Jambi Province. Since appropriation of state forest land (*kawasan hutan*) has been illegal, obtaining *de jure* rights for such converted forest land is very difficult. Nevertheless, many farm households in Sumatra, especially those from the autochthonous population, perceive cultivation on such appropriated forest land as secure *de facto* (Resosudarmo *et al.*, 2013). On the other hand, especially migrant households clearly prefer *de jure* property rights through formal titles when purchasing land.

3. CONCEPTUAL FRAMEWORK AND HYPOTHESES

The relationship between land market development and deforestation driven by farm households is not straightforward. The evolution of land markets may reduce the need to directly appropriate the forest land for cultivation. Following Boserup (1965), a shift from direct appropriation to land purchases is considered as an institutional response to growing population pressure, land scarcity, and commercialization of agriculture. In addition, investment in improved land governance and strengthening of property rights are seen as prerequisites for land markets to effectively curtail deforestation and promote sustainable use of land resources (Streck, 2009). Much of the policy support for land market development is based on these notions.

Figure 1 provides a framework that includes the key economic drivers of decision-making about alternative pathways of land acquisition in a heterogeneous farming community. The horizontal axis shows the distance of a cultivable plot from the market center (center of economic activity). Two types of plots are considered: plots with *de jure* property right protection through a formal land title, and plots without formal title that may or may not have *de facto* rights under customary law. The vertical axis shows the shadow price of land, capturing the economic value of agricultural production and also any non-pecuniary values.[1] The real market price and the opportunity cost of labor are also depicted on the vertical axis. The cost of cultivation increases with distance from the market center, because of rising transportation costs and factors of production other than land becoming less accessible. This cost increase is assumed to limit the expansion of agriculture to more remote locations.

Building on a spatially-explicit von Thünen model (e.g., Angelsen, 2010), we assume that land is allocated to the use that generates the highest land rent. Heterogeneity in the farming community is explicitly addressed using differential shadow price functions for two types of farm households: non-migrants (autochthonous) and migrants. The shadow price of land used by non-migrants is depicted as $R_1R_1^*$, which declines with distance from the market. We assume human labor as the major limiting factor of production, and the agricultural frontier to be determined by the opportunity cost of labor, which is a positive function of distance (LL_1^*). As long as the potential rent from land is positive ($R_1R_1^* \geqslant LL_1^*$), the land will be under agricultural production (region OF_0). Beyond that point, the land will be under forest. The shaded area in Figure 1 could contain some of the traditionally cultivated plots. These plots, being managed privately for a longer period of time, are assumed to have or be eligible for *de jure* property right protection. This is the baseline scenario against which the potentials of land markets are evaluated.

Let us now suppose that migrants bring improved cultivation skills or are able to adopt cash crops (e.g., oil palm), which are labor-saving and/or land-sparing compared to the traditional land use followed by the local population (e.g., paddy, rubber). In-migration and introduction of labor-saving land uses will increase the labor availability in the village economy, thereby shifting the opportunity cost of labor in farming downward (LL_2^*). Migrants could acquire cultivable land either through the land market or through forest land appropriation. This decision depends primarily on their perception of the degree of internal (*de facto*) tenure security over appropriated forest land *vis-à-vis* the external (*de jure*) tenure security over the titled land available in the market. Adjusting for the risk of expropriation, the shadow price curve for the migrant household is depicted as $R_2wR_2^*$. The kinked function illustrates a typical situation of differential shadow prices for plots with varying degree of property rights security. The plots without *de jure* property rights are valued less in the market. If no land market exists in the village, an increasing demand for

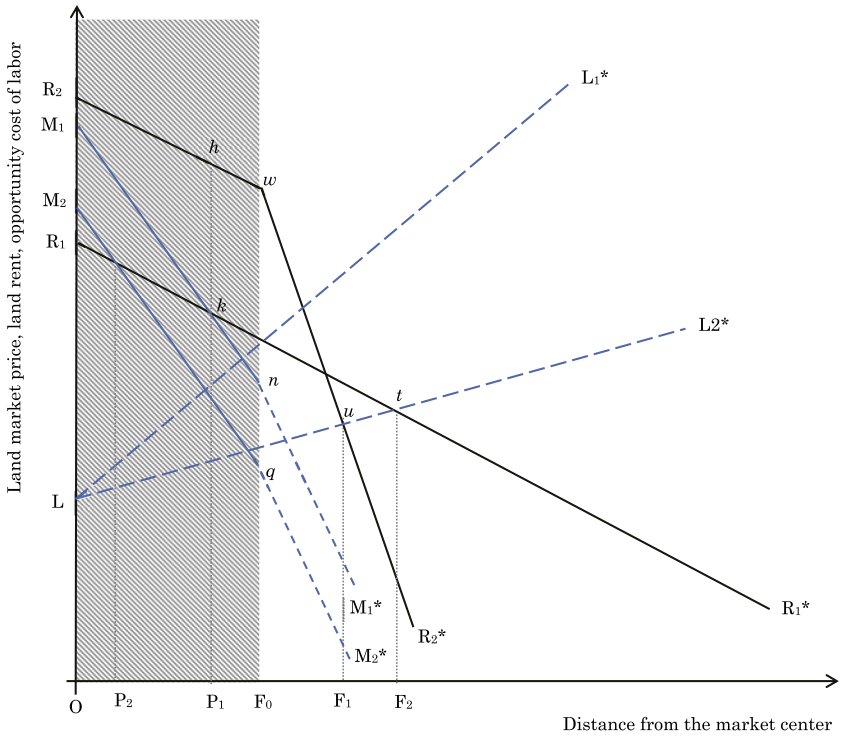

Figure 1. *Potential impact of market development on deforestation in a heterogeneous farming community. Notes: Shaded area (OF_0) shows de jure cultivable area. Beyond F_0 lies the forest land (already appropriated or unappropriated). $R_1R_1^*$ and $R_2wR_2^*$, are the shadow price functions of land, LL_1^* and LL_2^* are the opportunity cost of labor, and $M_1nM_1^*$ and $M_2qM_2^*$ are land market price functions.*

cultivable land due to an expanding labor base will result in additional forest land appropriation; the amount of additional deforestation through migration would be the segment between F_0 and F_1.

Let us also assume a land market price function, represented by $M_1nM_1^*$ as a negative function of distance from the market center. Land transactions in the market would occur only in the region OP_1, as the market price (M_1k) lies below the shadow value of land for a share of migrant households (R_2h) but above the expected shadow value for non-migrants (R_1k). The differences in shadow prices of land between households could arise due to a number of factors, including differences in managerial skills, easy access to working capital, and opportunity cost of family labor, among others. Of course, autochthonous households that are selling land could subsequently engage in forest land appropriation (deforestation) to acquire additional land. As explained, the internal (*de facto*) tenure security over appropriated forest land is perceived higher by autochthonous farm households than by migrants. Therefore, autochthonous farm households could have an incentive to sell titled land with *de jure* property protection in segment R_1k to migrants and then appropriate forest land for own cultivation within segment (F_1F_2). In this case, *de facto* property rights for some of the land would contribute to additional deforestation.

The model suggests that an increase in socioeconomic heterogeneity, resulting in different shadow prices of land and different preferences for *de facto* property rights over converted forest land by migrants and non-migrants, could spur the development of land markets and appropriation of additional forest land. Identifying the characteristics of farm households involved in different land acquisition pathways is hence a necessary step toward linking deforestation and land market development. We propose the following hypothesis to be tested:

Hypothesis 1. "*Households involved in forest land appropriation are different in terms of their socioeconomic characteristics from households that purchase land in the market. Differences are especially expected in terms of households' migration status and ethnicity.*"

Confirmation of this hypothesis could mean that selling cultivable land to migrants provides an incentive to autochthonous households to deforest further. However, this alone would not prove that the emergence of land markets affects deforestation. Land prices are another important element that needs scrutiny.

The cultivable land could be severely undervalued, especially when it cannot be protected by *de jure* property rights. In the conceptual model in Figure 1, this would imply that prices in the land market are lower than the shadow value for non-migrants, for instance, the market price curve could be $M_2qM_2^*$. In that case, fewer autochthonous households would be willing to sell land in the market; sales would only occur in the segment OP_2. This leads to two additional, interconnected hypotheses:

Hypothesis 2a. "*The lack of de jure property rights leads to undervaluation of land in the market.*"

Hypothesis 2b. "*Due to the undervaluation of land, own cultivation in appropriated forest land is more profitable for farm households than selling the land in the market.*"

4. DATA AND DESCRIPTIVE STATISTICS

The main source of data for this study is a survey of farm households in Jambi Province, Sumatra. This survey was carried out in two rounds, the first round in 2012 and the second in 2015. Farm households to be included were sampled in five regencies (Sarolangun, Bungo, Tebo, Batanghari, and Muaro Jambi). These regencies comprise the largest part of the lowland region in Jambi,[2] where most of the deforestation occurred during recent decades. Four districts per regency and two villages per district were randomly selected, resulting in a total of 40 villages in 20 districts. In addition, five villages near to the Bukit Duabelas National Park and the Harapan Rainforest, where supporting research activities were carried out (Clough, Krishna, Corre, *et al.*, 2016), were purposively selected.

A map with the location of sample villages is shown in Figure 2. In each village, complete household lists were compiled, from which farm households were randomly selected. The number of sampled households per village was adjusted to the village population size.[3] In 2012, we surveyed a total of 701 farm households. In 2015, we targeted the same households and were able to cover most of them again; with 6% the attrition rate was low.[4] The small number of households that could not be surveyed again were replaced with other randomly selected households in the same villages, thus keeping the sample size and structure constant across the two survey rounds.

Face-to-face interviews with the household heads were conducted in Indonesian language by a team of enumerators, who were trained and supervised by the researchers. Historical data on land acquisition and land-use changes were collected through a recall for all plots owned in both survey rounds. In case of land-use change following an ownership change, the original land-use type was also recorded. Since land transactions are non-frequent events, survey respondents did not find it difficult to recall details such as land prices and land use changes, even when referring to periods in the more distant past. The data from the two surveys were cross-checked; mismatches were followed up directly in the field. In total, we gathered information on 1,681 plantation plots owned by the sample households. Oil palm and rubber account for more than 95% of the total area cultivated by sample households.

In addition to the farm household survey, a village-level survey was carried out in the same villages in 2012 (Gatto *et al.*, 2015, 2017). The village survey focused on land-use changes and related institutional aspects at the village level covering three points in time, namely 1992, 2002, and 2012. During the farm household survey in 2015, we also updated some of the village-level data. We use selected variables from this village-level survey to explain land acquisition decisions by farm households.[5]

Based on the household survey data, four main pathways of land acquisition are identified. The last column of Table 1 shows that 49% of the plots presently cultivated with plantation crops were purchased in the land market, 18% were

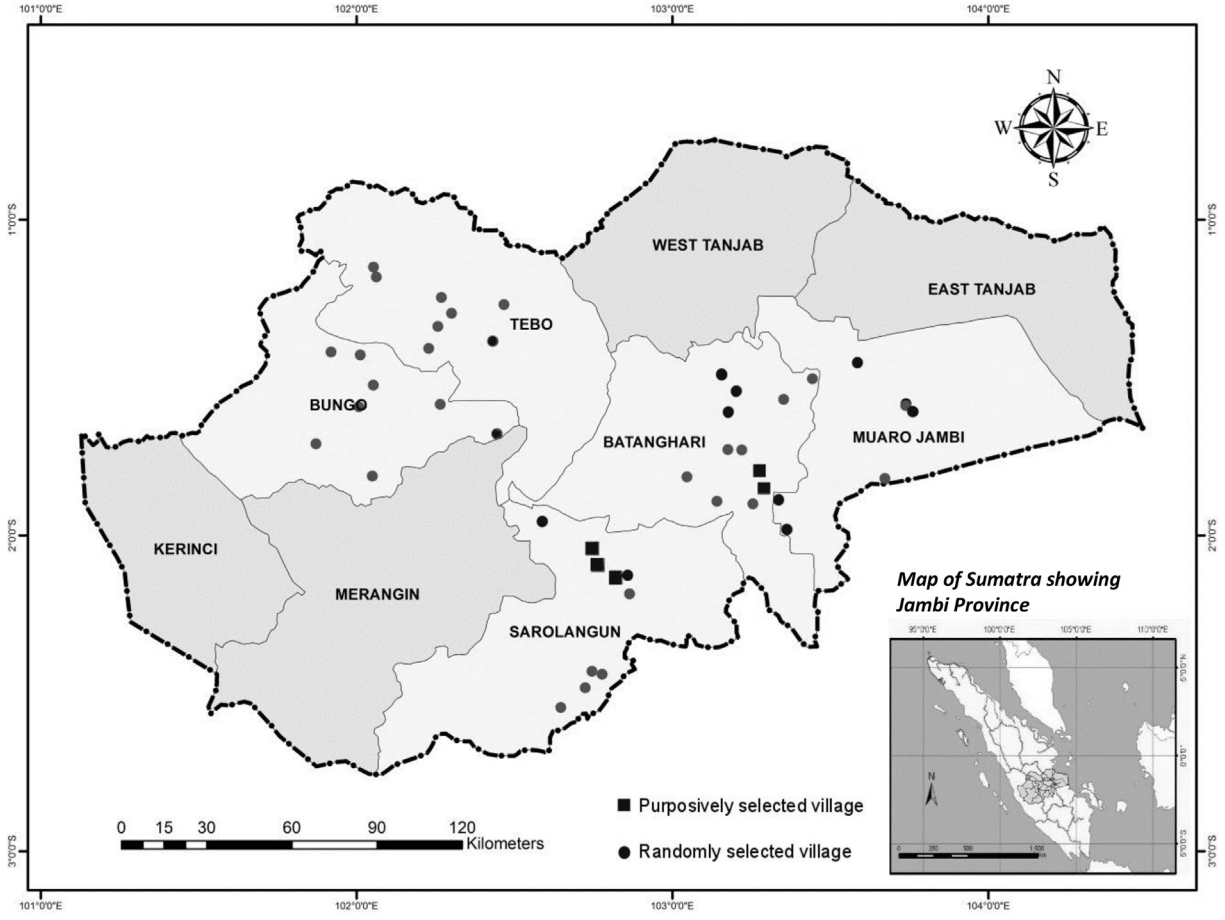

Figure 2. *Sample villages in Jambi Province.*

Table 1. *Pathways of land acquisition and land use at the time of acquisition*

		Land use at the time of land acquisition				Overall
		Crops	Grass and bush	Forest	No information	
Percentage of plots under different land uses at the time of acquisition						
Acquisition pathway	Market purchase	64.24	63.73	19.62	0.87	48.66
	Direct appropriation	0.30	0.41	71.53	0.00	18.02
	Government program	0.00	0.00	0.00	97.39	6.66
	Inheritance or inter–vivo transfer	30.30	33.81	8.61	1.74	23.97
	Other	5.15	2.05	0.24	0.00	2.68
	Overall	100.00	100.00	100.00	100.00	100.00
Mean (std. error) of plot size in hectares						
Acquisition pathway	Market purchase	2.27	2.45	3.35	1.50	2.45
		(0.12)	(0.13)	(0.80)		(0.11)
	Direct appropriation	2.50	1.25	2.58	—	2.57
		(0.50)	(0.75)	(0.13)		(0.13)
	Government program	—	—	—	1.80	1.80
					(0.10)	(0.10)
	Inheritance and inter–vivo transfer	1.92	1.60	1.73	1.25	1.77
		(0.11)	(0.09)	(0.17)	(0.75)	(0.07)
	Other	1.30	1.80	12.00	—	1.65
		(0.21)	(0.48)			(0.30)
	Overall	2.12	2.15	2.68	1.79	2.24
		(0.09)	(0.09)	(0.19)	(0.09)	(0.06)
Number of plots		*660*	*488*	*418*	*115*	*1681*

acquired through appropriation of forest land, 7% were allocated as part of government programs, especially the transmigration program, and 24% were obtained through inheritance or inter-vivo transfers. Table 1 also shows that the role of the different pathways varies by the type of land use at the time of land acquisition. For plots already cultivated with crops at the time of acquisition, market transactions and inheritance or inter-vivo transfers play the dominant role. The same holds true for grass and bush land. Grass and bush land, locally referred to as "sleeping land" (*lahan tidur*), is former forest land where the timber has already been extracted. [6] Unsurprisingly, forest land was primarily acquired through direct appropriation, although some forested plots were also purchased in the land market.

Figure 3 shows how the role of the different pathways of land acquisition has developed over time. Cumulative area shares are shown in Figure S1 (Supplementary Material). While a few plots had already been acquired before 1985, almost 90% of the area cultivated by farm households in 2015 was acquired after 1990. During the 1980s and early-1990s, around half of all the plots were acquired through direct forest land appropriation. Over time, land market transactions clearly gained in relative and absolute importance, reaching their peak during 2005–07. Possibly due to low market prices for rubber and palm oil in recent years, land market transactions declined after 2012. The area acquired through direct forest appropriation also declined more recently, pointing at increasing scarcity of forest land.

Figure 4 shows the changes in forest cover in Jambi Province since 1990 using remote sensing data combined with data on land market transactions from the household survey. The area covered with forest declined drastically. By 2012, most of the forest outside of protected conservation areas had vanished (Drescher *et al.*, 2016). During the same period, land market activities increased substantially. This could be an indication that the land deforested ends up being traded in the land market. However, it is not clear whether the existence of a land market caused deforestation.

5. EMPIRICAL METHODS

In this section, we describe the methods used to test the hypotheses that were developed in Section 3.

(a) *Testing of hypothesis 1*

To test whether households involved in forest land appropriation have different migration status and other socioeconomic characteristics than households involved in land purchases we use regression models with dummies for land acquisition pathways as dependent variables. Three dummy variables are defined to capture land ownership change during 1992–2015: $D_{1i} = 1$ if household i purchased land from the market (0 otherwise), $D_{2i} = 1$ if the household sold land in the market (0 otherwise), and $D_{3i} = 1$ if the household was involved in forest land appropriation (0 otherwise). [7] Households that were not involved in any of these activities after 1992 are excluded from the analysis. To account for possible error term correlation between the three equations, we employ a multivariate probit model:

$$D_{1i} = f(\boldsymbol{x}_i) + \varepsilon_i \tag{1a}$$

$$D_{2i} = g(\boldsymbol{x}_i) + \upsilon_i \tag{1b}$$

$$D_{3i} = h(\boldsymbol{x}_i) + \omega_i \tag{1c}$$

where $\boldsymbol{x}_i$ is a vector of household socioeconomic characteristics that may influence decisions on land acquisition and sales. We are particularly interested in the roles of migration and ethnicity, although we control for a broader set of socioeconomic factors. The error terms ε_i, υ_i, and ω_i are assumed to be identically distributed as bivariate normal with zero mean and unit variance.

The hypothesis of exogeneity of $D_j (j = 1, 3)$ is tested as $H_0 : \rho_1 = 0$, and for $D_j (j = 2, 3)$ as $H_0 : \rho_2 = 0$. Here, ρ_1 and ρ_2 are the correlation coefficients between ε_i and ω_i, and

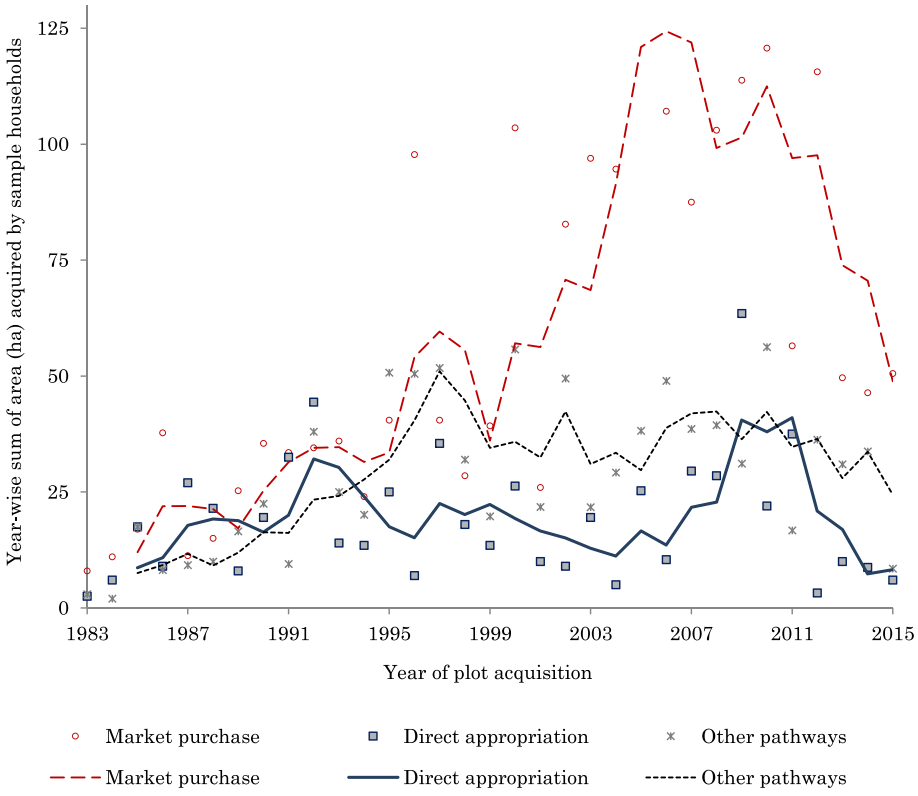

Figure 3. *Cultivated land acquired through different pathways over time. Notes: Total number of plots under cultivation by sample households in 2015: 1681. Aggregated cultivated area: 3770 ha. Trend lines were calculated with three-year moving averages.*

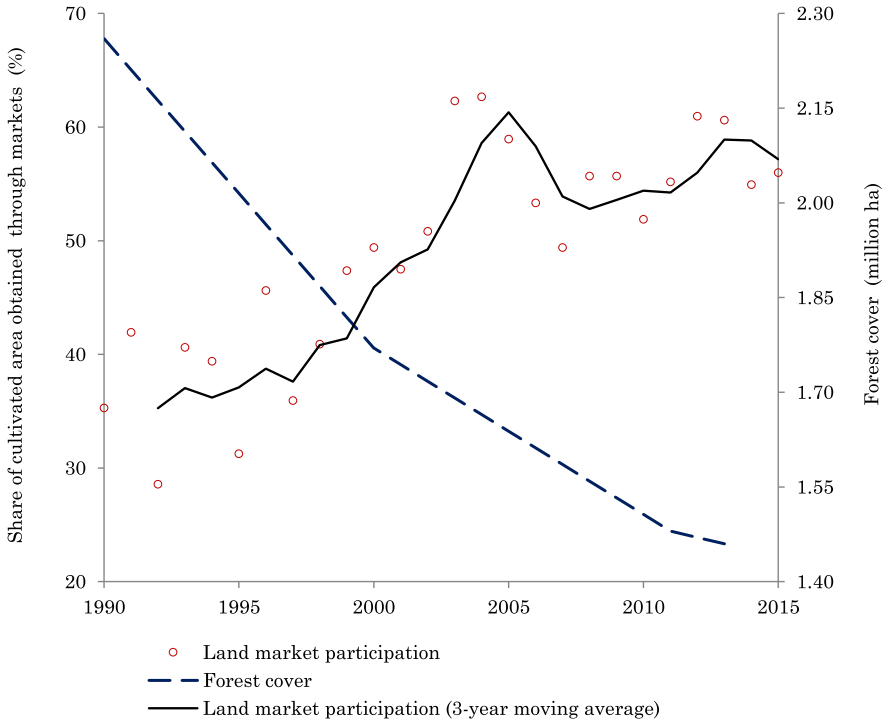

Figure 4. *Change in forest cover and land market activity in Jambi. Notes: Forest cover changes are derived from Drescher et al. (2016) and land market activity from authors' household survey data.*

between υ_i and ω_i, respectively. Significant coefficient estimates for $\boldsymbol{x}_i$ and differences between the three equations would lead to non-rejection of hypothesis 1. Furthermore, a negative estimate for ρ_1 would indicate that land purchase and forest land appropriation activities are less likely to occur in the same households.

In addition to this model at the household level, we also estimate a probit model at the plot level. For the plot-level model, we define $D_{4pi} = 1$ if household i purchased plot p from the market, and 0 if the plot was acquired through direct forest appropriation. Plots that were acquired already before 1992 or were obtained through other pathways are excluded from this model. Since several households acquired more than one plot during the 1992–2015 period, unobserved household characteristics could lead to intra-class correlation. To adjust the model to the data structure we use a multilevel mixed-effects probit (MMEP) with random intercepts ϑ_i at the household level, as follows (Snijders & Bosker, 1999).[8]

$$D_{4pi} = h(\boldsymbol{x}_i, \boldsymbol{z}_{pi}) + \vartheta_i + u_{pi} \quad (2)$$

where $\boldsymbol{z}_{pi}$ is a vector of plot-level characteristics such as distance to the farm households' place of residence. Again, we are particularly interested in the coefficient estimates for $\boldsymbol{x}_i$. Statistical significance would mean that socioeconomic characteristics matter for the land acquisition pathway, even after controlling for plot-level differences. This would further support hypothesis 1.

(b) *Testing of hypotheses 2a and 2b*

To test whether appropriated land is undervalued in the market such that own cultivation would be more lucrative than selling the land (hypothesis 2b), we compare land market prices reported by farm households in our sample (adjusted for inflation) with financial gains from oil palm and rubber cultivation, as reported by Euler, Krishna, Schwarze, Siregar, and Qaim (2017) and Krishna, Euler, Siregar, and Qaim (2017) for Jambi Province. To test whether the undervaluation of land in the market is due to the lack of *de jure* property rights protection (hypothesis 2a), we compare land market prices with and without land titles at the time of plot acquisition. For the titled land, we differentiate between systematic and sporadic titles. Significantly higher prices for titled land would support hypothesis 2a.

We also estimate hedonic regression models to get further insights into what determines land prices in the market. The hedonic regression analysis only considers those plots that were actually traded in the market. We apply a power transformation to the data as proposed by Box and Cox (1964). Using a Box-Cox transformation following land valuation studies (e.g., Snyder, Kilgore, Hudson, & Donnay, 2007; Standiford & Scott, 2008), the market price is regressed on a time variable and a vector of plot characteristics, such as plot size, location, and previous land use at the time of the transaction as well as a variable indicating the degrees of tenure security. In a separate model, international market prices of rubber and palm oil are also used as explanatory variables, as these are expected to influence the land rent, which in turn is assumed to be a key determinant of the market value of land. Prices that local farm households receive for their harvest are different from international market prices due to transaction and processing costs and exploitation of market power by local traders and companies. Nevertheless, a strong correlation between farm-gate prices in Jambi and international market prices is observed (Kopp, Alamsyah, Fatricia, & Brümmer, 2014). Average export prices of palm oil and rubber for the three years prior to the land transaction are used as proxies for the expected land rent.

Confirmation of hypotheses 2a and 2b would suggest that the evolution of land markets has not significantly contributed to forest land appropriation, due to the specific institutional context with weak property protection. To gain further insights into this relationship, we also look at the direct correlation between land market developments and deforestation at the village level. Data on deforestation are taken from the village-level survey: deforestation is measured in terms of the net permanent change in forest land during the period 1992–2002. Land market developments are based on the farm household survey. We measure the share of plots transacted in the market relative to the total number of plots acquired by farm households living in a particular village for two time periods, namely 1992–2015 and 2002–2015. Insignificant correlation coefficients would suggest that land market developments and deforestation are not directly related.

6. RESULTS AND DISCUSSION

(a) *Analysis of land acquisition decisions*

To analyze whether farm households involved in forest land appropriation are different from those who acquired land through the land market (hypothesis 1), we use a multivariate probit model at the household level, as explained above. Key results are shown in Table 2 (full estimation results are shown in Table S2 in the Supplementary Material). The time variable (time of acquisition of first plot) indicates that households that started agricultural production more recently are less likely to be involved in forest land appropriation (Eqn. (1c)) or land sales (Eqn. (1b)), whereas the effect on the probability of land purchases (Eqn. (1a)) is not statistically significant. One main factor that prevents newly established farm households from forest land appropriation is the reduced availability of forests in the immediate village surroundings. Decentralization policy after 1999 probably plays a lesser role, because regional governments still only have minor authority in terms of forest planning (Susanti & Budidarsono, 2014).

The results also confirm that aspects related to migration and ethnicity play an important role for households' land acquisition decisions. Households that migrated to one of the transmigrant villages are more likely to acquire land from the market and less likely to be involved in forest land appropriation than autochthonous households. One reason is that transmigrant villages were artificially created through the government's transmigration program during the 1980s and 1990s. In these villages, community structures are less traditional, and customary land claims over forest land do not apply to the same extent as in autochthonous villages. Another reason why land market transactions are more common in transmigrant villages is that most of the transmigrant households have formal titles for the land allocated to them by the government. Formal land titles facilitate later sales.

But even in autochthonous villages, migrants are more likely to acquire land through market purchase, because people coming from outside the community cannot easily obtain *de facto* property rights for appropriated forest land. This is also supported by the statistical significance of estimation coefficients for Javanese and Sundanese ethnicities, both originating from Java. Farm households belonging to these ethnicities are more likely to purchase land (Eqn. (1a)) and less likely to appropriate forest land (Eqn. (1c)). The reference ethnicity in this model is the autochthonous Melayu population, which

Table 2. *Determinants of land market transaction and direct forest land appropriation by farm households during 1992–2015*

Explanatory variables (unit)	Multivariate probit at household level			Multi-level probit at plot level
	Eqn. (1a): Land purchase [1 = purchased from market; 0 = otherwise]	Eqn. (1b): Land sale [1 = sold in the market; 0 = otherwise]	Eqn. (1c): Appropriation [1 = direct forest appropriation; 0 = otherwise]	Eqn. (2): Acquisition pathway [1 = plot purchased from the market 0 = plot acquired through direct forest appropriation]
Time of acquisition of first plot of household [year]	0.016	−0.047***	−0.067***	0.065**
	(0.011)	(0.017)	(0.015)	(0.022)
Household head's education [years of formal education]	0.007	0.021	0.029	−0.016
	(0.017)	(0.024)	(0.021)	(0.042)
Household migrated to transmigrant village [dummy]	0.483***	0.376	−0.747***	2.380***
	(0.187)	(0.267)	(0.263)	(0.637)
Household migrated to autochthonous/ traditional village [dummy]	0.344**	0.298	−0.051	0.528
	(0.157)	(0.235)	(0.187)	(0.385)
Javanese or Sundanese ethnicity [dummy]	0.418***	−0.169	−0.316*	1.243**
	(0.152)	(0.227)	(0.186)	(0.432)
Altitude of place of residence [meters]	4.E−04	−0.003	−0.009*	
	(0.003)	(0.004)	(0.004)	
Household wealth [number of bedrooms at the time of household establishment]	0.095	−0.041	0.062	0.007
	(0.070)	(0.099)	(0.086)	(0.172)
Household belongs to any of the purposively selected villages [dummy]	0.607***	0.332	−0.386	1.959**
	(0.223)	(0.283)	(0.262)	(0.636)
Presence of forest in the village in 1992 [dummy]	−0.225	0.203	0.627***	−1.375**
	(0.166)	(0.236)	(0.223)	(0.519)
Correlation of error term with that in Eqn. (1c)	−0.291*** (0.092)	0.147 (0.111)	–	
Number of observations	483		729	
Log-likelihood	−627.491		−278.488	
Wald χ^2 statistic	126.484***		29.58**	

Notes: Figures in parentheses show std. errors. $^{***}p \leq 0.01$, $^{**}p \leq 0.05$, $^{*}p \leq 0.10$. Full model results with additional explanatory variables included are shown in Table S2 (Supplementary Material).

Table 3. *Average land market prices across land use and land title at the time of acquisition*

	Number of plots	Median market price [million IDR per ha]	Test statistic for equality of median prices[#]
Plantation crops			
Systematic title	72	41.63	
Sporadic title	32	30.32	
Absence of formal title	158	20.41	
Overall	262	25.55	10.96***
Grass and bush land			
Systematic title	24	11.94	
Sporadic title	24	10.23	
Absence of formal title	160	7.53	
Overall	208	8.00	2.27
Forest			
Systematic title	6	8.77	
Sporadic title	4	2.46	
Absence of formal title	42	4.66	
Overall	52	4.90	3.76

Notes: Plantation crops include oil palm and rubber. [#]To test the difference between the land prices across different land title categories, a non-parametric k-sample test statistic on equality for medians was estimated. ***$p \leq 0.01$. 1 US $ = 9.37 thousand IDR in 2012 and 13.39 IDR in 2015 (World Bank, 2016).

is more likely to appropriate forest land as a legitimate strategy for securing *de facto* property rights under communal law.[9] The negative correlation between the error terms in Eqns. (1a) and (1c), which is shown in the bottom part of Table 2, also suggests that households involved in land purchase are mostly not the same as those involved in forest land appropriation.

One other result worth highlighting is the positive and significant coefficient of the presence of forest in the village in 1992 in Eqn. (1c). Having forest in the village increases the probability of deforestation activities. At the same time, the forest variable is not significant in Eqn. (1b), suggesting that there is no association with the probability of land sales. The correlation between the error terms in Eqns. (1b) and

Table 4. *Hedonic models of land prices (1992–2015)*

	Model (a)	Model (b)	Model (c)
Year of transaction [1992 = 0, .., 2015 = 23]	0.087*** (0.014)	−0.063 (0.058)	
Square of year of transaction		0.006*** (0.002)	
Change in export price of palm oil from previous year [%]			0.008*** (0.003)
Change in export price of rubber from previous year [%]			−0.014*** (0.004)
Interaction: Change in export price of palm oil × Change in export price of rubber			4.E−04*** (1.E−04)
Plot characteristics			
Land use at time of transaction			
Plantation crops [oil palm or rubber, dummy]	1.522*** (0.173)	1.223*** (0.460)	1.633*** (0.172)
Interaction: Plantation crops × Year of transaction		0.020 (0.031)	
Forest [dummy]	−0.555* (0.296)	−0.752 (0.664)	−0.603** (0.293)
Interaction: Forest × Year of transaction		0.012 (0.049)	
Possession of land titles at the time of transaction [dummies, reference: having no titles]			
Systematic	0.546** (0.234)	0.567** (0.236)	0.445** (0.233)
Sporadic	0.232 (0.268)	0.195 (0.270)	0.317 (0.267)
Buyer characteristics			
Household head's education [years of schooling]	0.032 (0.024)	0.032 (0.024)	0.050** (0.023)
Javanese and Sundanese ethnicity [dummy]	0.764*** (0.207)	0.728*** (0.209)	0.652*** (0.205)
Migrant to transmigrant villages [dummy]	−0.274 (0.244)	−0.253 (0.246)	−0.237 (0.242)
Migrant to non-transmigrant villages [dummy]	−0.052 (0.232)	−0.039 (0.234)	−0.010 (0.231)
Village characteristics			
Village with no forest in 1992 [dummy]	1.072*** (0.292)	1.069*** (0.294)	1.079*** (0.289)
Village with more than 50% forest loss during 1992–2002 [dummy]	0.295 (0.240)	0.294 (0.242)	0.411* (0.238)
Box-Cox transformation parameter, θ	0.189*** (0.021)	0.194*** (0.022)	0.180*** (0.022)
Test for $\theta = -1$ (inverse function)	3555.81***	−4085.58***	3387.77***
$\theta = 0$ (log function)	81.09***	−2346.33***	69.24***
$\theta = +1$ (linear function)	1012.2***	−2808.73***	1001.65***
Log-likelihood	−2308.17	−2304.02	−2222.11
LR χ^2	228.43***	236.74***	218.08***
Number of observations	581	581	562

Notes: Figures in parentheses show std. errors. ***$p \leq 0.01$, **$p \leq 0.05$, *$p \leq 0.10$. Full model results with additional explanatory variables included are shown in Table S5 (Supplementary Material).

(1c) is insignificant, suggesting that decisions to appropriate forest land and to sell land in the market are unrelated.

Complementing the household-level analysis, we also estimate a multi-level probit model at the plot level, explaining the factors that influence whether a plot was either purchased in the market or acquired through direct forest appropriation. Key results from this multi-level probit model are shown in the last column of Table 2 (full results are shown in Table S2 in the Supplementary Material). The results are consistent with those from the household-level analysis. For example, the positive and significant coefficient for the time of acquisition variable confirms that the role of market transactions increased over time, while direct forest appropriation became less relevant. Moreover, migrants from Java are more likely to acquire a plot through market purchase than autochthonous Melayu households, even after controlling for plot location and other characteristics.

The models in Table 2 were estimated using observations from all households surveyed in 2012 and 2015. As explained above, some attrition occurred during the second survey round. To test whether attrition leads to any systematic bias, we re-estimated the models including observations only from those households that were interviewed in both survey rounds. These results are shown in Table S3 (Supplementary Material). In Table S4 (Supplementary Material), we re-estimated the models with all observations but additionally including village fixed effects. [10] These additional results are very similar to those in Table 2, which underlines the robustness of the findings.

(b) *Analysis of land prices*

To test whether the lack of *de jure* property rights for appropriated forest land leads to undervaluation in the land market (hypothesis 2a), we compare prices observed in market transactions for land with different degrees of property protection. Results are shown in Table 3 (prices referring to different points in time are adjusted for inflation). As the type of land use on a plot at the time of the transaction can also affect prices, we differentiate between plantation crops (oil palm and rubber), grass and bush land, and forest. The comparisons show that land under plantation crops fetches the highest average prices in the market, followed by grass and bush land, and then forest land. More importantly, in all three categories, land with systematic land titles is priced higher than land with only sporadic titles or no titles at all. Due to the small number of observations in some of the categories, not all of the differences are statistically significant, but the patterns observed clearly suggest that *de jure* property rights affect land market prices. We will return to this issue below.

The average market price for grass and bush land, the typical state where farm households decide whether to establish a plantation or to sell the plot, is calculated at 8 million Indonesian Rupiah (IDR) (US$ 597) per hectare in 2015 prices, which is significantly below the financial gains from oil palm and rubber plantations (Euler *et al.*, 2017; Krishna *et al.*, 2017). [11] One of the most plausible explanations for the undervaluation of land in the market is weak tenure security. In 2015, only about 50% of all plots in our sample had a formal land title (either systematic or sporadic). While *de facto* property right protection under customary law might provide sufficient internal tenure security for autochthonous households, it is insufficient to attract potential buyers, who are predominantly migrants, to the market. The property rights regulations in Jambi may not prevent forest land appropriation for own use by autochthonous households, but they do not seem to encourage forest appropriation for selling land in the market. [12]

We use hedonic regression models to further analyze the factors influencing land market prices. Key results are shown in Table 4 for three different model specifications (full models are shown in Table S5 in the Supplementary Material).

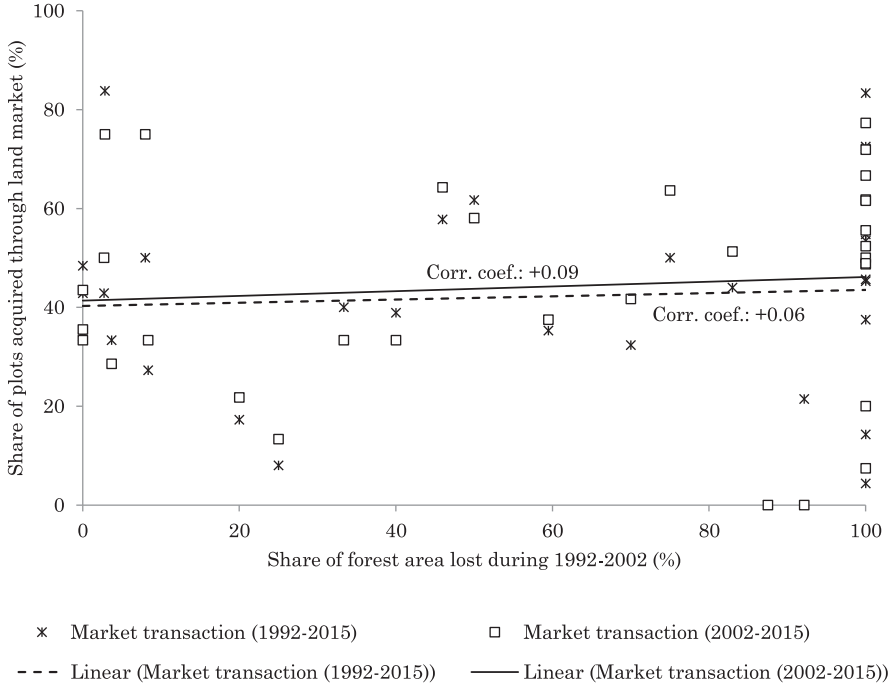

Figure 5. *Correlation between deforestation and market development at the village level. Notes: Number of village observations = 32. Correlation coefficients are statistically insignificant ($p > 0.10$). Forest area lost (horizontal axis) refers to state- and community-owned forest land.*

Regardless of the exact specification, plots with a systematic land title at the time of transaction are priced significantly higher than plots without any land title, which is further confirmation of hypothesis 2a. The coefficients for sporadic land titles are also positive, but not statistically significant. Also across the different model specifications, the type of land use on a plot at the time of transaction matters, with plantation land fetching higher prices than grass and bush land. The results further suggest that Javanese and Sundanese buyers pay higher prices per hectare of land than autochthonous households, holding other factors constant.

Looking more specifically at the different specifications in Table 4, the time trend in model (a) suggests that land prices increased over time during 1992–2015. However, results in model (b), which additionally includes a square term of the time trend, reveal that land market prices first decreased and then increased, with a turning point in 2002. In model (c), instead of the time trend we include information on the development of commodity export prices. As export prices for palm oil and natural rubber are closely correlated, we use percentage price changes relative to previous years to avoid multicollinearity. The estimates show that international commodity price developments significantly affect local land prices and thus land use decisions, which was also observed in other settings (e.g., Meyfroidt, Phuong, & Anh, 2013).

(c) *Links between land markets and deforestation*

The multivariate probit estimates above showed that — while the presence of forest in the village in 1992 was associated with a higher probability of deforestation — the variable was not significantly associated with households' decisions to participate in the land market as buyer or seller. We also found that the existing land markets and property rights regulations provide little incentive for strategic deforestation aimed at selling appropriated forest land. To conclude, we examine the meso-level patterns of land market development and deforestation, using the sub-sample of 32 villages that had state, communal, or private forests in 1992. While market transactions of forest land are not often observed in Jambi Province, there could be indirect effects of land markets on forest cover (e.g., by inducing speculative trading of land). We use simple correlation analysis to analyze possible associations. In Figure 5, deforestation rates during 1992–2002 are plotted against land market developments during 1992–2015 and 2002–15. The correlation coefficients are small and statistically insignificant, suggesting that the evolution of land markets has neither promoted nor deterred the deforestation rate in Jambi.

7. CONCLUSION

We have analyzed the relationship between evolving land markets and forest land appropriation in Sumatra, Indonesia, over the period 1992–2015. If land market transactions had a direct and positive influence on the decision of farm households to appropriate forest land, this would support the hypothesis that land market developments contribute to deforestation with immediate policy implications. However, we did not find evidence for this type of relationship.

Households involved in land market purchases differ from households involved in appropriating forest land in terms of their migration status, ethnicity, and other socioeconomic characteristics. In principle, these differences provide opportunities for Pareto-improving land market transactions that could entail further deforestation. But we found that appropriated forest land is not extensively traded in the market, which we largely attribute to weak property right protection. In the absence of *de jure* property rights, appropriated forest land is undervalued in the market, so that own cultivation of plantation crops on this land is much more lucrative than selling the land. While around 70% of Indonesia's land territory is legally declared as state forest land, a large part of this land is occupied by farm households claiming land rights under customary law. This legal ambiguity contributes to weak *de jure* property rights.

We conclude that land markets did not have significant effects on forest land appropriation and deforestation by farm households in Jambi Province. Instead, our data suggest that forest land appropriation and deforestation were primarily instigated by a booming export sector and facilitated by legal ambiguity and high internal tenure security for appropriated land.

The Indonesian government has ongoing programs to provide formal land titles for privately owned land. This could potentially contribute to more deforestation in the future, especially when global demand for palm oil and rubber continues to rise. Both stronger property rights and rising global demand could lead to upward shifts in land prices, which would provide new incentives for local communities to sell their land and appropriate new plots through forest encroachment. Alongside land titling programs, it will therefore be crucial to clearly demarcate the forest land together with local communities and establish effective monitoring systems to reduce encroachment activities. Such processes could build the foundation for land markets that contribute to effective and secure allocation of land resources without negatively affecting forest cover.

CONTRIBUTIONS TO THE MANUSCRIPT

VVK, UP, and MQ have developed the concept and design of the study; VVK and CK have collected, analyzed, and interpreted the data; VVK, CK, UP, and MQ have written the manuscript; all authors have approved the final version of the manuscript.

NOTES

1. The shadow price of land is determined not only by the marginal revenue function of agricultural production, but also by the households' managerial ability and constraints in labor, credit, and land markets (Deininger & Feder, 2001).

2. Regencies are second-level administrative subdivisions in Indonesia, below the provinces and above the districts (Turner, Podger, Sumardjono, & Tirthayasa, 2003).

3. Further details of the sampling procedure are provided by Drescher, Rembold, Allen, *et al.* (2016).

4. Forty-one households covered in 2012 could not be re-interviewed in 2015, mostly due to outmigration (23 households), refusal to be interviewed again (10 households), and death or old age of respondents (4 households).

5. Summary statistics for key variables from the farm household and village-level surveys are shown in Table S1 (Supplementary Material).

6. Bush land is sometimes difficult to distinguish from degraded forest. In some statistics in Indonesia, land with more than 60% canopy tree cover is classified as forest, whereas land with 25–60% canopy tree cover is classified as bush land (Romijn *et al.*, 2013). However, with this classification even some of the plantation crops qualify as forest land. Here, we classify a plot as grass and bush land if timber extraction was completed. In contrast, plots where forest trees still existed are classified as forest land. This classification builds on the responses during the farm household survey.

7. We do not use dummies for land inheritance or inter-vivo transfers as these pathways are of lesser importance for land markets and deforestation.

8. The MMEP model with random intercepts for each household also accounts for heteroscedastic standard errors due to clustering at the household level. The estimated intra-class correlation coefficient is +0.81, demonstrating strong correlation between plots belonging to the same households.

9. Similar differences between ethnicities in terms of communal land rights were also observed elsewhere (Angelsen, 2001; Angelsen & Kaimowitz, 1999; Araujo *et al.*, 2009; Mendelsohn, 1994).

10. We also considered using household fixed effects for the plot-level model, but then decided that this would not be useful in our case for two reasons. First, the number of households that acquired more than one plot during the period of observations is relatively small. Second, most of the explanatory variables of interest (migration status, ethnicity etc.) are time-invariant, so they would drop out when using household fixed effects.

11. The calculation of financial gains from plantation crops depends on the discount rate used, and also on market prices of inputs and outputs and other factors that can vary over time. However, the difference between the mean market price of untitled bush land (7.5 million IDR per ha) and the financial gain of a mature oil palm plantation (Krishna *et al.* (2017) report 14 million IDR in one year) is so large that reasonable changes in prices and discount rates will not reverse the comparison.

12. Despite the higher financial returns from land under plantation crops, about 29% of the sample households had sold part of their land at some point in time. During the interviews, many of them indicated that they did so for reasons of financial distress rather than profit-maximizing objectives.

REFERENCES

Alston, L. J., Libecap, G. D., & Schneider, R. (1996). The determinants and impact of property rights: Land titles on the Brazilian frontier. *The Journal of Law, Economics, and Organization, 12*(1), 25–61.

Angelsen, A. (2001). Playing games in the forest: State-local conflicts of land appropriation. *Land Economics, 77*(2), 285–299.

Angelsen, A. (2010). Policies for reduced deforestation and their impact on agricultural production. *Proceedings of the National Academy of Sciences USA, 107*(46), 19639–19644.

Angelsen, A., & Kaimowitz, D. (1999). Rethinking the causes of deforestation: Lessons from economic models. *World Bank Research Observer, 14*(1), 73–98.

Araujo, C., Bonjean, C. A., Combes, J.-L., Motel, C. P., & Reis, E. J. (2009). Property rights and deforestation in the Brazilian Amazon. *Ecological Economics, 68*(8), 2461–2468.

Barbier, E. B. (2001). The economics of tropical deforestation and land use: An introduction to the special issue. *Land Economics, 77*(2), 155–171.

Barraclough, S. L. (2013). *Agricultural expansion and tropical deforestation: International trade, poverty and land use*. New York: Earthscan.

Bhattarai, M., & Hammig, M. (2001). Institutions and the environmental Kuznets curve for deforestation: A cross-country analysis for Latin America, Africa and Asia. *World Development, 29*(6), 995–1010.

Boserup, E. (1965). *The conditions of agricultural growth: The economics of agrarian change under population pressure*. London: Earthscan Publication Limited.

Box, G. E., & Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society Series B, 26*(2), 211–252.

Clough, Y., Krishna, V. V., Corre, M. D., *et al.* (2016). Land-use choices follow profitability at the expense of ecological functions in Indonesian smallholder landscapes. *Nature Communications, 7*, 13137.

Deininger, K., & Feder, G. (2001). Land institutions and land markets. In B. Gardner, & G. Rausser (Eds.). *Handbook of Agricultural Economics* (Vol. 1, pp. 288–331). Amsterdam: Elsevier.

Deininger, K., Zegarra, E., & Lavadenz, I. (2003). Determinants and impacts of rural land market activity: Evidence from Nicaragua. *World Development, 31*(8), 1385–1404.

Deininger, K., & Jin, S. (2008). Land sales and rental markets in transition: Evidence from rural Vietnam. *Oxford Bulletin of Economics and Statistics, 70*(1), 67–101.

Deininger, K., Jin, S., & Nagarajan, H. K. (2009). Determinants and consequences of land sales market participation: Panel evidence from India. *World Development, 37*(2), 410–421.

de Janvry, A., & Sadoulet, E. (2001). *Access to land and land policy reforms. Policy Brief No. 3*. Helsinki, Finland: The United Nations University World Institute for Development Economics Research.

Drescher, J., Rembold, K., Allen, K., *et al.* (2016). Ecological and socioeconomic functions across tropical land-use systems after rainforest conversion. *Philosophical Transactions of the Royal Society B, 371*, 20150275.

Euler, M., Schwarze, S., Siregar, H., & Qaim, M. (2016). Oil Palm expansion among smallholder farmers in Sumatra, Indonesia. *Journal of Agricultural Economics, 67*, 658–676.

Euler, M., Krishna, V. V., Schwarze, S., Siregar, H., & Qaim, M. (2017). Oil palm adoption, household welfare, and nutrition among smallholder farmers in Indonesia. *World Development, 93*, 219–355.

FAO (2010). *Global forest resources assessment 2010. Forestry Paper 140* (p. 378). Rome, Italy: Food and Agriculture Organization of the United Nations.

Fenske, J. (2011). Land tenure and investment incentives: Evidence from West Africa. *Journal of Development Economics, 95*(2), 137–156.

Fitzpatrick, D. (1997). Disputes and pluralism in modern Indonesian land law. *Yale Journal of International Law, 22*(1), 170–212.

Fitzpatrick, D. (2006). Evolution and chaos in property rights systems: The third world tragedy of contested access. *Yale Law Journal, 115*(5), 996–1048.

Gatto, M., Wollni, M., Asnawi, R., & Qaim, M. (2017). Oil palm boom, contract farming, and rural economic development: Village-level evidence from Indonesia. *World Development, 95*, 127–140.

Gatto, M., Wollni, M., & Qaim, M. (2015). Oil palm boom and land use dynamics in Indonesia: the role of policies and socioeconomic factors. *Land Use Policy, 46*, 292–303.

Geist, H. J., & Lambin, E. F. (2002). Proximate causes and underlying driving forces of tropical deforestation. *BioScience, 52*(2), 143–150.

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences USA, 107*(38), 16732–16737.

Godoy, R., Kirby, K., & Wilkie, D. (2001). Tenure security, private time preference, and use of natural resources among lowland Bolivian Amerindians. *Ecological Economics, 38*(1), 105–118.
Grimm, M., & Klasen, S. (2015). Migration pressure, tenure security, and agricultural intensification: Evidence from Indonesia. *Land Economics, 91*(3), 411–434.
Haverfield, R. (1999). 'Hak ulayat' and the state: Land reform in Indonesia. In T. Lindsey (Ed.), *Indonesia: Law and society*. Sydney: The Federation Press.
Hertel, T. W., Ramankutty, N., & Baldos, U. L. C. (2014). Global market integration increases likelihood that a future African Green Revolution could increase crop land use and CO_2 emissions. *Proceedings of the National Academy of Sciences USA, 111*(38), 13799–13804.
Holden, S. T., Otsuka, K., & Place, F. M. (2009). Understanding land markets: Questions and hypotheses. In S. T. Holden, K. Otsuka, & F. M. Place (Eds.), *The emergence of land markets in Africa* (pp. 18–56). Washington DC: Resources for the Future.
Indrarto, G. B., Murharjanti, P., Khatarina, J., Pulungan, I., Ivalerina, F., Rahman, J., Prana, M. N., Resosudarmo, I. A. P., & Muharrom, E. (2012). The context of REDD+ in Indonesia: drivers, agents and institutions. CIFOR Working Paper 92, Bogor, Indonesia: Center for International Forestry Research.
Johnson, K. A., & Nelson, K. C. (2004). Common property and conservation: The potential for effective communal forest management within a national park in Mexico. *Human Ecology, 32*(6), 703–733.
Kissinger, G., Herold, M., & De Sy, V. (2012). *Drivers of deforestation and forest degradation: A synthesis report for REDD+ policymakers* (p. 47). Vancouver Canada: Lexeme Consulting.
Kopp, T., Alamsyah, Z., Fatricia, R. S., & Brümmer, B. (2014). Have Indonesian rubber processors formed a cartel? Analysis of intertemporal marketing margin manipulation. EFForTS Discussion Paper Series No. 3, Goettingen, Germany: University of Goettingen.
Krishna, V. V., Euler, M., Siregar, H., & Qaim, M. (2017). Differential livelihood impacts of oil palm expansion in Indonesia. *Agricultural Economics*. http://dx.doi.org/10.1111/agec.12363, in press.
Kunz, Y., Hein, J., Mardiana, R., & Faust, H. (2016). Mimicry of the legal: Translating de jure land formalization processes into de facto local action in Jambi province, Sumatra. *Austrian Journal of South-East Asian Studies, 9*(1), 127–146.
Lawry, S., Samii, C., Hall, R., Leopold, A., Hornby, D., & Mtero, F. (2016). The impact of land property rights interventions on investment and agricultural productivity in developing countries. A systematic review. *Journal of Development Effectiveness*, 1–21.
Lee, J. S. H., Abood, S., Ghazoul, J., Barus, B., Obidzinski, K., & Koh, L. P. (2014). Environmental impacts of large-scale oil palm enterprises exceed that of smallholdings in Indonesia. *Conservation Letters, 7*(1), 25–33.
Lindsey, T. (1998). Square pegs and round holes: Fitting modern title into traditional societies in Indonesia. *Pacific Rim Law & Policy Association, 7*, 699–719.
Liscow, Z. D. (2013). Do property rights promote investment but cause deforestation? Quasi-experimental evidence from Nicaragua. *Journal of Environmental Economics and Management, 65*, 241–261.
Margono, B. A., Turubanova, S., Zhuravleva, I., Potapov, P., Tyukavina, A., Baccini, A., ... Hansen, M. C. (2012). Mapping and monitoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010. *Environmental Research Letters, 7*(3), 034010.
Mendelsohn, R. (1994). Property rights and tropical deforestation. *Oxford Economic Papers, 46*, 750–756.
Meyfroidt, P., Lambin, E. F., Erb, K.-H., & Hertel, T. W. (2013). Globalization and land use: distant drivers of land change and geographic displacement of land use. *Current Opinion on Environmental Sustainability, 5*, 1–7.
Meyfroidt, P., Phuong, V. T., & Anh, H. V. (2013). Trajectories of deforestation, coffee expansion and displacement of shifting cultivation in the Central Highlands of Vietnam. *Global Environmental Change, 23*, 1187–1198.
MoF (2009). *Eksekutif data strategis kehutanan 2009*. Jakarta: Ministry of Forestry, Government of Indonesia.
Peluso, N. L. (2005). Seeing property in land use: Local territorializations in West Kalimantan, Indonesia. *Geografisk Tidsskrift-Danish Journal of Geography, 105*(1), 1–15.
Phelps, J., Carrasco, L. R., Webb, E. L., Koh, L. P., & Pascual, U. (2013). Agricultural intensification escalates future conservation costs. *Proceedings of the National Academy of Sciences USA, 110*(19), 7601–7606.
Place, F., & Otsuka, K. (2001). Population, tenure, and natural resource management: The case of customary land area in Malawi. *Journal of Environmental Economics and Management, 41*, 13–32.
Platteau, J.-P. (1996). The evolutionary theory of land rights as applied to Sub-Saharan Africa: A critical assessment. *Development and Change, 27*, 29–86.
Pülzl, H., & Rametsteiner, E. (2002). Grounding international modes of governance into National Forest Programmes. *Forest Policy and Economics, 4*(4), 259–268.
Reerink, G., & van Gelder, J. L. (2010). Land titling, perceived tenure security, and housing consolidation in the kampongs of Bandung, Indonesia. *Habitat International, 34*(1), 78–85.
Resosudarmo, I. A. P., Atmadja, S., Ekaputri, A. D., Intarini, D. Y., Indriatmoko, Y., & Astri, P. (2013). Does tenure security lead to REDD+ project effectiveness? Reflections from five emerging sites in Indonesia. *World Development, 55*, 37–52.
Robinson, B. E., Holland, M. B., & Naughton-Treves, L. (2014). Does secure land tenure save forests? A meta-analysis of the relationship between land tenure and tropical deforestation. *Global Environmental Change, 29*, 281–293.
Romijn, E., Ainembabazi, J. H., Wijaya, A., Herold, M., Angelsen, A., Verchot, L., & Murdiyarso, D. (2013). Exploring different forest definitions and their impact on developing REDD+ reference emission levels: A case study for Indonesia. *Environmental Science & Policy, 33*, 246–259.
Slaats, H., Rajagukguk, E., Elmiyah, N., & Safik, A. (2009). Land law in Indonesia. In J. M. Ubink, A. J. Hoekema, & W. J. Assies (Eds.), *Legalizing land rights: local practices, state responses and tenure security in Africa, Asia and Latin America*. Leiden: Leiden University Press.
Snijders, T. A. B., & Bosker, R. J. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modelling*. New York: Sage Publications.
Snyder, S. A., Kilgore, M. A., Hudson, R., & Donnay, J. (2007). Determinants of forest land prices in northern Minnesota: a hedonic pricing approach. *Forest Science, 53*(1), 25–36.
Standiford, R. B., & Scott, T. (2008). Value of oak woodlands and open space on private property values in southern California. *Forest Systems, 10*(3), 137–152.
Streck, C. (2009). Rights and REDD+: Legal and regulatory consideration. In A. Angelsen, M. Brockhaus, M. Kanninen, E. Sills, W. D. Sunderlin, & S. Wertz-Kanounnikoff (Eds.), *Realizing REDD+: National strategy and policy options* (pp. 151–162). Bogor, Indonesia: Center for International Policy Research.
Susanti, A., & Budidarsono, S. (2014). Land governance and oil palm development: Examples from Riau Province, Indonesia. In A. Zoomers, & M. Kaag (Eds.), *The great global land grab: Beyond the hype* (pp. 119–134). London: Zed Publishers.
Szczepanski, K. (2002). Land policy and *adat* law in Indonesia's forests. *Pacific Rim Law & Policy Journal, 11*, 231–255.
Thorburn, C. C. (2004). The plot thickens: land administration and policy in post-New Order Indonesia. *Asia Pacific View Point, 45*(1), 33–49.
Turner, M., Podger, O., Sumardjono, M. S., & Tirthayasa, W. K. (2003). *Decentralization in Indonesia: Redesigning the state*. Canberra, Australia: Asia Pacific School of Economics and Government, Australian National University.
USAID (2010). Country profile (Indonesia): Property rights and resource governance. Washington DC: US Agency for International Development. http://usaidlandtenure.net/indonesia. Last accessed 15 July 2014.
Wallace, J., & Williamson, I. (2006). Building land markets. *Land Use Policy, 23*(2), 123–135.
Wilcove, D. S., Giam, X., Edwards, D. P., Fisher, B., & Koh, L. P. (2013). Navjot's nightmare revisited: Logging, agriculture, and biodiversity in Southeast Asia. *Trends in Ecology & Evolution, 28*(9), 531–540.
World Bank (2007). *World Development Report: Agriculture for Development*. New York: Oxford University Press.

World Bank (2016). Official exchange rate (LCU per US$, period average). Online database. http://data.worldbank.org/indicator/PA.NUS.FCRF. Last accessed 23 July 2016.

Zimmerman, F. J., & Carter, M. R. (1999). A dynamic option value for institutional change: marketable property rights in the Sahel. *American Journal of Agricultural Economics, 81*(2), 467–478.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.worlddev.2017.05.018.

Available online at www.sciencedirect.com

ScienceDirect