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Migration and Deforestation in Indonesia

Rivayani Darmawan, Stephan Klasen, and Nunung Nuryartono

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Georg-August-Universität Göttingen
Johann-Friedrich-Blumenbach Institut für Zoologie und Anthropologie, Fakultät für Biologie und Psychologie

Abstract: Indonesia now has the highest deforestation rate in the world, with an average increase of about 47,600 ha per year. As a result, the nation is one of the largest emitters of greenhouse gases in the world and is putting its rich biodiversity at risk. Although the literature discussing the political economy of Indonesia commercial's logging is growing, only a small amount focuses on the relationship between migration and deforestation. Migration may contribute to the forest cover change, as migrants often face serious constraints from the local residents in claiming the land, and thus tend to find new forest land which can be used as a means of living or converted into an agricultural plantation. This paper empirically investigates the relationship between recent in-migration and deforestation in Indonesia. By combining available population census data with the satellite image data MODIS, we find a significant positive relationship between migration and deforestation at the district level using a fixed effects panel econometric framework. The results also suggest that the expanding oil palm production is one significant driver for the fast disappearance of Indonesia's forest.

Keywords: deforestation, migration, oil palm, Indonesia

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Migration and Deforestation in Indonesia

Rivayani Darmawan[1], Stephan Klasen[2], and Nunung Nuryartono[3]

Abstract

Indonesia now has the highest deforestation rate in the world, with an average increase of about 47,600 ha per year. As a result, the nation is one of the largest emitters of greenhouse gases in the world and is putting its rich biodiversity at risk. Although the literature discussing the political economy of Indonesia commercial's logging is growing, only a small amount focuses on the relationship between migration and deforestation. Migration may contribute to the forest cover change, as migrants often face serious constraints from the local residents in claiming the land, and thus tend to find new forest land which can be used as a means of living or converted into an agricultural plantation. This paper empirically investigates the relationship between recent in-migration and deforestation in Indonesia. By combining available population census data with the satellite image data MODIS, we find a significant positive relationship between migration and deforestation at the district level using a fixed effects panel econometric framework. The results also suggest that the expanding oil palm production is one significant driver for the fast disappearance of Indonesia's forest.

Keywords: deforestation; migration; oil palm; Indonesia

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1. Introduction

The extensive forest cover clearing in Indonesia in recent decades has given it the highest rate of increasing deforestation in the world. It has been estimated that the average deforestation rate in Indonesia was 47,600 ha per year from 2000 to 2012. In 2012, it was reported that the total forest lost in Indonesia was 0.84 million ha, surpassing the previous first rank, Brazil, which has lost 0.46 million ha (Margono, et al., 2012). Unsurprisingly, Indonesia is currently the world's third largest emitter of greenhouse gases, which at the same time has put its extremely rich biodiversity at risk.

In this paper, we study the relationship between district level in-migration and deforestation in Indonesia, the 4th largest country in terms of population size.[4] It is claimed that the population growth has put pressure on the environment and that particularly migration is liable for the loss of forest cover in Indonesia (Burgess and Strand, 1993; Fraser, 1998; Amelung and Diehl, 1992; Kartasubrata, 1993; World Bank, 1990). It has also been argued that migration increases population pressures, which promotes technological change and income growth, but also accelerates deforestation (Klasen et al., 2010; Grimm and Klasen, 2015). Migrants, who come to new areas, tend to open forested land as they usually face serious constraints in claiming land from the local people, especially when land is scarce.[5] Codjoe and Bilsborrow (2011) argue that migrants tend to have a more destructive effect on the forests compared to the resident population, given their short term planning horizon.

Of almost 240 million people living in Indonesia, about 58 percent of them are located on Java Island, making it as the most populous island in the world. In the 1960s, the government of Indonesia sponsored a so-called transmigration program which aimed to resettle people to the outer islands of Indonesia: Sumatera, Kalimantan, Sulawesi, and Papua. During its implementation, the program resettled more than 3.6 million people who also received houses, land and a subsistence package in the early years of their resettlement (World Bank, 1994). The program, however, was considered to be a failure due to its impact on Indonesia's forest loss and human rights (World Bank, 1990; Fearnside, 1997). Comparing districts that received different numbers of transmigrant families, Abatayo (2015)

[4] Indonesia territory is divided into 33 provinces. Provinces are further divided into districts, locally labelled as *kabupaten* (regencies) or *kota* (cities).

[5] A recent study of Klasen and Grimm (2015) shows that an increase share of migrants is associated with a higher probability of formal land title adoption being demanded by the resident population, also related to a higher incidence of conflict over land between migrants and locals.

shows that 31 additional transmigrant families caused an acre of forest loss to deforestation. As a result, the program was temporarily stopped in the 1990s.[6]

Despite the temporary discontinuation of the program, studies have claimed that transmigration program has stimulated spontaneous migration, which refers to migration without the sponsorship by the government. These studies argued that the flow of spontaneous migrants has further increased the demand for land in the less densely settled areas. Holmes (2002) noted that the spontaneous migrants may be responsible for forest encroachment along the forest boundaries, particularly when there is land scarcity and the rejection from the local residents concerning land title.[7] Billsborrow (1992) argued that the spontaneous migrants may have a more damaging effect compared to transmigration participants as they can independently intrude to the nearby forest, without any supervision from the sponsored government.

Motivated by the above-mentioned issues, we examine the relationship between the in-migration and deforestation rates between 2000 and 2010 in the outer islands of Indonesia: Sumatera, Kalimantan, Sulawesi, and Papua. By exploiting the district level satellite image MODIS data from Burgess et al. (2012), the Indonesia population census, and the district level data from the World Bank, we confirm a positive relationship between the recent in-migration and deforestation. Although we cannot prove causality, our findings confirm a positive contribution of migration on the clearing of Indonesia's primary forest. Additionally, we test the claim that the major source of Indonesia's deforestation comes from the expansion of oil palm plantations. Our econometric results confirm that the expansion in oil palm plantations has a significant effect on forest clearing in Indonesia.

The paper is organized as follows: Section 2 provides the institutional background of forestry policy in Indonesia. Section 3 presents the empirical specification used in this study and section 4 describes the datasets. Section 5 discusses the econometric results, while section 6 concludes.

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[6] Although the program was discontinued during the reformation era, the recent government administration Joko Widodo has claimed that the re-born of transmigration program is indispensable, stressing the need to change the focus of the program from reducing the population density in Java-Bali to further expanding development to the outer islands.

[7] Angelsen and Resosudarmo (1999) studied the impact of 1998 economic crisis on farmers. They point out that changes in the price of export commodity were mainly enjoyed by the better-off farmers, in-migrants, and urban dwellers who have access to capital and resources, and therefore were more likely to convert forests into high profitability crops.

2. Institutional background

The main and the most recent policy instrument regulating Indonesia's forestry management is the Indonesia Forestry Law 41/1999. Based on this law, the national forest, or the so-called "forest estate" (*kawasan hutan*), is defined as the permanent designated forest area managed entirely by the Ministry of Forestry (MoF). Under the MoF jurisdiction, the forest estate amounts to about 71 percent of Indonesia's total land area, equivalent to 90.1 million ha.[8] Inside the forest estate, the land is sub-divided into four zones based on its function, namely production forest, conversion forest, conservation forest, and protection forest. In 1999 the MoF determined how much forest area belongs to each of the zones.[9] Production forest is the forest area designated for the production of timber and other forest products. The MoF issued a non-transferable concession right (*Hak Pengelolaan Hutan,* HPH) for a period of up to 20 years to the state-owned or private timber operated in this area. The HPH holder should, in principle, follow the sustainable forest management standards through the selective cutting system. The second category inside the forest estate is the conversion forest, in which the holders of Wood Utilization Permit (*Izin Pemanfaatan Kayu, IPK*) were granted the right to cut natural forest for settlement, agriculture (i.e. oil palm and other estate crops plantations) and other non-forestry uses. Logging activities inside the conversion and production forests are legal as long as loggers get the required permits. Thus, when trees are cut without the right permits, harvested beyond the concession permit limit, transported without proper documentation, smuggled, etc., it is considered as illegal logging.

Unlike the conversion and production forests, where logging with a permit is allowed, in the conservation and protection forests all logging activities are illegal. The protection forest should be maintained because of its function of providing a life support system for hydrology, preventing soil erosion, and maintaining soil fertility. Similarly, the conservation zone is the forest area where biodiversity and ecosystems should be preserved. The remaining forest category inside the forest

[8] The forest area outside the forest estate is relatively small compared to the forest estate. It covers around eight million ha of forest land (Verchot, et al., 2010.).

[9] The process of forest zone classification basically started in the 1980s, when a collaboration of government agencies attempted to produce Indonesia's forest maps with the agreed borders of the forest estate and the allocation of different forest functions inside the forest estate. This agreement is known as the Consensus Classification of Forest Function (TGHK) and became the basis of the forest zone classification regulated by the Forestry Law of 1999. Studies reveal that there are many issues concerning the forest land classification caused by poor data, subjective interpretation and inaccuracies (World Bank, 2006, p.22). As a result, the MoF has undertaken mapping operations as an effort to correct this data inadequacy. In this study, we rely on the forest zone classification used by Burgess et al., 2012.

estate is the "other forest", which is the forest land that does not serve any of the forest functions mentioned above.

Although the conversion of forests into oil palm estates is often held responsible for Indonesia's fast deforestation in the last decades, the migration of people from Java to the outer islands is also considered to be a contributing factor (Abatayo, 2015; Fearnside, 1997; World Bank, 1990). In the 60s the government of Indonesia started the so-called transmigration program aimed at reducing the population density on Java Island, the densest island in the world. According to the law, people who migrated through this program should either settle in the conversion zone, typically clearing forested areas for homes and converting the natural forest into agricultural plantations, or collect forest products as the means of living. During the early years of its implementation, each family received 2 ha of agricultural land from the government (World Bank, 2006).

The program, however, was temporarily discontinued in the 1990s due to its damaging effect on human rights and the environment. Still, it has been claimed that despite the program's abandonment, it stimulated spontaneous migration which has further increased the demand for land in less densely settled areas. Unlike the beneficiaries of the transmigration program who received the subsistence package and agricultural land, spontaneous migrants started with no access to land rights.

It is, therefore, challenging to empirically investigate the role of spontaneous migrants in Indonesia's deforestation. Since spontaneous migration is independent from the government sponsorship, it is difficult to find an accurate data on spontaneous migrants. Thus, this paper fills the gap in the research by using the flow of recent in-migration for 2000-2010 provided by the Indonesia population census as the proxy for spontaneous migration.

3. Empirical specifications

To examine the relationship between the recent in-migration and deforestation at the district level, the following panel specification is estimated:

$$D_{it} = \alpha M_{it} + \beta X_{it} + u_i + \varepsilon_{it} \quad (1)$$

The dependent variable D_{it} is the number of pixels of deforested land in district i during period t, where t consists of two five-year periods: 2000-2005 and 2005-2010. A higher value of D_{it} indicates a larger area of deforestation, measured by the number of satellite image pixels that have changed its color spectrum (from forest to non-forest) during the five-year interval.

Our variable of interest is M, which stands for the recent in-migration that has moved to district i. The coefficient α represents the effect of deforestation with respect to the changes of recent in-migration, where a positive coefficient indicates a positive relationship between the recent in-migration and the number of pixels that have been deforested in the last 5 years.

The variable recent in-migration M is a flow variable, which represents the number of people who have migrated to the specific district i. This variable is derived from the population census of 2000 and 2010, and the intercensal sample survey of 2005. In the survey instrument, the particular question on migration allows us to compare the place of residence of the people surveyed between the survey time and the previous five years. Thus, the number of people who answered that their residence was in a different district five years beforehand, is basically the amount of people who moved to that particular district in those previous five years.

The vector X_{it} is a set of district-level control variables. Here, we include the change in population during the five-year periods, the initial level of the population at the beginning of each of the five-year periods (2000 and 2005), and the total forest stock that can be extracted at the beginning of the period. In order to control for the level of economic development, we use the district level non-oil GDP with constant price, measured at the beginning of the five-year period. Furthermore, we also take into account the agricultural related activities in every district by including the share of the population working in agriculture, fishing, and forestry (in percentage) in every district.[10]

An additional control variable that we believe is important to include in our analysis is the oil palm agriculture, which is often blamed for destroying thousands of ha of forest every year. To capture this, we include the increase of total area planted with oil palm between 2000-2005 and 2005-2010 in every district. By doing this, we expect to control for a potential spurious correlation on the cause of

[10] As the census 2000 does not provide the data on "the share of labor in agriculture, fishing, and forestry", this specific variable is measured at the end-year of the five-year period.

deforestation. Still, we also add district fixed effects u_i to capture any further unobserved heterogeneity at the district level.

4. Data

There are three datasets used in this paper. The first dataset is the Moderate Resolution Imaging Spectroradiometer (MODIS) satellite images from Burgess et al. (2012), which allow us to track the patterns of forest clearing annually from 2000 to 2008 at the district level. The data contains the smallest spatial resolution, where each pixel represents an area of 250m x 250m. In the data, deforestation is identified when a pixel changed its color spectrum from forest to non-forest. Thus, by combining MODIS and the GIS data on district boundaries and forest-zone classification, the final deforestation data ultimately reveal the changes in the Indonesia's forest cover across districts and different forest zones: conversion, conservation, production, and protection zones.

Table 1. Summary statistics at district level

Variables	2000-2005					2005-2010				
	N	Mean	Std.	Min	Max	N	Mean	Std.	Min	Max
*MODIS Data**										
Deforestation (# pixels):										
- Conversion	88	1,407	3,052	0**	14,970	88	967	2,275	0	14,848
- Conservation	125	369	1,356	0	11,817	125	192	615	0	4,763
- Production	161	1,927	4,774	0	38,542	161	1,594	4,295	0	42,521
- Protection	165	280	845	0	8,054	165	120	267	0	2,347
- Others	187	896	1,721	0	13,111	187	973	2,296	0	16,577
Available forest to extract in t_0 (# pixels):										
- Conversion	88	35,100	67,480	9	474,802	88	33,693	65,420	0	463,209
- Conservation	125	23,434	46,583	0	309,508	125	23,065	45,775	0	297,691
- Production	161	59,412	116,442	0	975,686	161	57,485	113,728	0	955,021
- Protection	165	29,551	58,551	0	590,757	165	29,271	57,971	0	582,703
- Others	187	26,284	36,543	0	193,268	187	25,388	35,320	0	189,471
Population Census										
Recent in-migration	167	16,219	18,239	743	140,742	186	20,100	18,851	1,340	132,320
Population Δ	172	31,972	36,237	-106,872	208,438	172	46,087	63,297	-67,592	673,675
Population t_0	188	355,192	305,756	10,520	1,960,120	172	403,154	327,229	35,948	2,168,558
INDODAPOER Data										
Labor in agricultural, fishing and forestry (%)	172	23.3	12.5	0.8	64.4	186	22.4	11.7	0.9	46.6
RGDP non-oil constant (in IDR trillion)***	188	1,904	2,229	109	18,957	188	2,508	2,975	133	25,272
Total change in area of oil palm plantation (in ha)	88	45,951	55,192	-9,209	287,361	107	26,754	50,987	-28.330	360,791

Notes: *) For MODIS data, an observation is a forest zone is a district in the particular time period. For the rest of the variables, the observation is at the district level. **) Zero deforestation occurred in between 5-24 districts. ***) In the regression analysis, variable RGDP is measured in billion IDR.

The second dataset is the Indonesian population census 2000 and 2010, and the intercensal population survey of 2005. These data are obtained from the IPUMS, which provide the 10 and 0.51 percent random sample of the total population for the census and intercensal survey, respectively. Some indicators provided by the census data include the respondent's employment activities, as well as the current and the previous five year's residence. Thus, we construct district level in-migration and population data from these datasets.

The remaining variables in our analysis are derived from the Indonesia Database for Policy and Economic Research (INDO-DAPOER) provided by the World Bank. These data provide a rich district-level information for our analysis, namely total district area, regional GDP (constant price), and the total area of oil palm plantation.

The final combination of the three datasets provides us with around 188 districts, located in Sumatera, Kalimantan, Sulawesi, and Papua, which are the areas with the largest forests in Indonesia.[11] Table 1 reports descriptive statistics for our sample at the district level for two points in time: 2000-2005 and 2005-2010. The table reports that, on average, the flow of the recent in-migration to every district is increasing from around 16,000 to around 20,000 individuals. This figure is varying across districts with standard deviation of 18,639 individuals (ranging from 743 until 140,742). Concerning deforestation, there were almost 3,400 pixels (representing 21.2 thousand ha) on average being deforested in every district from 2000 to 2010. Most of this change occurs in the production forest with 1,760 pixels were coded as deforested, followed by conversion forest with 1,186 pixels. A smaller changes in forest pixels are reported for conservation and protection zones, with 481 pixels (3 thousand ha). It appears that there is a sizeable variability in both time interval and districts, as the variance of deforestation is quite large (more than two times the mean). Interestingly, although there has been a considerable expansion of oil palm plantation in the last decade, the data suggest that, on

[11] As we combined three different datasets with different time intervals, there are some data issues, which give some limitation in our analysis. First, since the Indonesian population census is only available in five-year intervals, it is natural to analyze the results for every five-year change. This includes the change of forest pixels from forest to non-forest between the year 2000-2005, and 2005-2010. However, since the MODIS satellite data are only available annually from 2000 to 2008, we use the change in forest cover between 2005-2008 as the proxy of deforestation between 2005 and 2010. Here, we assume that there no deforestation has occurred between 2008 and 2010. Second, census data do not provide information on whether a respondent is a participant of the transmigration program. Thus, we assume that the flow of recent in-migration during year 2000-2005 and 2005-2010 was spontaneous migration and not part of the transmigration program, as the program was temporary discontinued after the fall of Suharto in 1998. Third, as census data do not provide the information regarding district location of the respondent's previous residence five years before the survey, thus we are unable to compute the net-migration at the district level.

average, the increase in the total area of oil palm plantation decreased from around 45,000 ha to 26,000 ha. This can be interpreted that the expansion of oil palm plantation in 2005-2010 is not as massive as the expansion that occurred in 2000-2005.

5. Results

The results of the regression analysis begin by estimating specification (1) using the full sample, where all types of forest zones are included in the sample. Subsequently, specification (1) is estimated separately using each category of forest zones. Table 2 reports the result of estimating the number of pixels of all forest zones that have been deforested, with district fixed effects. Given that not every district has all types of forest zones, we include forest zone dummies in the regressions presented in Table 2.

The point estimates in Table 2 suggest that district in-migration is significant and positively associated with total deforestation, which holds even after adding control variables one by one. The coefficient of recent in-migration in regression (5) is 0.021, significant at the 0.01 level. This means that one standard deviation increase in the number of in-migrants in the five-year interval (around 18,500 migrants), corresponds to an increase of 391pixels (the equivalent of 2,446 ha) being deforested in the same year interval; this would suggest that 8 migrants are associated with about 1 ha of deforestation in the subsequent five-year interval.

Table 2 further reports the contribution of the remaining independent variables on district-level forest loss. The forest area available for extraction at the beginning of the period (t_0) is, not surprisingly, significant and positively associated with the number of forest pixels deforested: where there is more forest available for deforestation, the opportunities for deforestation are larger. This also suggests that there are apparently not many heavily forested districts in the country that are off-limits to deforestation (as this would have implied a negative relationship between forest pixels and deforestation). In terms of population, the results suggest a convergence pattern. Districts with a low number of inhabitants at the beginning of the period tend to have a faster rate of deforestation. This suggests that deforestation takes place in areas with low population density. Interestingly, population growth does not have any impact on deforestation. Thus it is not demographic pressure per se which leads to higher deforestation, but the particular demographic and socioeconomic pressures associated with in-migration. In fact, population levels and growth are associated with slight decreases in deforestation in our fixed effects specification.[12] The results also suggest that higher district income is associated with higher deforestation, while the economic structure does not seem to play a role. In regression (6), we include the variable change in oil palm plantation area at the district level. The results suggest that the change in the total area of oil palm has a significant positive effect on deforestation.[13] We repeat the regressions in Table 2 using an OLS estimation (appendix 1). It gives a similar result, with a stronger effect of oil palm expansion on deforestation.

In Table 3, we look at the effect of recent migrants at different types of forest zones. The table shows that the positive relationship between migration and deforestation, as presented in Table 2, is evident not only in the conversion and production forests where logging activities with a permit are legal, but also in the conservation zone where any logging activities are illegal. The results suggest that the most significant changes occurred in the production forest followed by the conversion forest. The coefficient of migration is 0.150 and 0.080 for the production and conversion zone, respectively. In the production zone, a one standard deviation increase in the number of in-migrants in the particular district during the five-year interval is associated with an increase of 2,800 pixels (representing 17,500 ha) of production forest being deforested in the corresponding five-year interval. In the conversion zone, on average 1,491 pixels (representing 9,320 ha) were likely deforested in each district during the five-year period.

The table also shows that the variable oil palm area seems to have a positive effect on deforestation in the conversion forest, significant at the 0.1 level. An increase of a thousand ha of the oil palm area at the district level, corresponds to an increase of 37.5 ha of forest clearing in the conversion forest in each district during the five-year period. It seems that the role of palm oil is major, but in-migration still retains its positive effect.

[12] See Grimm and Klasen (2015) for very similar results on the impact of migration versus population growth on the emergence of land rights and endogenous technological change.

[13] The oil palm data provided by the Indodapoer data contain a considerable amount of missing values, yet no zeros. In this paper, we assumed those missing values as zeros because: (1) missing values occur in the city regions, where normally there wouldn't be any oil palm plantations and (2) missing values occur in the early years, yet it turns to positive values in the later years. This treatment increases the number of observations, but does not change our results substantially.

Table 2. Fixed effects regression: deforestation and migration

	Panel district fixed effects					
	(1)	(2)	(3)	(4)	(5)	(6)
Recent in-migration	0.004	0.009	0.024***	0.024***	0.021***	0.021***
	(0.655)	(1.402)	(3.399)	(3.402)	(3.054)	(2.960)
Available forest to extract in t_0	0.024***	0.024***	0.024***	0.024***	0.024***	0.024***
	(15.509)	(14.900)	(14.932)	(14.930)	(14.924)	(14.926)
Population Δ		-0.002*	-0.003***	-0.003***	-0.003***	-0.003***
		(-1.671)	(-3.173)	(-3.152)	(-3.362)	(-3.363)
Population t_0			-0.007***	-0.006***	-0.009***	-0.008***
			(-4.761)	(-4.726)	(-5.298)	(-4.465)
Share of labor in agriculture, fishing and forestry				2.940	2.608	1.811
				(0.183)	(0.163)	(0.113)
RGDP non-oil constant					0.196**	0.170**
					(2.519)	(2.173)
Oil palm expansion						0.004**
						(2.388)
Conversion forest dummy	-55.436	-63.005	-63.596	-63.594	-63.494	-63.480
	(-0.199)	(-0.214)	(-0.218)	(-0.218)	(-0.217)	(-0.217)
Conservation forest dummy	-632.128***	-655.729**	-656.746**	-656.749**	-656.465**	-656.380**
	(-2.593)	(-2.509)	(-2.528)	(-2.528)	(-2.523)	(-2.522)
Production forest dummy	65.106	65.204	67.990	68.000	67.185	66.929
	(0.287)	(0.267)	(0.280)	(0.280)	(0.276)	(0.75)
Protection forest dummy	-784.075***	-814.657***	-814.685***	-814.681***	-814.742***	-814.777***
	(-3.559)	(-3.424)	(-3.445)	(-3.445)	(-3.440)	(-3.439)
District fixed effects	yes	yes	yes	yes	yes	yes
R^2	0.2072	0.0957	0.0783	0.0784	0.0858	0.0926
Number of observations	1,358	1,308	1,308	1,308	1,308	1,308

Notes: An observation is a forest zone in a district in the specific five-year interval. The dependent variable is the number of forest pixels that have been deforested in the given district-forest zone in the last five years. The constant is not shown. The regression include forest zone dummies. T-statistics are reported in parentheses. *** significant at 0.01 level, ** significant at 0.05 level, * significant at 0.1 level.

We repeat the regressions in Table 3 using an OLS estimation (Appendix 2). The results show a stronger effect that the increase of the oil palm area is significant and positively associated with forest clearing. This occurs not only in the conversion forest, but also in the production and protection forests.[14] Altogether this suggests that the expansion of oil palm is one of the drivers of deforestation,

[14] Using the same full sample, the OLS results show that the insertion of variable oil palm area not only decreases the significance of migration, but the variable oil palm area itself enters with a significant and positive effect at the 0.01 level of significance.

yet in-migration retains a major significant influence, suggesting that migration promotes deforestation independently of the impact of oil palm expansion.[15]

Table 3. Fixed effects regression: migration and deforestation by forest zone

	Panel district fixed effects				
	conversion	conservation	production	protection	others
	(1)	(2)	(3)	(4)	(5)
Recent in-migration	0.080***	0.015**	0.150***	0.001	0.010
	(3.520)	(2.153)	(3.658)	(0.480)	(0.302)
Available forest to extract in t_0	0.544***	0.586***	0.324***	0.613***	0.251**
	(8.305)	(14.139)	(5.767)	(12.870)	(2.062)
Population Δ	-0.001	0.000	-0.008	-0.000	0.006
	(-0.142)	(0.255)	(-0.766)	(-0.131)	(0.778)
Population t_0	-0.007	0.001	-0.007	0.001	-0.008
	(-0.827)	(0.628)	(-0.695)	(1.223)	(-0.910)
Share of labor in agriculture, fishing and forestry	-10.197	22.012	10.676	11.937**	64.328
	(-0.206)	(1.190)	(0.123)	(2.293)	(0.858)
RGDP non-oil constant	0.531	-0.016	0.093	0.018	1.134***
	(0.925)	(-0.177)	(0.196)	(0.692)	(2.598)
Oil palm expansion	0.006*	0.001	0.007	0.000	0.002
	(1.957)	(0.897)	(1.134)	(0.875)	(0.446)
District fixed effects	yes	yes	yes	yes	yes
R^2	0.7028	0.8079	0.3932	0.7962	0.1603
Number of observations	106	132	168	157	172

Notes: An observation is a forest zone in a district in the specific year. The dependent variable is the number of forest pixels that have been deforested in the given district-forest zone in the last five years. The constant is not shown. T-statistics are reported in parentheses. *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level.

6. Conclusion

Indonesia is now the country with the highest deforestation rate in the world, surpassing Brazil. This has not only been putting the nation's extremely rich biodiversity at risk, but more importantly, makes

[15] Although our estimation has included sets of district-level control variables as well as district fixed effects, a potential concern is the possibility that in-migration might have resulted from some sort of behavior or incentive that attracts for laborers to migrate to the specific district and promotes deforestation at the same time. There might still be some time-variant unobserved heterogeneity that drives the relationship between migration and deforestation.

Indonesia as one of the world's top three carbon emitters. Although the literature discusses the main determinants of Indonesia's deforestation, this paper focuses on the relationship between in-migration and deforestation. A long history of Indonesia's transmigration program, which resettled people from Java to the outer islands, has triggered a spontaneous migration to these islands even though the program has been temporarily discontinued.

This paper exploits the district level satellite image data on deforestation and recent in-migration from the population census. Using a panel estimation of two data points: 2000-2005 and 2005-2010, we find a significant positive relationship between the recent in-migration and deforestation. Dividing forest areas into different zones named after the forest area's specific use: conversion, conservation, production, protection, and others, the positive relationship is evident not only in the conversion and production zones, where logging activities are legal, but also in the conservation zone.

We further find that the recent oil palm expansion has a positive effect on deforestation, particularly in the conversion forest. Our results clearly suggest that recent in-migration is one of the contributors to the forest cover clearing in Indonesia. This implies certain policy prescriptions concerning migration and environmental sustainability, particularly as the current government plans to bring back the transmigration program to further develop the outer islands. Migrants, who are mostly poor, need to be supported to improve their livelihood. Therefore, designing the policies to improve the livelihood of migrants in the region of destination is also critical. Such policies should value high environment protection and at the same time encourage sustainable land-use practices. Moreover, to reduce deforestation, the focus should be on reducing the conversion of forests into oil palm plantations. Here, policy issues might include more intensive (rather than extensive) oil palm production, and making sure that all negative externalities associated with oil palm production are internalized to the producers.

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9. Appendices

Table A 1. Total deforestation and migration, OLS

	OLS					
	(1)	(2)	(3)	(4)	(5)	(6)
Recent in-migration	0.013***	0.017***	0.018***	0.019***	0.020***	0.018***
	(3.481)	(3.966)	(3.507)	(3.523)	(3.594)	(3.241)
Available forest to extract in t_0	0.021***	0.021***	0.021***	0.021***	0.021***	0.020***
	(17.721)	(17.091)	(16.977)	(16.682)	(16.601)	(17.020)
Population Δ		-0.002**	-0.002**	-0.002**	-0.002**	-0.003***
		(-2.282)	(-2.319)	(-2.389)	(-2.428)	(-2.961)
Population t_0			-0.000	-0.000	-0.000	-0.000
			(-0.400)	(-0.526)	(-0.061)	(-0.253)
Share of labor in agriculture, fishing and forestry				5.278	4.007	-1.293
				(0.666)	(0.494)	(-0.167)
RGDP non-oil constant					-0.031	-0.042
					(-0.740)	(-1.046)
Oil palm expansion						0.011***
						(9.184)
Conversion forest dummy	60.232	54.141	56.113	37.548	44.627	-51.626
	(0.212)	(0.180)	(0.186)	(0.124)	(0.147)	(-0.183)
Conservation forest dummy	-629.599**	-646.472**	-643.878**	-656.335**	-656.530**	-688.516**
	(-2.484)	(-2.379)	(-2.360)	(-2.401)	(-2.393)	(-2.707)
Production forest dummy	187.841	206.510	208.526	201.604	200.006	209.683
	(0.788)	(0.805)	(0.809)	(0.782)	(0.773)	(0.874)
Protection forest dummy	-819.109***	-842.519***	-841.624***	-849.259***	-849.535***	-854.004***
	(-3.498)	(-3.337)	(-3.321)	(-3.348)	(-3.337)	(-3.619)
District fixed effects	no	no	no	no	no	no
R^2	0.0465	0.0477	0.0474	0.0450	0.0437	0.0432
Number of observations	1,358	1,308	1,308	1,308	1,308	1,308

Notes: An observation is a forest zone in a district in the specific five-year interval. The dependent variable is the number of forest pixels that have been deforested in the given district-forest zone in the last five years. The constant is not shown. The regression includes forest zone dummies. T-statistics are reported in parentheses. *** significant at 0.01 level, ** significant at 0.05 level, * significant at 0.1 level.

Table A 2. Total deforestation and migration by forest zone, OLS

	OLS				
	conversion	conservation	Production	protection	others
	(1)	(2)	(3)	(4)	(5)
Recent in-migration	0.028	0.009	0.081**	0.001	0.005
	(1.424)	(0.970)	(2.505)	(0.532)	(0.366)
Available forest to extract in t_0	0.019***	0.016***	0.019***	0.002	0.048***
	(5.551)	(5.627)	(5.825)	(1.238)	(14.297)
Population Δ	-0.001	-0.005**	-0.009	-0.002***	0.004
	(-0.176)	(-2.159)	(-1.042)	(-2.727)	(0.901)
Population t_0	-0.002	0.000	-0.000	-0.000	-0.001*
	(-1.155)	(0.408)	(-0.211)	(-0.035)	(-1.686)
Share of labor in agriculture, fishing and forestry	-6.391	2.903	-39.633	7.690	-14.632
	(-0.206)	(0.177)	(-0.824)	(1.551)	(-0.845)
RGDP non-oil constant	-0.030	-0.018	-0.416	-0.002	0.154
	(-0.142)	(-0.218)	(-1.521)	(-0.065)	(1.456)
Oil palm expansion	0.017***	0.002	0.031***	0.001**	0.003
	(5.399)	(1.475)	(5.607)	(2.376)	(1.346)
District fixed effects	no	no	no	no	no
R^2	0.1173	0.1157	0.0624	0.2020	0.0897
Number of observations	106	132	168	157	172

Notes: An observation is a forest zone in a district in the specific year. The dependent variable is the number of forest pixels that have been deforested in the given district-forest zone in the last five years. The constant is not shown. T-statistics are reported in parentheses. *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level.

Table A 3. Fixed effects regression: deforestation and migration

	Panel district fixed effects					
	(1)	(2)	(3)	(4)	(5)	(6)
Recent in-migration	0.004	0.009	0.024***	0.024***	0.021***	0.025*
	(0.655)	(1.402)	(3.399)	(3.402)	(3.054)	(1.886)
Available forest to extract in t_0	0.024***	0.024***	0.024***	0.024***	0.024***	0.026***
	(15.509)	(14.900)	(14.932)	(14.930)	(14.924)	(11.848)
Population Δ		-0.002*	-0.003***	-0.003***	-0.003***	-0.005
		(-1.671)	(-3.173)	(-3.152)	(-3.362)	(-1.316)
Population t_0			-0.007***	-0.006***	-0.009***	-0.010***
			(-4.761)	(-4.726)	(-5.298)	(-2.832)
Share of labor in agriculture, fishing and forestry				2.940	2.608	3.032
				(0.183)	(0.163)	(0.098)
RGDP non-oil constant					0.196**	0.291*
					(2.519)	(1.648)
Oil palm expansion						0.003*
						(1.656)
Conversion forest dummy	-55.436	-63.005	-63.596	-63.594	-63.494	-169.152
	(-0.199)	(-0.214)	(-0.218)	(-0.218)	(-0.217)	(-0.400)
Conservation forest dummy	-632.128***	-655.729**	-656.746**	-656.749**	-656.465**	-936.847**
	(-2.593)	(-2.509)	(-2.528)	(-2.528)	(-2.523)	(-2.369)
Production forest dummy	65.106	65.204	67.990	68.000	67.185	217.952
	(0.287)	(0.267)	(0.280)	(0.280)	(0.276)	(0.587)
Protection forest dummy	-784.075***	-814.657***	-814.685***	-814.681***	-814.742***	-1,032.258***
	(-3.559)	(-3.424)	(-3.445)	(-3.445)	(-3.440)	(-2.799)
District fixed effects	yes	yes	yes	yes	yes	yes
R^2	0.2072	0.0957	0.0783	0.0784	0.0858	0.0910
Number of observations	1,358	1,308	1,308	1,308	1,308	735

Notes: An observation is a forest zone in a district in the specific five-year interval. The dependent variable is the number of forest pixels that have been deforested in the given district-forest zone in the last five years. The constant is not shown. The regression include forest zone dummies. T-statistics are reported in parentheses. *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.1 level.