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Does oil palm certification create trade-offs between environment and development in Indonesia?

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Abstract

Environmental and social problems triggered by rapid palm oil expansion in the tropics have spurred the proliferation of sustainability certification systems such as the Roundtable on Sustainable Palm Oil (RSPO). While the RSPO aims to improve the impact of oil palm production on people and environments, its effect on local development, environmental quality, and, especially, potential trade-offs between these outcomes remain unclear. Here, we evaluate whether RSPO certification of large-scale industrial concessions has promoted village development and supported environmental quality in Indonesia, the top global palm oil producer. Using a panel dataset with observations from 11 000 villages in Kalimantan and Sumatra from 2003 to 2014, we apply rigorous quasi-experimental methods to quantify the RSPO's impacts on village development and environmental outcomes. In the short-run, RSPO contributed to environmental conservation, but had limited development outcomes. On average, relative to villages with non-certified concessions, RSPO certification reduced deforestation and protected primary forests in Sumatra and lowered the incidence of village-reported land pollution in Kalimantan. RSPO certification also increased the number of private educational facilities in Kalimantan, but had no statistically significant impacts on other development indicators. However, the trade-offs and complementarities between conservation and development vary by slope, a proxy for ecosystem fragility and oil palm profitability. On gentler slopes, we generally find complementarities between conservation and development outcomes. In Kalimantan, certification increased the number of private educational facilities and reduced deforestation and the incidence of land pollution on slopes $< 2°$. In Sumatra, certification retained more primary forests, decreased deforestation and the incidence of water pollution on slopes $< 1°$, along with a decrease in population density. Higher slopes in both locations were associated with environment and development trade-offs. We highlight the need to better understand the mechanisms behind the impacts of RSPO and emphasized how the outcomes of certification depend on the communities' bargaining power and the profitability of the land for oil palm production. Thus, we provide insights into understanding these mechanisms behind the impacts of RSPO, which is a prerequisite for improving the design of certification systems and their impacts on the ground.

1. Introduction

Globally, about a third of forest disturbance from 2000 to 2015 was associated with commodity-driven deforestation [1] and commodities including oil palm, beef, soy, and timber were primary drivers of deforestation and forest degradation in the tropics [2]. The rapid large-scale expansion of these commodities in developing tropical regions has spurred concerns related to land grabbing, destruction of ecosystems, loss of traditional livelihoods, lack of worker safety, increased poverty, and increased migration [3–6].

In response to these environmental and social problems, voluntary market-based sustainability certification programs have grown substantially in recent years [7]. These programs aim to provide incentives to commodity producers to adopt environmentally appropriate and socially beneficial practices [8, 9]. However, despite the recent proliferation of these programs, recent syntheses have found limited evidence of their impacts. Especially scarce are the studies examining both socio-economic and environmental outcomes and the complementarities and trade-offs between social and environmental goals [10–12].

The Roundtable on Sustainable Palm Oil (RSPO) was created in 2004 to incentivize sustainable production of palm oil [13]. Initiated by non-government organizations and palm oil producing companies, RSPO offers a voluntary certification system to oil palm producers; based on a set of Principles and Criteria (P&C) designed to reduce the negative impacts of oil palm cultivation on people and the environment [13]. While the RSPO P&C require, at minimum, adherence to all local regulations, the RSPO certification system has been criticized for providing insufficient benefits beyond what is legally required [14–16].

RSPO certification is granted to mills and their associated supply bases ('plantations') as well as independent smallholder producers after evaluation by independent third-party auditors who verify compliance with the RSPO P&C. If a producer fails to comply with RSPO requirements, certification is revoked. As of May 2020, the volume of RSPO certified palm oil produced globally was $\sim$ 15.7 M tonnes or 19% of global annual palm oil production [13]. Since 2009 when the first RSPO certificate was issued in Indonesia, the country's share of certified oil palm production expanded rapidly and by 2020 approximately 56% of total global certified palm oil production was produced in Indonesia, also the world's leading producer of palm oil [13].

We focus on Indonesia, a major tropical forested country with substantial carbon-rich peatlands and forests but rapid deforestation rates that are the focus of several multinational conservation and climate change mitigation efforts [17, 18]. Indonesia faces significant problems like poverty and high disease burden in part due to environmental factors like air and water pollution [19], insufficient infrastructure like electricity and roads [20], and limited access to healthcare and education, especially in rural areas [21]. Touted as a way to promote higher worker incomes, economic growth, and rural development in Indonesia [22, 23], most oil palm is grown in rural areas with high poverty levels [24]. However, the oil palm industry in Indonesia has also been implicated in land grabbing [25], importation of workers at the expense of local communities [26], exploitation of labour [27], and environmental degradation [18, 28, 29].

While RSPO aims to address social and environmental issues related to oil palm production and expansion, limited evidence exists regarding its impacts. An emerging body of literature has quantified the impact of RSPO certification using quasi-experimental and other research designs. Much of this research has focused on Indonesia in part due to availability of oil palm concession and social and environmental indicator data. Using oil palm concessions in Sumatra and Kalimantan as the unit of analysis, Cattau *et al* [30] found that RSPO membership significantly decreased fire activity in certified concessions on lands other than peatlands during wet years, but had no statistically significant impact during dry years, when the likelihood of fires was high. Morgans *et al* [31] evaluated the difference in economic profits, orangutan habitat, and fire activity at the plantation level as well as poverty and health centers in villages surrounding certified and non-certified concessions, in Kalimantan and found no statistically significant differences due to certification except for increased economic returns. Noojipady *et al* [32] found that certification is correlated with a decrease in deforestation and fire-driven deforestation, but did not eliminate forest loss. Using concessions as the unit of analysis, Carlson *et al* [33] demonstrated that RSPO certification lowered deforestation rates in Sumatra and Kalimantan, although the total amount of avoided deforestation was small. In their assessment of spillovers from RSPO certification, Heilmayr *et al* [34] used pixels as the unit of analysis and showed that exposure to certification reduced deforestation inside Indonesia's forest estate, but increased deforestation in areas zoned for agricultural production. Using villages as the unit of analysis, Santika *et al* [35] examined the impact of certification on poverty and village development in Sumatra, Kalimantan, and Papua and suggested heterogeneity in outcomes correlated with pre-existing village level of development.

Of all previous studies, only Santika *et al* [35] and Morgans *et al* [31] use villages as the unit of analysis; and these studies focus predominantly on the potential socio-economic impacts of certification. However, trade-offs may exist between conservation initiative goals [36]. For instance, there is concern that certification may lead to exclusion of smallholder

producers from global value chains due to high costs that smallholders face in meeting environmental standards of certification systems [37]. Understanding such trade-offs and potential synergies between and among social and environmental conditions is critical to improve the design and implementation of sustainability certification systems [36]. Yet, little is known about the trade-offs and complementarities between the environmental and socio-economic goals of RSPO at the village level or the potential channels through which the certification scheme effects change on the ground.

Building upon previous studies, here we examine the impact of RSPO certification on a set of village development and environmental indicators in Sumatra and Kalimantan, the two major oil palm producing regions in Indonesia. We use a detailed theory of change framework, rigorous quasi-experimental methods, and a rich village-level panel dataset from 2003 to 2014. We also examine the heterogeneity of impacts across slope, a proxy for ecosystem fragility [38] and agricultural suitability [39]. We find that, relative to villages with non-certified concessions, increasing presence of RSPO certification contributed some environmental benefits (i.e. reduced deforestation and pollution in Kalimantan and protection of remaining primary forests in Sumatra), had a limited impact on village infrastructure, and, depending on the region, generated trade-offs or complementarities between environmental and development outcomes. These appear to be correlated with changes in the population density. By illustrating the heterogeneity of RSPO certification's impacts, our results support better understanding of the mechanisms behind RSPO's impacts and potentially inform improvement to the certification system's design.

2. Materials and methods

2.1. Theory of change framework

We developed a theory of change framework that synthesizes causal pathways between RSPO certification of oil palm plantations and subsequent change in environmental and development outcomes due to certification. Following Blackman *et al* [40], our framework is based on a literature review of the effectiveness of RSPO as well as a review of the 2007 RSPO P&C (figures S1–S2 (available online at https://stacks.iop.org/ERL/15/124064/mmedia), table S1). Specifically, we link the intervention (i.e. RSPO certification), with outcomes (proxies for village development and environmental quality) and impact of the intervention (improved village social well-being), and elaborate on the assumptions that inform these links. We focus on the provision of public goods in the village, proxied by the presence of village infrastructure like educational facilities, electricity, and health centers, and the abatement of 'environmental bads' like water, air, and land pollution, deforestation, loss of primary forests, and incidence of fires, which are often associated with oil palm expansion and production. Hereafter, we refer to these collectively as 'village public goods'.

We note that there is a body of literature that is critical of the way the RSPO has formulated its sustainability standards to address social issues related to oil palm expansion [41–43]. Some concerns include the dispossession of smallholders and communities of their way of life and a reliance on companies or non-governmental organizations (NGOs) for certification [44], the focus on economic principles and efficiency practices instead of local concerns of land sovereignty [45], as well as the skewed processes of inclusion and poor participation of local communities [46]. We acknowledge these broader societal problems related to the RSPO but limit our study to focus only on specific environmental and development outcomes which we were able to derive data for.

2.1.1. Intervention and channels of impact

The process of RSPO certification for companies begins when the oil palm company submits a letter of intent (LOI) to the RSPO Secretariat, notifying stakeholders of the intent to pursue RSPO certification of a plantation.

The LOI defines the scope of the certification and planned assessment dates and invites interested parties to submit comments. In preparation for certification, plantation managers may undertake measures to comply with the certification requirements. For this reason, the LOI better represents the beginning of the certification process ('certification initiation') than the date of certification [33]. Upon compliance with the certification standard, a third-party audit takes place. If the audit finds that the plantation adheres to the RSPO P&C, the plantation is awarded a RSPO certificate.

We assume that all RSPO-certified plantations comply with all of the RSPO's P&C, which is required to gain and maintain certification. If producers seeking certification were initially not in compliance with the standard, implementing these practices to achieve certification could result in major changes in plantation management, compared to non-certified oil palm concessions; for producers already in compliance, certification will result in no additional changes. Cases of non-compliance occur and have been recorded in audit reports [47], but no certificates were revoked during our study period [48]. A recent review of audit reports showed that the most frequently reported non-compliances were related to issues on health and safety, waste, and smallholder training, and that most non-compliances are resolved with time [47].

Consistent with previous work (e.g. Gnych *et al* [49]; Morgans *et al* [31]), we argue that credible sustainability certification systems like that offered by the RSPO may provide some incentives (e.g. in the form

of market access and price premiums) to oil palm producers to adhere to governmental regulations and adopt additional improved practices to contribute to village development. Specifically, we assume an implicit model of a bargaining game between local communities and industrial oil palm producers, the outcome of which depends on the relative bargaining power of communities. Consistent with previous studies (e.g. Engel *et al* [50]), we expect higher bargaining power of local communities to translate into higher provision of village public goods by the industrial oil palm producer. A community's bargaining power is likely to increase with the degree to which the plantation depends on a local community for labor and land [51, 52], in the presence of strong informal village institutions (e.g. as in Engel *et al* [50] in the context of logging), and with enforcement of government regulations that bolsters community claim to land [53]. This negotiation is required under Indonesian law for companies to secure land leases [54] and thus even non-certified oil palm companies may provide some village public goods, although compliance is not guaranteed [55–57].

We hypothesize that certification may result in additional village public goods for two reasons. First, because the RSPO requires that all land tenure conflicts be resolved before certification can be granted, which can increase a community's bargaining power [53, 58]. Second, the P&C's emphasis on resolving land tenure disputes with local communities and maintaining clear tenure may incentivize more active bargaining with local communities [53, 58]. Thus, in cases where land tenure disputes remain when a company begins to pursue certification or threaten to arise after a company gains certification, industrial RSPO certified producers may provide additional village public goods as a compensation to local communities, to secure rights to produce oil palm on village land and therefore meet certification requirement (see Miteva *et al* [59] for an overview of the some of the channels through which a voluntary certification scheme can help resolve land tenure issues). While most of the certified plantations in our sample were established long before certification and some compensation to communities may have been negotiated at the time of establishment (e.g. 47, 52), the process of securing certification may lead RSPO certified companies to further compensate communities to address additional, unresolved issues related to land tenure. In these areas we expect to see significant additional impacts of RSPO.

As with village development, the additional impact of RSPO certification on minimizing environmental 'bads' depends on the environmental practices of the non-certified oil palm companies, which are shaped by government regulations and their enforcement as well as pressure from communities, NGO, and markets. For instance, all producers in Indonesia are required to comply with the government-mandated Indonesian Sustainable Palm Oil (ISPO) system, a legality standard that includes several environmental rules but lacks incentives to assure compliance [49]. If compliance with ISPO is low, we expect significant additional impacts due to RSPO. Conversely, we expect negligible impact of RSPO in cases where oil palm producers have already adopted better practices prior to certification. For example, driven by international market and NGO pressures, large multinational oil palm producers may choose to adopt improved practices even in the absence of certification [49].

2.2. Heterogeneity of the impacts by slope

The optimal slope for oil palm plantings is between 0 and 4 degrees; higher slopes increase fertilizer runoff, cause weak anchorage of the oil palm plants, and may require land terracing, increasing oil palm growers' costs [39]. Oil palm production on gentle slopes is thus most profitable. Given that adopting improved practices is costly (e.g. Tan-Soo & Pattanayak [60]), we hypothesize that oil palm companies may be able to afford to adopt more mitigation practices on more profitable lands, whereas on less profitable land, we would expect fewer such practices. In the absence of incentives to non-certified plantations to comply with government regulations, we expect that the additional impact of RSPO on mitigating impacts on the environment is likely to vary with slope, with the highest additional impact on gentle slopes and smaller additional impacts on higher slopes.

Provision of village infrastructure due to RSPO may also vary with slope, specifically, in cases when certified plantations provide village public goods as a form of compensation to local communities to gain or maintain access to land for oil palm production. Again, we posit that the level of compensation depends on the profitability of the land: The more profitable the land is, the more the company would be willing to pay to use the land for oil palm production. Because steeper slopes impose additional costs on oil palm producers and are not as profitable, we predict that the level of compensation from the concession to the village will be smaller in villages with greater average slope. Conversely, on profitable land with gentle slopes, we expect higher compensation from the concession to the village. Thus, we expect that RSPO certification has enhanced impacts on infrastructure in villages with more gentle slopes and small or negligible impacts in villages with relatively steeper slopes.

2.2.1. Outcome proxies for village development

Based on our review of the RSPO P&C, we categorized how each RSPO criterion may contribute to the provision of 14 categories of village development indicators, ranging from improving land acquisition transparency and tenure security, to improving worker safety and reducing discrimination in the plantation's workforce (table S1). Our analysis did not evaluate

the empirical impact of certification on all 14 categories due to a lack of data for outcomes in most categories (e.g. reduce child labour, improve rights for employees), especially for non-certified oil palm companies. Following the United Nations Sustainable Development Goals [61] and prior studies (e.g. Litzow *et al* [62]), we used the following indicators to evaluate the impact that RSPO certification has on village infrastructure, which we use as a proxy for village development: the number of private educational facilities, the number of households with access to non-state sources of electricity, and the presence of health centers in the village (table S2).

RSPO-certified plantations are expected to provide adequate housing, water supplies, and medical, educational, and welfare amenities at or above national standards, especially where no such public facilities are available or accessible (RSPO Criterion 6.5). As Criterion 6.5 requires companies to meet only minimum legal requirements, we hypothesize that compliance is likely to improve village infrastructure only in villages without legally mandated facilities already in place; in all other areas we expect no additional impact. Certified plantations are also encouraged to contribute to local sustainable development (RSPO Criterion 6.11), although the vague wording of this requirement suggests context-dependent application and impacts. Contributions by oil palm companies in Indonesia under Criterion 6.11 may include Community Development or Corporate Social Responsibility programs, and/or provision of healthcare facilities and services and participation in school construction.

2.2.2. Outcome proxies for environmental quality

Given oil palm's substantial negative environmental impacts, the RSPO P&C focus strongly on ensuring environmentally responsible palm oil production. Specifically, certified plantations are expected to reduce soil erosion, maintain water quality, practice responsible waste disposal, reduce air pollution, and preserve High Conservation Value areas (RSPO Criteria 4.3, 4.4, 5.1, 5.2, 5.3 and 5.6). In addition, RSPO-certified plantations must avoid the use of fires for waste disposal or any form of land clearing and preparation (RSPO Criterion 5.5). We thus used the following indicators to evaluate the impact of RSPO certification on environmental quality: the presence of air, land, or water pollution, deforestation, the loss of primary forests, and the incidence of fires at the village level (table S2).

2.3. Study area

Between 1970 and 2017, oil palm area in Indonesia increased from 0.1 to 12.3 million ha [63, 64], making Indonesia the top oil palm producer in the world. While ISPO was introduced in 2011 to address some of the environmental and social issues underlying the production and expansion of oil palm, previous studies have found ISPO to be less strict than the RSPO certification system and its compliance low [65].

The first Indonesian oil palm plantations were established in Sumatra during the colonial era and long before Kalimantan oil palm development began [55]. As a result, patterns of oil palm establishment differ between these two regions. In 1995, the extent of oil palm plantations in Sumatra was ∼1.6 Mha, slightly more than three times the oil palm area in Kalimantan (∼0.5 Mha) [66]. By 2015, oil palm plantation area totaled ∼5.9 Mha in Sumatra and ∼5 Mha in Kalimantan [66]. While both regions showed high growth rates in oil palm extents, the rate of expansion in recent times (2006–2010) was significantly higher in Kalimantan than Sumatra [67]. Due to these differences in oil palm expansion, more recent deforestation and community conflict happen in Kalimantan, and communities in Kalimantan have less experience with oil palm cultivation [66, 68, 69].

We focus on nine Indonesian provinces (four in Sumatra, five in Kalimantan), which represent 83% (26.7 M tonnes) of Indonesia's palm oil production and 90% (1.5 Mha) of Indonesia's RSPO certified concessions in 2017 [13, 63] (figure 1). Because of the different timing of oil palm development in Kalimantan and Sumatra, we examined each region separately.

2.4. Spatio-temporal coverage and unit of analysis

Combining village-level census data and fine resolution geospatial information, our dataset covers five time points (2003, 2005, 2008, 2011, and 2014) across 11 years, and includes 7983 and 3545 villages in Sumatra and Kalimantan, respectively. To evaluate the impact of certification on the outcomes of interest, we use the village as our unit of analysis. An Indonesian village (*Desa*) includes human settlements and adjacent land as mapped by the Indonesian Bureau of Statistics (BPS). Because community development programs and corporate social responsibility programs from oil palm companies, including non-certified companies, are often implemented at the village level, we expect any impacts from RSPO to be detectable at this administrative level.

2.5. Village development and environmental indicators

We extracted indicators from the Indonesian Village Potential Statistics (PODES) datasets [70] as well as spatial data on forest cover and fires. PODES data are based on information collected from village heads (*kepala desa*) every 3 years and are intended to represent overall socio-economic conditions of a village. The village head is the single elected government official in each village. PODES data have been used widely to evaluate the effect of social and environmental governance initiatives such as REDD + [71], forest certification schemes [72], and

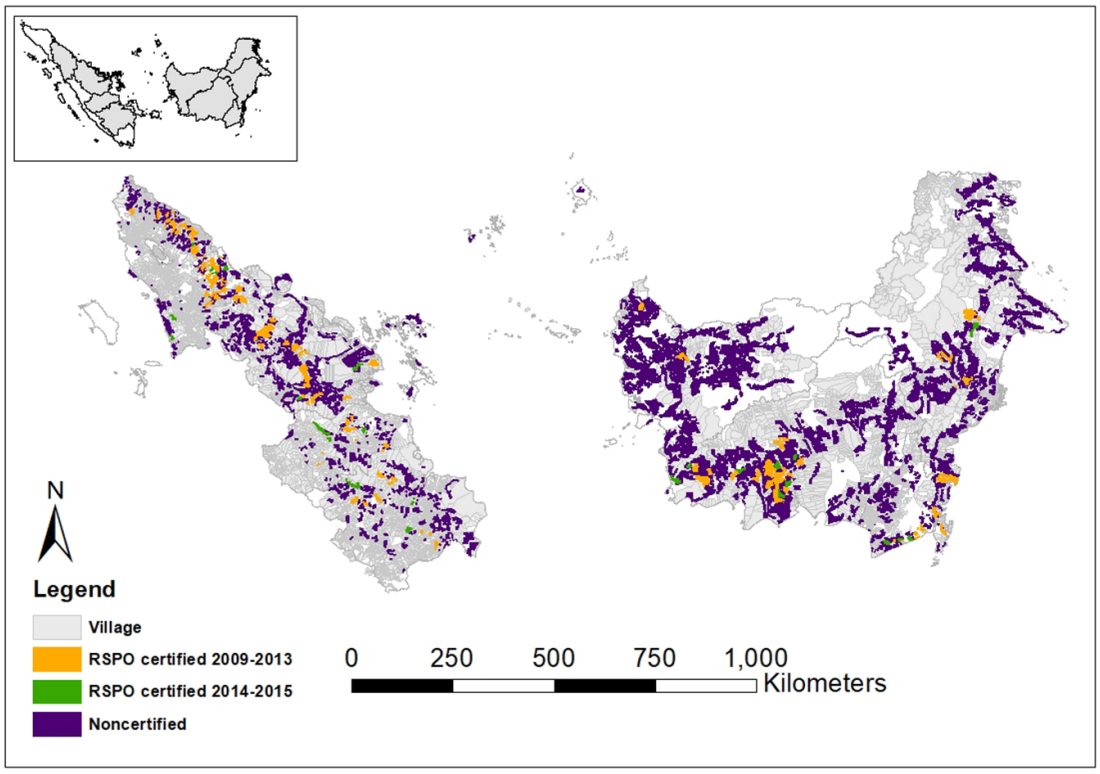

Figure 1. Distribution of the RSPO certified and non-certified oil palm concessions in select provinces of Sumatra and Kalimantan. The RSPO concessions with a letter of intent (LOI) from 2009 to 2013 are in orange, and the concessions with a LOI from 2014 to 2015 are in green. A village is considered as treated if it overlaps with a certified RSPO concession with a LOI from 2009 to 2013, and a control village is one that is intersected by a non-certified oil palm concession.

social forestry programs [73], and oil palm development [24] on social and environmental outcomes.

We obtained six village infrastructure outcomes and three environmental outcomes from PODES (table S2) and derived three additional environmental outcomes using spatial data on forest cover and fires (table S2). We chose the indicators based on their ability to proxy village development and environmental quality, and their availability and variability across space (i.e. Kalimantan and Sumatra) and time (i.e. the study period). Because sample village population data were available only until 2011, we chose not to standardize counts of facilities and number of households with access to electricity by population; however, we present these standardized results up to 2011 in the supplementary material (tables S3–S4, figure S3).

2.6. Sample processing and treatment definition

In constructing the panel dataset, we only retained villages with names that were consistent in our PODES dataset for 2003, 2005, 2008, 2011, and 2014 and removed any villages with incomplete data. This process reduced our original dataset from 11 874 to 7983 villages in Sumatra, and from 6524 to 3545 villages in Kalimantan. We limited our analysis to villages that partially or fully overlapped with an industrial oil palm concession [33].

Villages that overlap partially or fully with concessions that submitted Letters of Intent (LOI) were considered treated in the LOI year (hereafter, 'certified villages' or 'treated villages'). Villages that overlapped with both RSPO certified and non-certified concessions were considered part of the treatment group. We excluded villages whose overlapping concessions submitted a LOI in 2014 and 2015, as we do not have outcome data post 2014. The control group comprised villages that have at least a fraction of their area overlap only with one or more non-certified concessions ('non-certified villages' for short). Our final sample consists of 569 and 149 treated (as of 2013) and 1779 and 1607 control villages in Sumatra and Kalimantan, respectively (table S5). In the statistical analyses, we use a continuous treatment based on the percentage of village area under RSPO certification which ranges between 0.00062% and 83.34% in Kalimantan, and between 0.00016% and 100% in Sumatra.

2.7. Covariates

We chose covariates based on the placement of RSPO certification as well as hypothesized drivers behind the outcomes (table S6). For example, RSPO certified plantations tend to have a longer history of oil palm establishment and less forest prior to certification [33]. Because they contain fewer residual forests, certified plantations likely faced lower opportunity costs to participate in the RSPO compared to other plantations. To account for this non-random

placement of RSPO plantations, we included covariates on the extent of different types of land cover in a village, including primary forest cover in 2000 [17] and planted oil palm extent in 2000 [66]; we also included peatland extent [74, 75] and the number of expected bird species [76]. To control for distance to markets and proxy for transportation costs, we used village proximity to oil palm mills, ports, and cities, and the length of the river network and the road density within a village. In addition, we included covariates to control for biophysical oil palm suitability (i.e. slope, elevation, temperature, and precipitation) [39]. We also controlled for the baseline values of the outcomes as well as the village area, population density [77], and village dependence on fuelwood [70]. Further, we controlled for a host of land zoning characteristics because we expect land designation to influence the distribution of certification. Specifically, RSPO certified plantations have to abide by national regulations that allow for development of oil palm plantations over areas zoned for non-forestry uses (*areal pengunaan lain*; APL) but prohibit such development within the forest estate (*kawasan hutan*) including conservation forests, limited production forests (*hutan produksi terbatas*; HPT), permanent production forests (*hutan produksi*; HP), and convertible production forests (*hutan produksi yang dapat di konversi*; HPK). Thus, we included the village-level extent of overlap with APL, Production Forests (i.e. HPT, HP, and HPK), and Conservation Forests. The differential regulations across land-use zones defined by the Indonesian Ministry of Environment and Forestry are expected to influence a company's decision to certify its oil palm plantations as well as influence outcomes at the village level [78].

2.8. Estimation

Because the placement of certification depends on the location and characteristics of the villages it spans, the placement of RSPO (i.e. in which villages) is endogenous. Endogeneity, when uncorrected, leads to biased estimates, which can be unstable and depend on model specification if there is limited overlap in the covariate distributions of the treatment and control groups [79]. To address the endogeneity issue and estimate the impact of RSPO certification on the environmental and development indicators, we used a combination of fixed effects panel data models and matching. Specifically, we used matching to preprocess the sample and ensure sufficient covariate overlap between the treatment and control groups (Ho *et al* [80]; Imbens & Wooldridge [79]). We then applied a fixed effects panel data estimator on the matched sample, using frequency weights to account for some observations in the control group being used more than once. The fixed effects model further helps address potential endogeneity by removing linear time-invariant unobserved characteristics that may not have been balanced by the matching procedure.

For each outcome we estimated a fixed effects equation of the kind:

$$y_{itd} = \alpha_i + \lambda_t + Treat_{itd}\beta + Treat_{itd} * x_{i0d} + x_{itd}\delta + \varepsilon_{it} \quad (1)$$

where y_{itd} is the outcome for village i in district d at time t, α_i is a set of individual village fixed effects, λ_t -year fixed effects, x_{itd} is a set of exogenous time-varying covariates (rainfall) assumed to affect the outcome, and x_{i0d} is a baseline covariate (average village slope) likely to modify the impact of the treatment, indicated by $Treat_{itd}$. The treatment variable denotes a vector of continuous variables indicating the village area under RSPO certification in a given year. That is, it has a value of 0 before concession lands within a village become certified; for years after initial certification it contains the fraction of the village area under certification. The treatment variable thus defined allows for villages to become certified during different years. The control group comprises villages that overlap only with industrial oil palm concessions that have never been certified. We estimate equation (1) via a fixed effects regression, clustering the standard errors at the administrative district (*kabupaten*) level to account for the hierarchical nature of the model [81]. Because of the relatively large number of districts ($n = 55$), we did not need to employ corrections of the standard errors due to the small number of clusters (e.g. Cameron *et al* [82]).

To examine the heterogeneity of the impacts along slope, we calculated the marginal effects at representative values of slope, following the estimation of equation (1). These represent the predicted change in an outcome due to the treatment along with significance levels representing whether the predictions are statistically different from 0, at varying values of the slope variable.

2.9. Matching

To preprocess the sample and ensure sufficient covariate overlap, we used nearest neighbour covariate matching with a Mahalanobis distance metric and trimmed on the propensity score. The covariates used in the matching include population density in 2003, road density, proportion of the village area under peat, oil palm in 2000, forest and primary forest, proportion of the village under non-forest, production forest and conservation forest land use, dependence on fuelwood, the proximity to cities, mills, and ports, the village area, the length of the river network within a village, slope, elevation, temperature, precipitation, the number of bird species expected in a village, as well as the baseline values of the village development proxies (i.e. the presence of health facilities, water, air, and land pollution in 2003, number of households with electricity in 2003, the number of educational facilities in 2003).

Table 1 Average impact of RSPO certification on environmental indicators using the matched sample (standard errors in parentheses).

Outcome	Outcome transformation	Variable	Kalimantan		Sumatra	
			Coefficient (ste)	n	Coefficient (ste)	n
Deforestation	Cubic root	Treatment	−0.22[a] (0.13)		−0.08[a] (0.05)	
		Treatment × Slope	0.11[a] (0.06)	1300	0.05[b] (0.02)	4545
Fire density = #Fire/ village area	Square root	Treatment	−0.11 (0.19)		0.02 (0.05)	
		Treatment × Slope	0.04 (0.11)	1315	−0.01 (0.03)	5395
Primary forest remaining	Cubic root	Treatment	−0.05 (0.06)		0.03[b] (0.02)	
		Treatment × Slope	0.02 (0.03)	1315	−0.003 (0.01)	5376
Incidence of water pollution	None	Treatment	−0.48 (0.41)		−0.05 (0.04)	
		Treatment × Slope	0.25 (0.22)	1315	−0.0005 (0.02)	5395
Incidence of air pollution	None	Treatment	0.05 (0.17)		0.09 (0.14)	
		Treatment × Slope	−0.05 (0.13)	1315	−0.06 (0.09)	5395
Incidence of land pollution	None	Treatment	−0.21[b] (0.09)		−0.03 (0.02)	
		Treatment × Slope	0.08 (0.07)	1315	0.01 (0.01)	5395

Significance levels: [b]5%, [a]10%

The resulting covariate balance tables from the matching procedure are given in the supplementary material (tables S7–S9).

2.10. Robustness checks to rule out alternative explanations

We conducted a series of robustness checks to alternative specifications regarding the role of matching to preprocess the sample, functional form of the equation, and outcomes (See supplementary material tables S3–S4). In addition, we tested whether the results are driven by changes in population density. Considering population density when quantifying the impacts of certification is important as significant changes in the number of people may translate into measurable changes in village infrastructure and environmental quality, regardless of the effectiveness of the intervention. For example, regardless of the effectiveness of RSPO, a significant outmigration in a village may result in less infrastructure like schools as these amenities may not be needed. Similarly, substantial outmigration may result in improved environmental conditions due to decreased population pressure, regardless of RSPO. Because population data were unavailable for 2014, we restricted the analysis of population to 2011. Further, in order to control for the possibility that government provision of village public goods may crowd out privately funded improvements due to RSPO certification, we also considered changes in government-funded infrastructure over time.

3. Results

3.1. Average impacts of RSPO in Sumatra and Kalimantan

Between 2003 and 2014, we find small average impacts of RSPO certification on environmental conditions in Indonesian villages (table 1, figure 2(a)). Specifically, relative to villages with non-certified concessions, certified concessions reduced village deforestation by ∼0.05% and 1% in Sumatra and Kalimantan, respectively. RSPO certification also conserved more remaining primary forest in Sumatran villages and decreased the incidence of village land pollution in Kalimantan by 21%, *ceteris paribus*. These results are consistent with previous studies that find small benefits or statistically insignificant impacts on environmental outcomes (e.g. Carlson *et al* [33].; Morgans *et al* [31]).

In terms of village infrastructure, we find that RSPO certification increased the average number of private educational facilities in villages in Kalimantan, but had no statistically significant effect on other village development indicators in either region (table 2). However, the average positive effect in Kalimantan becomes insignificant when changes in population density are considered (table S2).

Our results indicate that, although the RSPO has had limited impacts on the number of village educational and health facilities in the first few years since its implementation, it had an overall positive impact on supporting environmental quality. While RSPO certification had no statistically significant impact on population density in Kalimantan, it decreased population density in Sumatra (table 2).

3.2. Heterogeneity of RSPO impacts across slope

The coefficients on the interaction terms in equation (1) suggest that the impact of certification changes with slope. For example, the impact on deforestation decreased with village slope in both regions, *ceteris paribus* (table 1). In Sumatra, with increases in the slope, RSPO certification decreased the number of private educational facilities, *ceteris paribus* (table 2). In Kalimantan, with increases in slope, RSPO certification increased the probability of a village having a health center.

Using the marginal effects from the regression models, we plot additional impact of certification on environmental outcomes as a function of the village slope and illustrate the heterogeneity in impacts

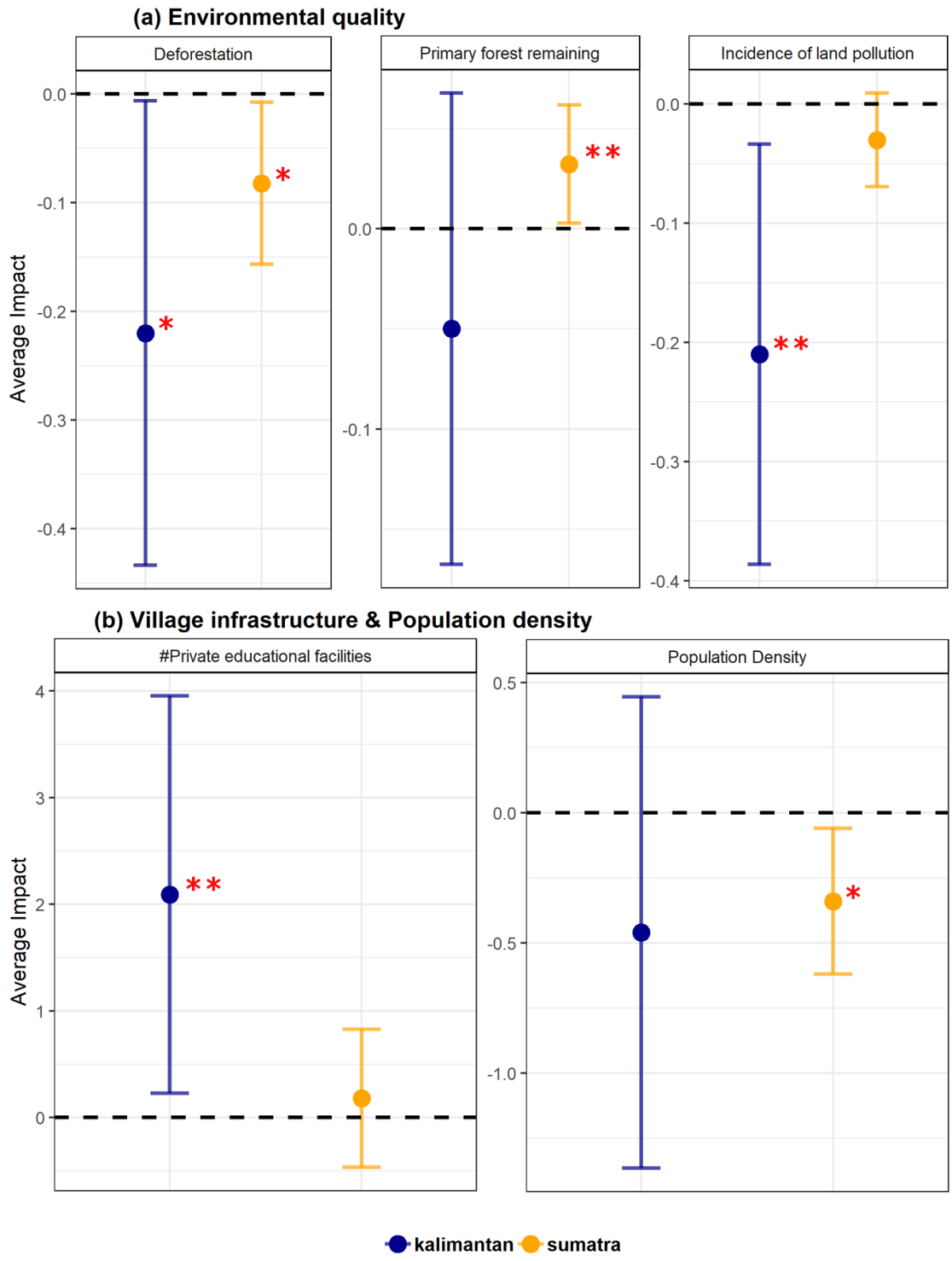

Figure 2. Average impacts of RSPO certification on (a) environmental quality and (b) village infrastructure and population density for Kalimantan and Sumatra, Indonesia. **Indicates significance at the 5%, and * at the 10%. Only statistically significant indicators are presented here.

in more detail (figures 3(a) & b). For example, we show that, relative to villages with non-certified concessions, RSPO certification decreased deforestation on gentle slopes (<2°, impacts significant at the 10% level), but had the opposite effect on slopes > 3° in both Kalimantan and Sumatra. More land area under RSPO certification also resulted in more remaining primary forest and reduced the incidence of water pollution in Sumatra villages on slopes < 3° (impact significant at the 10% level); in Kalimantan, certification reduced the incidence of land pollution on slopes < 2° (impact significant at the 10% level).

With the marginal effects, we also find some heterogeneity in certification's impacts on village development. Relative to villages with non-certified concessions, we find that concessions with RSPO certification were associated with more private educational

Table 2 Average impact of RSPO certification on village infrastructure indicators and population density using the matched sample (standard errors in parentheses). Because the data on population were not available for 2014, we restrict the analysis on the changes in population density to 2011.

Outcome	Outcome transformation	Variable	Kalimantan		Sumatra	
			Coefficient (ste)	n	Coefficient (ste)	n
#Private educational facilities	none	Treatment	2.09[b] (0.95)		0.18 (0.33)	
		Treatment × Slope	−0.68 (0.44)	1315	−0.31[a] (0.18)	5395
#Households with non-state electricity	none	Treatment	290.41 (195.81)		−30.60 (76.02)	
		Treatment × Slope	−129.31 (82.00)	1262	−25.73 (37.63)	5177
Presence of health centers (1 if present)	none	Treatment	−0.35 (0.27)		−0.06 (0.05)	
		Treatment × Slope	0.26[b] (0.12)	1315	0.02 (0.05)	5395
Population density	Cubic root	Treatment	−0.46 (0.55)		−0.34[a] (0.17)	
		Treatment × Slope	0.25 (0.23)	1052	0.12 (0.10)	4316

Significance levels: [b]5%, [a]10%

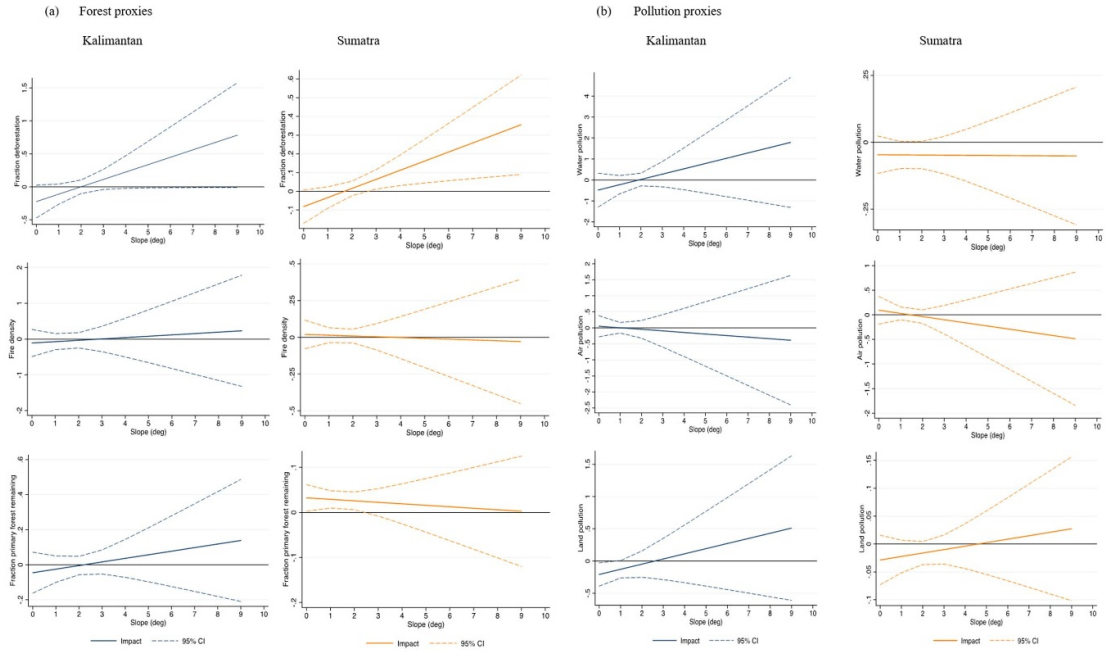

Figure 3. Heterogeneity in the impacts of RSPO certification on the proxies of (a) forest health and (b) pollution for Kalimantan (blue) and Sumatra (yellow) based on marginal effects from the panel data regression models on the matched sample (equation (1)). An impact is statistically significant if the 95% CI do not cross the 0 line.

facilities on slopes < 3° in Kalimantan and fewer such facilities on slopes > 1° in Sumatra (figure 4). However, these results are likely driven by changes in population density. In Sumatra, adjusting by the village population results in no statistically significant effects of certification (figure S3). In Kalimantan we find that adjusting by the population density changes the direction of the relationship between slope and private educational facilities, and results in no statistically significant effects of certification (figure S3).

We did not find a statistically significant impact of RSPO certification on the number of households with non-state sources of electricity even after accounting for changes in population density in Kalimantan (figures 4, S3). In Sumatra, certification resulted in a decrease in the number of households with non-state sources of electricity on slopes between 1° and 3°, relative to non-certified concessions (figure 4); these patterns remained consistent after accounting for changes in population density (figure S3). In Sumatra, although RSPO certification did not have a statistically significant impact on the probability of a village having a health center, it increased this probability in villages on slopes > 3° in Kalimantan (figure 4). Finally, we observe a statistically significant reduction in the number of people in treated villages on gentle slopes (<2°) in Sumatra between 2003 and 2011 relative to observationally similar control villages.

3.3. Trade-offs and complementarities

We also find evidence of trade-offs and complementarities in the environmental and development outcomes along slope, our proxy for agricultural suitability and ecosystem fragility (figure 5). In Kalimantan,

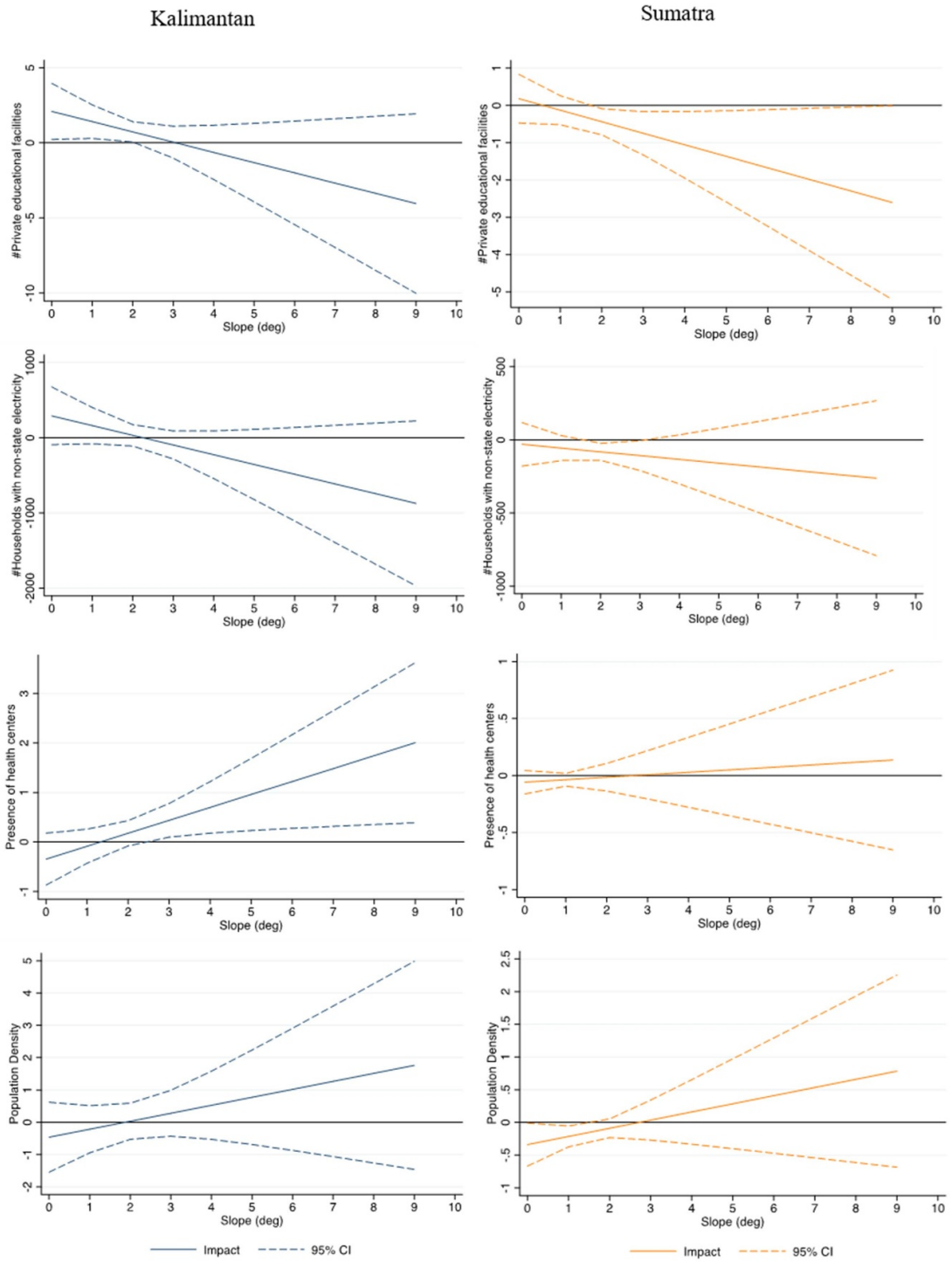

Figure 4. Heterogeneity in the village infrastructure and population impacts of RSPO certification for Kalimantan (blue) and Sumatra (yellow) based on marginal effects from the panel data regression models on the matched sample (equation (1)). An impact is statistically significant if the 95% CI do not cross the 0 line.

treatment villages with slopes < 2°, the statistically significant increase in the number of private educational facilities coincides with lower incidence of land pollution and decreased deforestation, a complementarity. In villages with slopes > 3°, we observe apparent environment-development trade-offs in the form of a positive impact from RSPO certification on both the probability a village will have a health center and on deforestation rates. In Sumatra, there is a reduction of deforestation and water pollution as well as an increase in primary forests and no statistically significant impacts on infrastructure on slopes < 1°. The trade-offs between environmental and development goals occur where villages have slopes > 1°. In these villages, RSPO certification decreased deforestation and water pollution and protected remaining primary forests, but resulted in lower household access to non-state sources of electricity and less

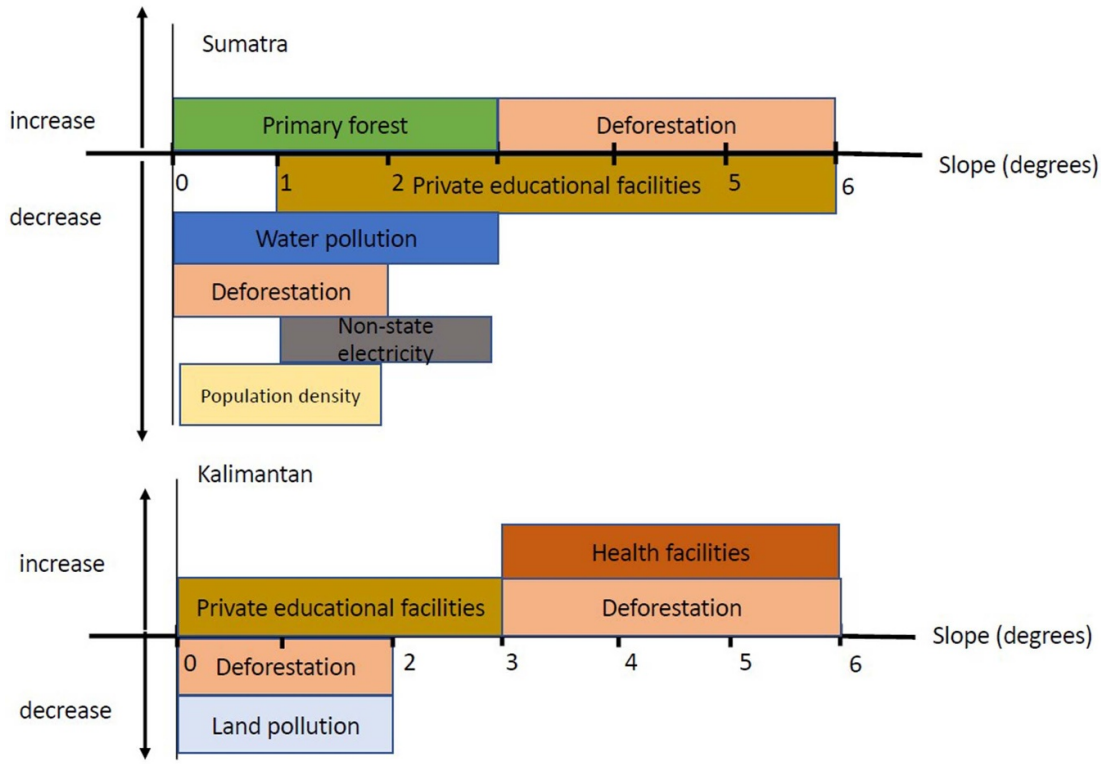

Figure 5. Trade-offs and complementarities between the environmental and village development outcomes from RSPO certification along village slope (horizontal axis), which proxies for agricultural suitability and ecosystem fragility. The boxes above the horizontal line indicate increases in the outcome; those below indicate decreases in the outcome associated with certification. Only the statistically significant predictions from the marginal effects are shown in the figure.

private educational facilities as well as lower population density, relative to non-certified concessions.

3.4. Robustness checks

Our results are robust across multiple specifications (tables S3–4). We also do not find evidence of substitution between state and non-state infrastructure. In Kalimantan, we find no statistically significant impacts of RSPO certification on the number of state educational facilities and households with access to state electricity (figure S4, tables S3–4). In Sumatra, we find no statistically significant impact on state educational facilities, but a significant decrease in the number of households with access to state electricity. The direction of impacts coincides with that of private educational facilities (figures 4, S4) but the impact disappears when we consider changes in the population density (tables S3–4).

4. Discussion

Using a novel village-level dataset spanning 2003–2014 and rigorous quasi-experimental methods, we demonstrate that RSPO certification resulted in small, often heterogeneous and geographically limited changes in village environmental quality and infrastructure relative to villages with non-certified oil palm concessions. We identify several trade-offs between environmental and developmental outcomes in both regions, but also some complementarities in Kalimantan.

Observed patterns in the provision of village public goods due to RSPO certification are consistent with our theory of change, for the most part. Especially on gentle slopes where oil palm production is most profitable, certification may create incentives for improving village infrastructure and mitigating negative environmental impacts associated with oil palm production and expansion. Below we offer some potential explanations for the observed patterns-specifically focusing on changes in population density, changes in observationally similar non-certified concessions, and data limitations.

4.1. Changes in population density

The unexpected decline in the number of private educational facilities and households with access to non-state electricity on slopes $> 1^{\circ}$ in Sumatra may be correlated with a concomitant change in population density. While certification had no significant impact on village population in Kalimantan, in Sumatra the trade-offs between the development and environmental outcomes on gentle slopes may be correlated with a significant decrease in the number of people living in the treated villages only two years after initial certification, relative to non-certified concessions. Although the lack of 2014 population data limits this analysis, in Sumatra we cannot rule out the possibility

that on gentle slopes improvements in environmental outcomes and reductions in village infrastructure in treated villages relative to control villages are due to reduced migration to or greater out-migration from villages overlapping with RSPO certified plantations. In other words, it is possible that observed impacts of RSPO certification could be driven not by changes in oil palm company practices induced by certification, but by decreased pressure on the natural environment and reduced need for infrastructure due to lower population density in treated villages. Future research needs to examine this possibility in greater detail and also consider who the migrating people are, why they migrated, and where they went.

4.2. Additionality

Critically, our analysis considers the *additional* impact of RSPO certification relative to effects of non-certified oil palm plantations. A potential explanation for RSPO certification's limited impact on village development is that most contributions to village infrastructure likely take place when oil palm plantations are initially developed. Previous research (Budidarsono *et al* [55] and Baudoin *et al* [53] in the context of oil palm; Engel *et al* [50] in the context of commercial logging) has suggested that in Indonesia, industrial actors compensate villages to gain access to areas that overlap with village land, a process that we expect to occur mainly during initial plantation development. Thus, the *additional* impact of certification that takes place after the plantation is established may be small and limited to areas with outstanding land tenure issues or other conflicts that require resolution for achievement and maintenance of RSPO certification. This could be the case for our study since most certified concessions were developed before 2005 [33]. Alternatively, compensation could occur at the individual or household level rather than the village-level or be in the form of programming and direct funds; because of data unavailability, we do not consider these types of compensation. Concomitant Indonesian government policies that aim to develop the oil palm producing regions, regardless of certification status, could further contribute to the lack of RSPO-induced village development additionality [55]. In addition, the sustainability criteria set out by the RSPO 2007 P&C and applied to most certified plantations in this study lack clarity on implementation other than what is legally required under national and regional policies for improving social well-being at the village-level.

4.3. Data limitations

Our study is subject to certain limitations. First, we do not control for the spatial dependence of many of the outcomes examined here (e.g. we do not distinguish between upstream and downstream villages for water pollution or account for wind patterns for air pollution and fire incidence). We also consider average annual impacts and do not allow for seasonality of the impacts even for outcomes that likely vary within a year (e.g. differences in fire between wet and dry seasons). Because many villages in our sample are only partially spanned by certified concessions, our estimates capture the net effect of certification on all areas within the treated villages, not only areas within certified concessions, and thus include within-village spillover effects. Because developing and testing a theoretical model for the location of spillovers (i.e. effects outside the policy boundary) is beyond the scope of this study, we do not attempt to capture the possibility of spillovers beyond examining the aggregate impact of certification at the village level. Previous work has shown that the spillovers from conservation and development policies do not necessarily occur in areas immediately adjacent to treated zones and may depend on factors such as the level of village market integration and size of markets, among others (e.g. Miteva *et al* [83]). Spillovers due to certification can be significant and may potentially offset or enhance direct certification-induced changes in development or environmental conditions. For example, Heilmayr *et al* [34] find that RSPO certification in Kalimantan induced heterogeneous spillovers to regional markets and distant locations.

Second, we also do not attempt to quantify the impact of RSPO on greenhouse gas emissions from palm oil production, even though the RSPO P&C include provisions for minimizing such emissions. Substantial land-based greenhouse gas emissions from oil palm production can occur during land clearing via removal of vegetation biomass and burning of peat carbon [84]. Ongoing emissions during oil palm production include CO_2 emissions from peatland drainage [85, 86] and CH_4 emissions from anaerobic decomposition of palm oil mill effluent [87]. We expect effects of certification on vegetation biomass emissions to be similar to certification's effects on forest cover, and we lack concession-specific data on peatland drainage practices and associated emissions and CH_4 emissions from effluent.

Third, our analysis focuses only on large-scale industrial concessions. Independent smallholder groups can also achieve RSPO certification, but only three groups in Sumatra with < 2000 ha total area had released LOIs by 2013. Previous studies suggest that, on average, oil palm production is beneficial to smallholders in Indonesia [88], but the impacts vary by smallholder access to land and labor, disparities within communities, and land tenure security [89]. Thus, the exclusion of land under smallholder certification from our analysis is likely to introduce a very slight downward bias of the extent and nature of RSPO impacts.

Our analysis focuses on *quantitative* changes in the village infrastructure. Because of the lack of data, we do not consider the quality, size, or target

populations of facilities and associated services. For example, despite the general lack of statistically significant positive impacts of RSPO certification on the number of private educational facilities, incidence of health centers, or household access to non-state electricity, certification may have improved the quality and size of these facilities or number and/or quality of the services they provide. For example, it is possible RSPO both improved the quality of health centers on gentler slopes and increased the likelihood of health facilities in villages on higher slopes in Kalimantan. In Sumatra, the decline in the number of private educational facilities relative to non-certified concessions can be possibly due to improvements in quality, but not numbers. Of course, it is also possible that new infrastructure provided by companies be undertaken not because of community needs, but for other reasons such as upward accountability or succeeding on paper to donors [90].

Our indicators for village infrastructure and environmental conditions may promote village development as they are correlated, albeit imperfectly, with sustainability and development goals like improved access to health care and education and reduced exposure to hazardous environmental conditions. For example, previous work has shown that exposure to smoke from fires used to clear land for oil palm production in Indonesia reduces adolescents' height-to-age scores and is correlated with significant losses in income [60]. Similarly, previous studies in Indonesia have found a positive impact of schooling and health care accessibility on children's health [91]. While our selected indicators provide initial insight into the impact of certification on village development, they are far from comprehensive. Future work needs to examine the impact of RSPO on individual outcomes like literacy, incomes, poverty, health, and security in both the short- and long-terms.

4.4. Long-term impacts of certification and implications for policy

The lack of significant improvements in most village development indicators found in this study may be due to the nature of criteria intended to ensure that companies contribute to village development. The 2007 criteria are vaguely worded and thus may have lacked stringency due to potentially broad interpretation by auditors. For example, the indicator for compliance with Criterion 6.11 ('Growers […] contribute to local sustainable development wherever appropriate') simply requires demonstrable contributions to local communities. Such contributions are likely to occur even in the absence of certification due to the need for oil palm companies to negotiate with local communities as well as Indonesian law [56]. Moreover, guidance on how to implement this Criterion (i.e. companies should consult local communities, and use their profit for social development projects), is vague [52]. The original 2007 RSPO standard has undergone two rounds of revisions, in 2013 and 2018 [92] which provided some clarity on how producers should implement the P&C. For example, the 2018 RSPO P&C provides more guidance on how companies can seek partnerships with NGOs and civil society organisations to contribute towards rural development, for instance via poverty reduction, access to healthcare, and support of food and water security. Such improved specificity may lead to greater beyond-business-as-usual changes by certified producers audited under the revised P&C, changes not captured in our study.

In addition to the revised P&C, the RSPO introduced a New Planting Procedure (NPP) in 2010 [93]. The NPP requires that prior to any new oil palm development or replanting, companies engage with local communities potentially impacted by the proposed development and ensure their legal and customary rights to land are respected [93]. The NPP also mandates companies to avoid developing areas with high conservation values [94] and/or high carbon stocks [95]. The implementation of these more stringent criteria prior to oil palm development is likely to have a larger additional impact on environmental and development outcomes compared to implementation of the P&C on a long-established plantation. However, translation of improved criteria and the NPP to better environmental and socio-economic outcomes is contingent on respect for human rights, good governance, transparency, accountability, rule of law, and access to justice [52, 96]. Given shortcomings in RSPO compliance monitoring and enforcement [97], it remains to be seen whether RSPO's impacts on development and environmental quality will change through time.

Improving the additional impact of RSPO on the ground is predicated on understanding the drivers of certification as well as incentives and disincentives for adoption across the spectrum of oil palm producers in Indonesia. *Why* certification is adopted by oil palm growers as well as where certification is granted are likely to shape impacts on the ground [98]. Previous work has shown that conflicts with local communities and pressure from NGOs (especially in areas with high conservation values have been significant drivers for adoption of RSPO certification and improvement of agricultural practices in Indonesia's oil palm industry (e.g. Gnych *et al* [49]). Thus, like Forest Sustainability Council (FSC) certification (Miteva *et al* [59]), RSPO has the potential to support resolution of land tenure insecurities in the absence of strong formal institutions and might contribute to rural development, while decreasing the impacts on the natural environment. However, it is less clear how RSPO is going to balance development goals with increasing pressure on natural resources due to concomitant increases in oil palm production [49].

Further, the impact of RSPO on the ground is also determined by which producers become certified.

Owing to international market pressures, multinational corporations may have already adopted better practices, with certification having little or no additional impact. In contrast, oil palm producing areas dominated by smallholders may be left out of the certification scheme due to prohibitively large costs and lack of incentives to employ improved oil palm production practices [98, 99]. While the certification of smallholder oil palm producers may generate significant additional benefits to local communities and ecosystems because of the change in practices, to date very few smallholder producers participate in RSPO. In 2019, the number of Indonesian smallholders (tied and independent) who achieved RSPO certification reached 2777 smallholders which is a fraction of the total estimated number of oil palm smallholders in Indonesia (2.3 million smallholders) [100, 101].

5. Conclusion

Evaluating the performance of sustainability certification systems is challenging for a variety of reasons: the lack of clear mechanisms linking cause and effect, the lack of reliable datasets spanning large areas and multiple outcomes as well as lack of consensus over appropriate measurable proxies for the outcomes [102]. Our study addresses these concerns by drawing on a rich panel dataset, spanning a large area in Indonesia, a hypothesized mechanism of change, and rigorous impact evaluation methods. We evaluate trade-offs between development and environmental impacts of RSPO on local communities. We demonstrate that, in the short-run, while RSPO has contributed to environmental conservation, its impact on rural development has been limited. The longer term impacts of certification on the local environment and communities remain to be seen. Future questions on measuring the impacts of palm oil certification systems should deepen our understanding of plausible mechanisms of how certification systems impact environmental and developmental outcomes (e.g. the role of NGOs in certification systems), as well as consider historical and longitudinal approaches to tackle some more challenging outcomes that defy easy measurement such as workers' rights, land tenure security, migration, and individual development outcomes like literacy, income, poverty, and health both in the short and long runs.

Our work addresses previous calls to strengthen conservation evaluation by considering the heterogeneity of impacts, in order to develop hypotheses about the mechanisms through which certification leads to change on the ground [103], and to assess trade-offs and synergies between the outcomes of sustainability initiatives [36]. Understanding mechanisms and tradeoffs or complementarities in a particular context is a prerequisite for improving the design of the intervention and its impacts on the ground. For example, such analyses can help identify the beneficiaries of RSPO certification and the time scales and location over which direct and indirect impacts are felt, and to guide the design of rigorous impact evaluations [104]. By highlighting the heterogeneity of the RSPO impacts across space and types of outcomes, we provide the first step needed to understand and model the mechanisms through which certification schemes effect change on the ground. Specifically, we identify several of the channels through which RSPO may have impacts on the ground in Indonesia—including the bargaining power of local communities and pressure from NGOs, changes in population density due to migration, lack of standard stringency, and international pressures versus local incentives especially on large-scale oil palm companies. All of these have important implications for policy makers and academics interested in designing and evaluating policies like voluntary sustainability certification schemes.

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Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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Author contributions

JSHL, DAM, KMC, RH, OS contributed to the study design and conceptual development of this paper. JSHL, KMC, RH and OS contributed and processed data, DAM performed the econometric analysis. JSHL and DAM drafted the manuscript and KMC, RH, OS contributed to revisions of the paper.

Competing interests

The authors declare they have no competing interests.

Data and materials availability

All data needed to evaluate the conclusions in the paper and/or the supplementary material. Additional data related to this paper may be requested from the authors.

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References

[1] Curtis P G, Slay C M, Harris N L, Tyukavina A and Hansen M C 2018 Classifying drivers of global forest loss *Science* **361** 1108–11
[2] Pendrill F, Persson M, Godar J and Kastner T 2019 Deforestation displaced: trade in forest-risk commodities and the prospects for a global forest transition *Environ. Res. Lett.* **14** 055003
[3] Kessler J J, Rood T, Tekelenburg T and Bakkenes M 2007 Biodiversity and socioeconomic impacts of selected agro-commodity production systems *J. Environ. Dev.* **16** 131–60
[4] Obidzinski K, Takahashi I, Dermawan A, Komarudin H and Andrianto A 2013 Can large scale land acquisition for agro-development in Indonesia be managed sustainably? *Land Use Policy* **30** 952–65
[5] Pye O, Daud R and Harmono Y Tatat 2012 Precarious lives: transnational biographies of migrant oil palm workers *Asia Pac. Viewp.* **53** 330–42
[6] Zoomers A, Leung M and Westen G V 2016 Local development in the context of global migration and the global land rush: the need for a conceptual update *Geogr. Compass.* **10** 56–66
[7] Lambin E F *et al* 2018 The role of supply-chain initiatives in reducing deforestation *Nat. Clim. Change* **8** 109–16
[8] Auld G, Gulbrandsen L H and McDermott C L 2008 Certification schemes and the impacts on forests and forestry *Annu. Rev. Environ. Resour.* **33** 187–211
[9] Cashore B, Auld G and Newson D 2004 *Governing through Markets: Forest Certification and the Emergence of Non-state Authority* (New Haven, CT: Yale University Press)
[10] Oya C, Schaefer F, Skalidou D, McCosker C and Langer L 2017 Effects of certification schemes for agricultural production on socio-economic outcomes in low- and middle-income countries: a systematic review *Campbell Systematic Rev.* **13** 1–346
[11] DeFries R S, Fanzo J, Mondal P, Remans R and Wood S A 2017 Is voluntary certification of tropical agricultural commodities achieving sustainability goals for small-scale producers? a review of the evidence *Environ. Res. Lett.* **12** 33001
[12] Garrett R, Rueda X, Levy S, Bermudez Blanco J F and Shah S 2018 *Measuring Impacts of Supply Chain Initiatives for Conservation: Focus on Forest-risk Food Commodities* (Washington, DC: Meridian Institute)
[13] RSPO 2019 Roundtable on sustainable palm oil (available at: http://www.rspo.org/certification)
[14] McCarthy J and Zen Z 2010 Regulating the oil palm boom: assessing the effectiveness of environmental governance approaches to agro-industrial pollution in Indonesia *Law Policy* **32** 153–79
[15] Laurance W F *et al* 2010 Improving the performance of the roundtable on sustainable palm oil for nature conservation *Conserv. Biol.* **24** 377–81
[16] Maxton-Lee B 2020 *Forest Conservation and Sustainability in Indonesia: A Political Economy Study of International Governance Failure. The Earthscan Forest Library* 1st edn (Abingdon: Routledge)
[17] Margono B A, Potapov P V, Turubanova S, Stolle F and Hansen M C 2014 Primary forest cover loss in Indonesia over 2000–2012 *Nat. Clim. Change* **4** 730
[18] Abood S A, Lee J S H, Burivalova Z, Garcia-Ulloa J and Koh L P 2014 Relative contributions of the logging, fiber, oil palm, and mining industries to forest loss in Indonesia *Conserv. Lett.* **8** 58–67
[19] Mboi N *et al* 2018 On the road to universal health care in Indonesia, 1990 & 2016: a systematic analysis for the global burden of disease study 2016 *Lancet* **392** 581–91
[20] Gibson J and Olivia S 2010 The effect of infrastructure access and quality on non-farm enterprises in rural Indonesia *World Dev.* **38** 717–26
[21] Bangay C 2005 Private education: relevant or redundant? Private education, decentralisation and national provision in Indonesia *Comp. A. J. Comp. Int. Educ.* **35** 167–79
[22] Qaim M, Sibhatu K T, Siregar H and Grass I 2020 Environmental economic, and social consequences of the oil palm boom *Annu. Rev. Resour. Econ.* **12** 321–344
[23] Edwards R 2017 Tropical oil crops and rural poverty SSRN (available at: https://ssrn.com/abstract=3040400)
[24] Santika T, Wilson K A, Budiharta S, Law E A, Poh T M, Ancrenaz M, Struebig M J and Meijaard E 2019 Does oil palm agriculture help alleviate poverty? A multidimensional counterfactual assessment of oil palm development in Indonesia *World Dev.* **120** 105–17
[25] McCarthy J F 2010 Processes of inclusion and adverse incorporation: oil palm and agrarian change in Sumatra, Indonesia *J. Peasant Stud.* **37** 821–50
[26] McCarthy J F and Cramb R A 2009 Policy narratives, landholder engagement, and oil palm expansion on the Malaysian and Indonesian frontiers *Geogr. J.* **175** 112–23 (http://www.jstor.org/stable/40205283)
[27] Bissonnette J-F 2013 Development through large-scale oil palm agribusiness schemes: representations of possibilities and the experience of limits in West Kalimantan *Sojourn: J. Soc. Issues Southeast Asia* **28** 485–511
[28] Lee J S H, Abood S A, Ghazoul J, Barus B, Obidzinski K and Koh L P 2014 Environmental impacts of large-scale oil palm enterprises exceed that of smallholdings in Indonesia *Conserv. Lett.* **7** 25–33
[29] Koh L P, Miettinen J, Liew S C and Ghazoul J 2011 Remotely sensed evidence of tropical peatland conversion to oil palm *Proc. Natl Acad. Sci. USA* **108** 5127–32
[30] Cattau M E, Marlier M E and DeFries R 2016 Effectiveness of Roundtable on Sustainable Palm Oil (RSPO) for reducing fires on oil palm concessions in Indonesia from 2012 to 2015 *Environ. Res. Lett.* **11** 10
[31] Morgans C L *et al* 2018 Evaluating the effectiveness of palm oil certification in delivering multiple sustainability objectives *Environ. Res. Lett.* **13** 64032
[32] Noojipady P, Morton D C, Schroeder W, Carlson K M, Huang C, Gibbs H K, Burns D, Walker N F and Prince S D 2017 Managing fire risk during drought: the influence of certification and El Nino on fire-driven forest conversion for oil palm in Southeast Asia *Earth Syst. Dyn.* **8** 749–71
[33] Carlson K M, Heilmayr R, Gibbs H K, Noojipady P, Burns D N, Morton D C, Walker N F, Paoli G D and Kremen C 2018 Effect of oil palm sustainability certification on

deforestation and fire in Indonesia *Proc. Natl Acad. Sci. USA* **115** 121–6
[34] Heilmayr R, Carlson K M and Benedict J J 2020 Deforestation spillovers from oil palm sustainability certification *Environ. Res. Lett.* **15** 75002
[35] Santika T *et al* 2020 Impact of palm oil sustainability certification on village well-being and poverty in Indonesia *Nature Sustainability* (https://doi.org/10.1038/s41893-020-00630-1)
[36] Gill D A, Cheng S H, Glew L, Aigner E, Bennett N J and Mascia M B 2019 Social synergies, tradeoffs, and equity in marine conservation impacts *Annu. Rev. Environ. Resour.* **44** 347–72
[37] Brandi C A 2017 Sustainability standards and sustainable development – synergies and trade-offs of transnational governance *Sustain. Dev.* **25** 25–34
[38] Nilsson C and Grelsson G 1995 The fragility of ecosystems: a review *J. Appl. Ecol.* **32** 677–92
[39] Pirker J, Mosnier A, Kraxner F, Havlík P and Obersteiner M 2016 What are the limits to oil palm expansion? *Glob. Environ. Change* **40** 73–81
[40] Blackman A, Corral L, Lima E S and Asner G P 2017 Titling indigenous communities protects forests in the Peruvian Amazon *Proc. Natl Acad. Sci.* **114** 4123–8
[41] Cheyns E 2014 Making 'minority voices' heard in transnational roundtables: the role of local NGOs in reintroducing justice and attachments *Agric. Human Values* **31** 439–53
[42] Oosterveer P, Adjei B E, Vellema S and Slingerland M 2014 Global sustainability standards and food security: exploring unintended effects of voluntary certification in palm oil *Glob. Food Sec.* **3** 220–6
[43] Delabre I and Okereke C 2019 Palm oil, power, and participation: the political ecology of social impact assessment *Environ. Plan* E **3** 642–62
[44] Cheyns E and Riisgaard L 2014 Introduction to the symposium *Agric. Human Values* **31** 409–23
[45] Silva-Castaneda L and Trussart N 2016 Sustainability standards and certification: looking through the lens of Foucault's dispositif *Glob. Netw.* **16** 490–510
[46] Ponte S and Cheyns E 2013 Voluntary standards, expert knowledge and the governance of sustainability networks *Glob. Netw.* **13** 459–77
[47] Bishop K J 2017 *Assessing the Role of Third-Party Audits in Ensuring Producer Compliance with the Roundtable On Sustainable Palm Oil (RSPO) Certification System* (Manoa: University of Hawai'i)
[48] Macdonald K and Balaton-Chrimes S 2016 The complaints system of the roundtable on sustainable palm oil (RSPO) SSRN (available at: https://ssrn.com/abstract=2880049)
[49] Gnych S, Limberg G and Paoli G 2015 Risky business: motivating uptake and implementation of sustainability standards in the Indonesian palm oil sector Bogor, Indonesia CIFOR Bogor, Indonesia Occasional Paper 139 (http://doi.org/10.17528/cifor/005748)
[50] Engel S, López R and Palmer C 2006 Community–industry contracting over natural resource use in a context of weak property rights: the case of Indonesia *Environ. Resour. Econ.* **33** 73–93
[51] Rutten R, Bakker L, Alano M L, Salerno T, Savitri L A and Shohibuddin M 2017 Smallholder bargaining power in large-scale land deals: a relational perspective *J. Peasant Stud.* **44** 891–917
[52] Colchester M and Chao S 2013 Conflict or consent? The oil palm sector at a crossroads (available at: http://www.forestpeoples.org/en/topics/palm-oil-rspo/publication/2013/conflict-or-consent-oil-palm-sector-crossroads)
[53] Baudoin A, Bose P M, Bessou C and Levang P 2017 Review of the diversity of palm oil production systems in Indonesia: case study of two provinces: Riau and Jambi Bogor, Indonesia CIFOR Bogor, Indonesia Working Paper 219 (http://doi.org/10.17528/cifor/006462)
[54] Peraturan Presiden 1996 PP-40 HGU dan Hak Pakai
[55] Budidarsono S, Susanti A and Zoomers A 2013 Oil palm plantations in indonesia: the implications for migration, settlement/resettlement and local economic development *Biofuels - Economy, Environment and Sustainability*, ed Z Fang (Rijeka: InTech) pp 173–93
[56] Colchester M *et al* 2006 *Promised Land: Palm Oil and Land Acquisition in Indonesia - Implications for Local Communities and Indigenous Peoples* (Perkumpulan Sawit Watch: Forest People Programme)
[57] Dhiaulhaq A, Gritten D, De Bruyn T, Yasmi Y, Zazali A and Silalahi M 2014 Transforming conflict in plantations through mediation: lessons and experiences from Sumatera, Indonesia *For. Policy Econ.* **41** 22–30
[58] Silva-Castañeda L 2012 A forest of evidence: third-party certification and multiple forms of proof—a case study of oil palm plantations in Indonesia *Agric. Human Values* **29** 361–70
[59] Miteva D A, Fortmann L and McNab R 2021 Voluntary market-based initiatives to overcome institutional failures related to land tenure security *Land Tenure and Sustainable Development* (London: Palgrave-Macmillan)
[60] Tan-Soo J-S and Pattanayak S K 2019 Seeking natural capital projects: forest fires, haze, and early-life exposure in Indonesia *Proc. Natl Acad. Sci.* **116** 5239 LP–5245
[61] United Nations 2020 Sustainable development goals (available at: (http://www.un.org/sustainabledevelopment/sustainable-development-goals/) (Accessed 1 Jul 2020))
[62] Litzow E L, Pattanayak S K and Thinley T 2019 Returns to rural electrification: evidence from Bhutan *World Dev.* **121** 75–96
[63] BPS Indonesian Oil Palm Statistics 2017 Badan Pusat Statistik, editor. Jakarta, Indonesia: Sub-directorate of Estate Crops Statistics, BPS-Statistics Indonesia; 2017
[64] Hasegawa T and Matsuoka Y 2015 Climate change mitigation strategies in agriculture and land use in Indonesia *Mitig. Adapt. Strateg. Glob. Chang.* **20** 409–24
[65] Hidayat N K, Offermans A and Glasbergen P 2018 Sustainable palm oil as a public responsibility? On the governance capacity of Indonesian Standard for Sustainable Palm Oil (ISPO) *Agric. Human Values* **35** 223–42
[66] Austin K G, Mosnier A, Pirker J, McCallum I, Fritz S and Kasibhatla P S 2017 Shifting patterns of oil palm driven deforestation in Indonesia and implications for zero-deforestation commitments *Land Use Policy* **69** 41–48
[67] Gunarso P, Hartoyo M E, Agus F and Killeen T J 2013 Oil palm and land use change in Indonesia, Malaysia and Papua New Guinea (Kuala Lumpur, Malaysia: RSPO)
[68] Li T M 2015 Social impacts of oil palm in Indonesia: A gendered perspective from West Kalimantan Bogor, Indonesia
[69] Abram N K *et al* 2017 Oil palm–community conflict mapping in Indonesia: A case for better community liaison in planning for development initiatives *Appl. Geogr.* **78** 33–44
[70] BPS 2016 Village potential statistics Jakarta, Indonesia: Badan Pusat Statistik (available at: (https://microdata.bps.go.id/mikrodata/index.php/catalog/PODES)
[71] Jagger P and Rana P 2017 Using publicly available social and spatial data to evaluate progress on REDD+ social safeguards in Indonesia *Environ. Sci. Policy* **76** 59–69
[72] Miteva D A, Loucks C J and Pattanayak S K 2015 Social and environmental impacts of forest management certification in Indonesia *PloS One* **10** e0129675
[73] Santika T *et al* 2019 Heterogeneous impacts of community forestry on forest conservation and poverty alleviation: evidence from Indonesia *People Nat.* **1** 204–19
[74] Wahyunto , Heryanto B, Bekti H and Widiastuti F 2006 Maps of peatland distribution, area and carbon content in papua, 2000–2001 Wetlands International-Indonesia Programme & Wildlife Habitat Canada (WHC)

[75] Wahyunto, Ritung S and Subagjo H 2005 Map of Peatland Distribution Area and Carbon Content in Kalimantan, 2000-2002
[76] Jenkins C N, Pimm S L and Joppa L N 2013 Global patterns of terrestrial vertebrate diversity and conservation *Proc. Natl Acad. Sci. USA* **110** E2602-E2610
[77] CIESIN 2019 Gridded Population of the World (available at: https://sedac.ciesin.columbia.edu/data/collection/gpw-v4/acknowledgments (Accessed 1 May 2018))
[78] Giessen L, Burns S, Sahide M A K and Wibowo A 2016 From governance to government: the strengthened role of state bureaucracies in forest and agricultural certification *Policy Soc.* **63** 1674–94
[79] Imbens G W and Wooldridge J M 2009 Recent developments in the econometrics of program evaluation *J. Econ. Lit* . **47** 5–86
[80] Ho D E, Imai K, King G and Stuart E A 2007 Matching as nonparametric preprocessing for reducing model dependence in parametric causal inference. *Polit. Anal.* **15** 199–236
[81] Angrist J D and Pischke J-S 2009 *Mostly Harmless Econometrics: An Empiricist's Companion* (Princeton, NJ: Princeton University Press) pp 392
[82] Cameron A C, Gelbach J B and Miller D L 2008 Bootstrap-based improvements for inference with clustered errors *Rev. Econ. Stat.* **90** 414–27
[83] Miteva D A, Kramer R A, Brown Z S and Smith M D 2017 Spatial patterns of market participation and resource extraction: fuelwood collection in Northern Uganda *Am. J. Agric. Econ.* **99** 1008–26
[84] Carlson K M, Curran L M, Asner G P, Pittman A M, Trigg S N and Marion Adeney J 2013 Carbon emissions from forest conversion by Kalimantan oil palm plantations *Nat. Clim. Change* **3** 283–7
[85] Carlson K M, Goodman L K and May-Tobin C C 2015 Modeling relationships between water table depth and peat soil carbon loss in Southeast Asian plantations *Environ. Res. Lett.* **10** 7
[86] Cooper H V, Evers S, Aplin P, Crout N, Bin D M P and Sjogersten S 2020 Greenhouse gas emissions resulting from conversion of peat swamp forest to oil palm plantation *Nat. Commun.* **11** 407
[87] Taylor P G, Bilinski T M, Fancher H R F, Cleveland C C, Nemergut D R, Weintraub S R, Wieder W R and Townsend A R 2014 Palm oil wastewater methane emissions and bioenergy potential *Nat. Clim. Change* **4** 151–2
[88] Lee J S H, Ghazoul J, Obidzinski K and Koh L P 2013 Oil palm smallholder yields and incomes constrained by harvesting practices and type of smallholder management in Indonesia *Agron. Sustain. Dev.* **34** 501–513
[89] Krishna V, Euler M, Siregar H and Qaim M 2017 Differential livelihood impacts of oil palm expansion in Indonesia *Agric. Econ.* (https://doi.org/10.1111/agec.12363)
[90] Wahlén C B 2014 Constructing conservation impact *Conserv. Soc.* **12** 77–88
[91] Park C 2010 Children's Health Gradient in Developing Countries: evidence from Indonesia *J. Econ. Dev.* **35** 25–44
[92] RSPO 2020 RSPO Principles & Criteria review (available at: https://rspo.org/principles-and-criteria-review (Accessed 1 Jul 2020))
[93] RSPO 2015 RSPO New Planting Procedure (https://rspo.org/resources/certification/new-planting-procedure)
[94] HCV 2020 High Conservation Value (HCV) Resource Network (available at: https://hcvnetwork.org/ (Accessed 1 Jul 2020))
[95] HCS Approach 2020 High Carbon Stock (HCS) Approach (available at: http://highcarbonstock.org/the-high-carbon-stock-approach/ (Accessed 1 Jul 2020))
[96] McCarthy J F 2012 Certifying in contested spaces: private regulation in Indonesian forestry and palm oil *Third World Q.* **33** 1871–88
[97] Kusumaningtyas R 2017 External Concern on the ISPO and RSPO Certification Schemes (Profundo: Amsterdam, The Netherlands)
[98] Garrett D R, Carlson M K, Rueda X and Noojipady P 2016 Assessing the potential additionality of certification by the round table on responsible soybeans and the roundtable on sustainable palm oil *Environ. Res. Lett.* **11** 45003
[99] Lee J S H, Rist L, Obidzinski K, Ghazoul J and Koh L P 2011 No farmer left behind in sustainable biofuel production *Biol. Conserv.* **144** 2512–6
[100] Hutabarat S, Slingerland M and Dries L 2019 Explaining the 'Certification Gap' for different types of oil palm smallholders in Riau Province, Indonesia *J. Environ. Dev.* **28** 253–81
[101] RSPO 2019 RSPO Impact Update 2019 (available at: https://rspo.org/news-and-events/news/press-release-increase-in-certified-smallholders-and-certified-volume-detailed-in-rspo-impact-report)
[102] van der Ven H and Cashore B 2018 Forest certification: the challenge of measuring impacts *Curr. Opin. Environ. Sustain.* **32** 104–11
[103] Miteva D A, Pattanayak S K and Ferraro P J 2012 Evaluation of biodiversity policy instruments: what works and what doesn't? *Oxford Rev. Econ. Policy* **28** 69–92
[104] Miteva D A 2019 The integration of natural capital into development policies *Oxford Rev. Econ. Policy* **35** 162–81