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Evaluating the effectiveness of palm oil certification in delivering multiple sustainability objectives

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Abstract

Industrial oil palm plantations in South East Asia have caused significant biodiversity losses and perverse social outcomes. To address concerns over plantation practices and in an attempt to improve sustainability through market mechanisms, civil society organisations and industry representatives developed the Roundtable on Sustainable Palm Oil (RSPO) in 2004. The effectiveness of RSPO in improving the sustainability of the palm oil industry is frequently debated and to date, few quantitative analyses have been undertaken to assess how successful RSPO has been in delivering the social, economic and environmental sustainability outcomes it aims to address. With the palm oil industry continuing to expand in South East Asia and significant estates being planted in Africa and South America, this paper evaluates the effectiveness of RSPO plantations compared to non-certified plantations by assessing the relative performance of several key sustainability metrics compared to business as usual practices. Using Indonesian Borneo (Kalimantan) as a case study, a novel dataset of RSPO concessions was developed and causal analysis methodologies employed to evaluate the environmental, social and economic sustainability of the industry. No significant difference was found between certified and non-certified plantations for any of the sustainability metrics investigated, however positive economic trends including greater fresh fruit bunch yields were revealed. To achieve intended outcomes, RSPO principles and criteria are in need of substantial improvement and rigorous enforcement.

Introduction

The rapid expansion of oil palm (*Elaeis guineensis*) crops over the last five decades, particularly in Indonesia and Malaysia, has contributed to significant declines in biodiversity and has become a major concern for conservation (Koh and Wilcove 2007, Gaveau *et al* 2014a and Vijay *et al* 2016). In Indonesian Borneo alone, oil-palm concessions cover over 115 500 km^2 (15.5%) of the land mass and are considered responsible for 5600 km^2 of forest loss between 2000 and 2010 Gaveau *et al* (2013). As the largest global producer, contributing 54% of global trade, palm oil is an important contributor to the development of Indonesia's national economy with 16 million metric tonnes of palm oil exported in 2011 worth over US$17 billion (7.3% of export earnings, second only to coal (12% and gas 9.1%, United Nations Statistics Division 2013)). Having the highest yield per hectare of any vegetable oil, palm oil and palm oil derivatives provide cost-effective and versatile compounds commonly used in food production, soap, detergents, household chemicals, animal feed and biofuel (Koh and Wilcove 2007). However, palm oil production has other associated costs and the industry is frequently criticised for human labour rights violations, land use conflicts and environmental degradation (Fitzherbert *et al* 2008, Wilcove and Koh 2010, Wicke *et al* 2011, Abram *et al* 2017).

In response to concerns over the industry's sustainability standards, the Roundtable on Sustainable Palm Oil (RSPO) was formed in 2004 by a collective of industry representatives and civil society groups (Ruysschaert and Salles 2014). As a market-based mechanism, RSPO broadly aims to provide an incentive for companies and producers to improve their practices and 'promote the growth and use of sustainable palm oil products through credible global standards and engagement of stakeholders' RSPO (2004). Although any interested party can become an RSPO member, RSPO certification can only be achieved by adhering to the 8 operating Principles covering 39 criteria that form the scheme's guidelines. Currently under review, these Principles and Criteria (P&C) relate to economic, social and environmental aspects of palm oil plantation development, management and production (see RSPO P&C 2013). Since initial establishment RSPO has grown to represent over 2000 members, certifying 2.65 million hectares of palm oil plantations and 11.65 million tonnes of palm oil equating to about 20% of global trade (RSPO 2015). However, despite the initial hopes for the certification scheme, RSPO is frequently criticized as a 'slow bus' lacking the authority to uphold and regulate standards in the palm oil industry and giving rise to numerous stakeholder concerns (Laurance *et al* 2010 Moreno-Peñaranda *et al* 2015, Ruysschaert and Salles 2014, Meijer 2015, Ruysschaert 2016).

The major challenge currently faced by RSPO is the differing interpretation of its primary objective, to 'promote sustainable palm oil'. Despite sharing the underlying assumption that sustainability implies moving from an unsatisfactory state to a more satisfactory state, stakeholder groups perceive sustainability differently and as such will interpret the term within often mutually exclusive economic, social or environmental frameworks (Lélé and Norgaard 1996, Callicott and Mumford 1997, Farrell and Hart 1998, Jones *et al* 2008). For example, Callicott and Mumford (1997) argue that in the context of conservation, 'sustainability' should be used to denote the process of 'conserving the biota of ecosystems that are humanly habituated and economically exploited'. This ecocentric interpretation of sustainability is in contrast to Franklin's (1993) interpretation of sustainability as an anthropocentric concept whereby the natural system is managed in a way that 'maintains potential and production of goods and services in perpetuity'. As a result of these varying interpretations of sustainability, different RSPO stakeholder groups prioritise certain criteria over others.

How the RSPO can achieve multiple and at times conflicting sustainability outcomes remains uncertain. RSPO's governance framework has been subject to several evaluations focused on improving capacity (Nikoloyuk *et al* 2010, Paoli *et al* 2010), legitimacy (Schouten and Glasbergen 2011), knowledge sharing Ponte and Cheyns (2013) and participation Winters *et al* (2015). Similarly, numerous critiques of the certification program's perceived short-comings, including weak standards (Laurance *et al* 2010), limited enforcement (Ruysschaert and Salles 2014) and a lack of sanctioning for non-compliance (Meijer 2015) have also been undertaken. To date however, few investigations have been undertaken to evaluate RSPO effectiveness in achieving sustainability aims and out of those that have, only single outcomes such as profitability (Levin *et al* 2012, Preusser 2016) and biodiversity conservation (McCarthy and Zen 2010, Carlson *et al* 2018) have been considered. Whilst these aforementioned studies have provided useful first steps, the focus on single and simplified components is inadequate for evaluating the success (or otherwise) of a multifaceted certification scheme. In addition, many of these studies fail to consider the counterfactual scenario, what would have happened in the absence of the scheme Miteva *et al* (2012). Presently, there is no evidence-base to answer if investment in RSPO has been an effective means of obtaining outcomes better than business as usual.

This paper aims to determine the effectiveness of RSPO certification in delivering multiple sustainability outcomes covering attributes relating to environmental, social and economic sustainability (summarized in table 1). The analysis is focused on six of the eight central pillars of the RSPO Principles and Criteria (P&C) including conservation of biodiversity, responsible development of new plantings, responsible consideration of communities, consideration of social impacts, economic viability, and commitment to best practice (see supplementary material available at stacks.iop.org/ERL/13/064032/mmedia for further detail). The remaining two criteria—commitment to transparency and compliance with local laws and regulations—were excluded from this particular analysis as they are less focused on improving industry sustainability and rather on ethical and lawful plantation operation. Controlling for key confounding variables, the performance of RSPO certified and non-certified concessions are compared before and after the establishment of the sustainability scheme.

Methods

RSPO concession map

A novel map outlining RSPO certified concessions in Kalimantan was created by cross-referencing spatial and statistical data from multiple sources. A base map of palm oil concessions developed by the Indonesian Ministry of Agriculture (Kalimantan oil palm concession shape file 2014) was obtained through World Resources Institute (WRI). Names, parent companies and provinces of all 535 palm oil plantations in Indonesian Borneo were then obtained through the oil palm plantation company directory produced by the Indonesian Bureau of Statistics (2014).

Table 1. Conceptual outline including key stakeholder groups, interests, focal metrics for analysis, key confounding variables and hypothesized outcomes.

Causal relationship	Sustainability interest	Metrics	Units key	Confounding variables	Hypothesised outcome
RSPO certification results in improved sustainability outcomes	Environmental	Orangutan	Orangutan presence	Concession size	RSPO > Non-RSPO
		Fire	Reduced number of fire incidents	Concession size	RSPO > Non-RSPO
	Social	Poverty	Reduced number of households receiving government assistance	Household density	RSPO > Non-RSPO
		Health Services	Availability of rural health facilities	Population density	RSPO > Non-RSPO
	Economic	Yield	Fresh fruit bunch (FFB) produced	Land under plantation	RSPO > Non-RSPO
		Profits	Share price	Total land bank	RSPO > Non-RSPO

From here, concession names were cross-referenced with data included in RSPO Annual Communication of Progress (ACOP) reports. As supply chain certificates are given to Palm Oil Mills (POM), the majority of the RSPO certified estate layer was derived from the record of RSPO certified mills and supply estates, with several estates often falling within one nationally recognized concession (figure 1). Additional verification was undertaken using the Sustainable Palm Oil Transparency Toolkit (Zoological Society of London Sustainable Palm Oil Platform (ZSL SPOM)) and from Global Forest Watch (GFW). Ninety one RSPO certified concessions identified, belonging to 41 companies, were then mapped in in ARC GIS v10 (see supplementary table S4 for further detail). These estates cover a total area of 5733 km^2 equating to 18% of planted palm oil concessions in Kalimantan and 22% of the area covered by RSPO certification globally. We note that our dataset likely excludes many small-and medium-sized oil palm growers because these estates are rarely registered at the national level (Gaveau *et al* 2016).

Analysis

Metrics selected to measure key sustainability impacts may be influenced by confounding factors (see table 1). To account for pre-existing variation in focus metrics and minimise rival explanations that may mimic or mask a relationship between cause (certification) and effect (sustainability outcome), we employed a propensity score matching technique. Propensity score matching was undertaken using the nearest neighbour method with calliper width of 0.25 standard deviations (Wang *et al* 2013). This method allows for outcome comparison between concessions that have been treated (RSPO certified) and comparable concessions that have not been treated (non-RSPO certified) at the concession level (Andam *et al* 2008, Caliendo and Kopeinig 2008, Ferraro 2009). Many factors are likely to be associated with both participation in RSPO and associated outcomes of the program. While we could not comprehensively include all of these variables, we included key confounding variables for which adequate data are available thereby controlling for variables that have not been considered in previous studies (e.g Levin *et al* 2012, Preusser 2016) These variables included concession size as larger concessions are theoretically more likely to host wide ranging, high conservation value species, and also have a higher risk of experiencing fire events. Village population density was controlled for when examining social sustainability metrics, as the number of health facilities should theoretically be positively correlated with increased population density. Similarly, larger populations should exhibit differential accumulation of wealth. Proportion of concession under oil palm crop plantation was controlled for when examining economic sustainability, as we were concerned with yields and profits as a result of plantation productivity rather than concession size (see table 1 and associated methodologies in supplementary material for further detail).

Matched data sets were then analysed using before and after control impact (BACI) analysis for each of the sustainability metrics highlighted in table 1. Whereby, certified and non-certified concessions were compared at a uniform point in time prior to the implementation of RSPO and again after implementation, allowing for the comparison of initial differences between samples that were to be treated and those that were not, as well as changes post treatment relative to both the starting point and treatment types (Conner *et al* 2016) Further details on metric selection and treatment are provided below.

Sustainability metrics

Environment

Orangutan presence and density

A central pillar of the RSPO is to manage palm oil plantations in a way that 'maintains and/or enhances' high conservation value (HCV) species (or fully protected species) (see table 1). As one example of a HCV and fully protected species, Bornean Orangutans (*Pongo pygmaeus*) are to be monitored and protected by palm oil growers. As the species has also become a global icon for biodiversity conservation efforts in the face of the rapid and continued expansion of

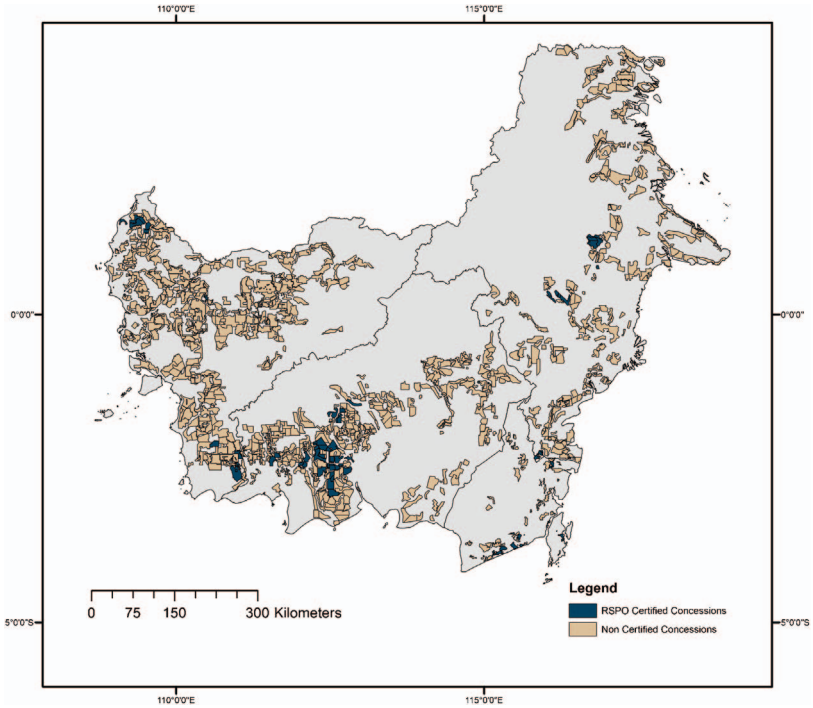

Figure 1. Kalimantan Oil palm concessions. Non-certified concessions in yellow, RSPO-certified concessions in blue.

industrial oil palm plantations (Struebig *et al* 2015), we would expect a stasis or at lease, a reduced rate of loss of orangutan population in RSPO certified concessions, attributable to RSPO status. We used a recently developed dynamic and spatially-explicit population distribution and density map, developed by Santika *et al* (2017), overlayed with concession boundary maps, to ascertain the presence and density of orangutans in palm oil concessions between 1999 and 2014. Santika *et al* predicted orangutan population estimates are based on Bayesian modelling that takes into consideration various input data (helicopter nest counts, transect nest counts, and interview data) and predictors. This mixed method approach provides a considerably more robust means of detecting population presence and density over the entire species range than prior estimates.

Number of fire hotspots detected

RSPO criteria aim to minimize the use of fire in plantation establishment and management through P&C 5.5 and 7.7, therefore we would expect a reduction in the amount of fire within RSPO concessions relative to the counterfactual. Fire is often used in palm oil concessions to clear land prior to planting, in between crop cycles and to clear existing crops of weeds and pests. However, when coupled with prolonged periods of drought and on high carbon peat soils, fires can have devastating environmental, human health and economic effects (Harrison *et al* 2009, Gaveau *et al* 2014b, Cattau *et al* 2016). To assess the effectiveness of RSPO certification in reducing fire outbreaks, we mapped fire incidents in Kalimantan at a 1 km^2 resolution from the Moderate Resolution Imaging Spectroradiometer (MODIS) Active Fire Detections, extracted from MCD14ML Collection 5 and distributed by NASA FIRMS for the years 2011–2015. Fire data for the years 1999–2004 were obtained from the MODIS archived records and extracted from the MCD45 collection.

Social

Rates of poverty in villages neighbouring concessions

In addition to receiving compensation for the transfer of land tenure, sustainable oil palm concession development should deliver benefits to members of neighbouring villages through increased employment opportunities both in the concession and through supporting services and infrastructure (RSPO P&C 6.1 & 6.11). Subsequently, we would expect the overall level of poverty within a village should decline in response to the sustainable operation of concessions, both from the baseline and relative to the counterfactual. Poverty was measured using the issuing of statement letters of poverty (SKTM) at the village level as a proxy indicator. SKTM letters are issued to families falling below a series of absolute poverty indicators to facilitate increased access to hospitals, scholarships and legal aid (Fiarni *et al* 2013) and have been found to be a reliable indicator of poverty rates in Kalimantan (Priebe and Howell 2014). Data on the number of SKTM letters issued over the course of the studies focus years (2000–2014) was obtained from the Indonesian Village Potential Survey (PODES), distributed by the Indonesian Bureau of Statistics for the years 2000

and 2014. The number of SKTM letters in villages with borders overlapping concessions was compiled and attributed to each concession for comparative analysis. Given the purported economic and social benefits industrial oil palm development provides World Growth Institute (2011), a decline in the number of SKTM letters was expected, reflecting an overall improvement in social well-being.

Provision of healthcare facilities

In addition to employment opportunities, the development of sustainable large-scale palm oil plantations is thought to deliver benefits to neighbouring communities through the increased provision of community services and social infrastructure. Indeed, to cope with an influx of workers, many palm oil companies provide housing, healthcare and education facilities for their employees and members of the surrounding communities as part of their Corporate Social Responsibility (CSR) commitments (Sime Darby 2014, Wilmar 2015) and as a requirement of RSPO P&C 6.5. The provision of healthcare facilities is seen as a particularly important factor to help address the inequitable access to health care services across districts (Efendi 2012). Subsequently, we would expect an increase in the number of healthcare facilities per capita provided in villages neighbouring both certified and non-certified concessions over time, and for villages neighbouring certified concessions to have greater access to facilities than those neighbouring non-certified concessions. For the current analysis, we focused on the type and number of rural health facilities available in villages bordering palm oil concessions and included facilities such as clinics and maternity services. Data on these facilities was obtained through Indonesian population and housing census (PODES) for the years 2000 and 2014 (BPS (Statistics Indonesia)). Attributes were assigned to concessions by overlaying village level data with concession maps.

Economic

Profit

In principle, RSPO certification should facilitate improved profitability for participating businesses through access to global markets, more effective plantation management, and higher price premiums. As certification is costly to obtain though, and principles and criteria can be challenging to enforce depending on the scale of operations Levin *et al* (2012), the profitability of RSPO certification remains a key concern for palm oil producers (Laurance *et al* 2010, Brandi *et al* 2015). We would, therefore, expect the profitability of certified concessions to be the same or increase relative to the counterfactual. Building upon methodology employed by the Zoological Society of London Sustainable Palm Oil Transparency Toolkit (ZSL SPOTT), we analysed share values of publically registered palm oil companies. Of the hundreds of palm oil companies operating in Kalimantan, only 29 are publicly listed, 14 of which had been publicly listed prior to the implementation of RSPO in 2005. Nine of the 14 companies are active members in RSPO and have actively certified at least a portion of their land holdings. In assessing profitability we, therefore, focus on these companies for which data is available and compare the 9 RSPO certified companies with the 5 non-certified companies. Pre-certification share prices were calculated on the company's closing price on the 1st of July 2005, and current prices calculated on the closing price on the 30th of June 2016. All share prices were converted into Singapore Dollar (SGD) at the average value for 2016.

Yields

RSPO certification involves numerous criteria to facilitate the adoption and continual improvement of best management strategies (RSPO P&C 2013). It can, therefore, be expected that effective program implementation will result in improved yields for plantations implementing these 'best practices' compared to the counterfactual. We assessed plantation yields through calculations of Fresh Fruit Bunch production (FFB) in metric tonnes for plantations with comparably ages crops as reported in organizational annual reports (see supplementary material) for the years 2005 and 2014. Where applicable, the proportion of RSPO certified area was also recorded with data obtained from RSPO ACOP reports.

Results

Environment

Orangutan

There was no evidence to support the sustainability of certified plantations with respect to orangutans. Orangutan populations declined in both certified and non-certified concessions between 2009–2014. Prior to certification, concessions that were to become RSPO certified held fewer orangutans than non-certified concessions, with a mean population per concession of 18 and 22 respectively. Certified concessions also experienced a faster, albeit non-significant rate of decline than non-certified concessions (figures 2 and 3(*a*) and table 2). When matched on initial density (number of orangutan/ha), certified and non-certified concessions showed a similar rate of decline (supplementary figure 3.1).

Fire

There was no evidence to support the sustainability of certified plantations with respect to fire incidence. Fire outbreaks in certified and non-certified concessions have increased between 1999–2015. No significant difference was found between treatments (figures 2 and 3(*b*) and table 2).

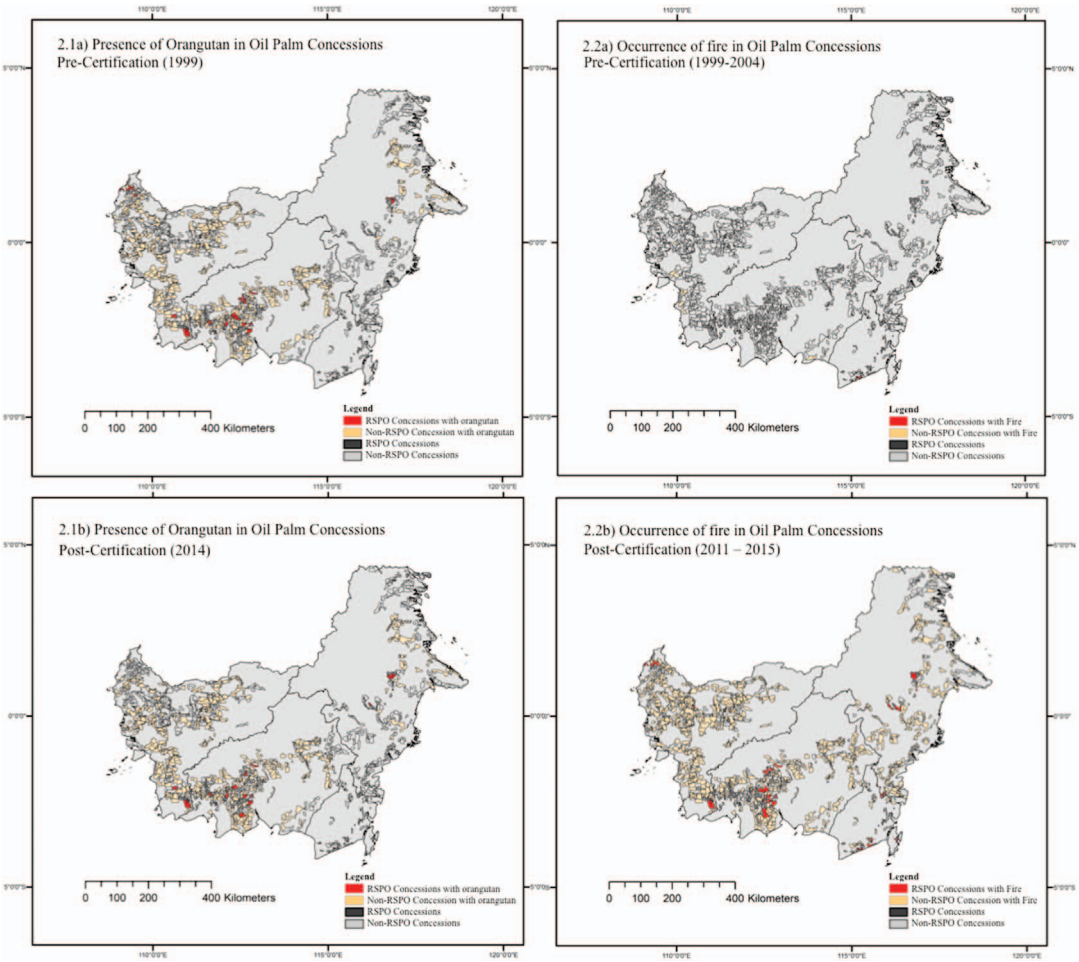

Figure 2. Environmental outcomes in certified and non-certified concessions before and after certification. Orangutan population distribution in oil palm concessions before certification (2.1a) and after certification (2.1b). Occurrence of fires in concessions before certification (2.2a) and post certification (2.2b).

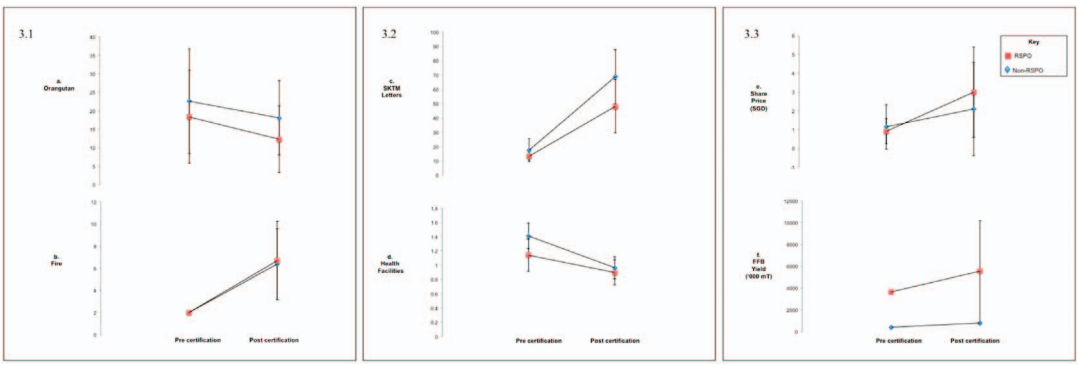

Figure 3. Environmental (3.1), social (3.2) and economic (3.3) outcomes of certified and non-certified oil palm plantations, before and after certification. Orangutan density measured before certification in 1999 and after certification in 2014. Fire occurrence measured before certification from 1999–2004 and after certification from 2011–2015. Provision of SKTM letters measured before certification in 2000 and after in 2014. Number of health facilities measured prior to certification in 2000 and after certification in 2014. Profit measured before to certification in 2004 and after certification in 2016. Yields measured before certification in 2005 and after certification in 2014.

Table 2. Result summary of matched pre and post treatment means of metrics and standard errors along with overall calculated difference.

		Pre treatment mean (SE)	Post treatment mean (SE)	DiD
Orangutan	RSPO certified	18 (6.4)	12.3 (4.6)	
(Number of individuals)	Non-certified	22.6 (7.3)	18.1 (5.1)	1.2
Fire	RSPO certified	2	6.69 (1.81)	
(Number of incidents)	Non-certified	2	6.38 (1.64)	0.303
Health facilities	RSPO certified	1.14 (0.11)	0.897 (0.09)	
(Number of facilities)	Non-certified	1.41 (0.09)	0.807 (0.07)	−0.0636
Reduced No. poverty letters	RSPO certified	13.3 (1.46)	48.1 (9.50)	
(Number of households)	Non-certified	17.5 (4.09)	68.8 (9.65)	−16.506
Yield	RSPO certified	1 479 000 (736 965)	7 922 984 (2 229 848)	
(Fresh fruit bunch mT)	Non-certified	403 036 (25 621)	789 900 (60 099)	6 057 117
Profit	RSPO certified	0.912 (0.66)	2.99 (1.23)	
(Share value SGD)	Non-certified	1.15 (0.60)	2.10 (1.27)	1.12

Social

Poverty

Certification did not reduce poverty, but was associated with a reduction in the rate of increase. The proportion of families receiving SKTM poverty letters has increased over time in villages neighbouring both certified and non-certified concessions. Although a similar number of families held SKTM letters prior to certification across treatment types, more SKTM letters were held by families neighbouring non-RSPO concessions than RSPO concessions post certification (figure 3(*a*), table 2). Supplementary analysis where concessions were matched on the initial number of SKTM letters, revealed a similar trend (S3.2).

Healthcare

Certification did not increase access to healthcare, but was associated with a reduced decline. The number of health care facilities per capita has declined between 2000–2014. Although villages neighbouring non-RSPO concessions had slightly more health facilities per capita than RSPO concessions prior to certification, the number of facilities across treatment types post certification are more similar (figure 3(*b*), table 2).

Economic

Profit

Certification was associated with a greater increase in profit. Share prices of RSPO and Non-RSPO concessions have increased in value between 2005–2016, increasing by 2.08 and.095 SGD respectively. Although having a similar value pre-certification, RSPO concessions share prices were valued slightly higher than Non-RSPO concessions post certification (figure 3(*a*), table 2).

Yields

Certification was associated with an increase in improved yield. Fresh Fruit Bunch yields from non-certified estates showed consistent production whereas RSPO estates displayed increasing yields over time. Although differences between treatment types are not statistically significant, RSPO estates with similar ages crops were producing 5 t of Fresh Fruit Bunches per hectare of planted area more than non-certified estates, equating to almost 3 times (4 000 000 metric tonnes) more FFB at an estate level than non-RSPO concessions (figure 3(*b*), table 2). Supplementary analysis revealed that when matched on levels of initial FFB outputs, RSPO concessions showed a significant increase in production levels (S3.3).

Discussion

Our analysis shows that RSPO certification has resulted in better outcomes for economic sustainability than business as usual from an industry perspective. Environmental and social benefits, however, are less clear. The palm oil industry continues to be criticised for its adverse environmental and social impacts (Fitzherbert *et al* 2008, Wilcove and Koh 2010, Wicke *et al* 2011, Abram *et al* 2017). Indeed, our results suggest that low confidence in the mechanisms for improving overall industry sustainability appears warranted in all but very narrow and economically-oriented interpretations of sustainability.

Environmental sustainability

No evidence was found to suggest that RSPO certified plantations were able to retain populations of orangutan better than non-certified concessions. RSPO concessions were also found to have fewer individuals per concession before certification ($\mu = 18$) than comparably sized non-certified concessions ($\mu = 22$). The difference in baseline orangutan population numbers likely reflects patterns of land use and clearing. As RSPO regulations prohibit new plantations from replacing primary forest from November 2005 (RSPO P&C 7.3), forested land and viable orangutan habitat would likely have been cleared in the years prior to certification for current and potential future plantation establishment. Conversely, as no clearing regulations exist for non-certified plantations: many still contain forest patches and viable habitat, particularly concessions that have been gazetted but are at present inactive Meijaard *et al* (2017).

The number of fire hotspots detected within palm oil concessions increased equally in both RSPO and non-RSPO concessions between 1999–2004 and

2011–2015 with no significant difference in the number of fire hotspots in certified and non-certified concessions. The pre-treatment time band (1999–2004) captures the period post the 1997 El Niño fire crisis, where 13.18 million hectares of Kalimantan were burned (17% of the total landmass) (Fuller and Fulk 2000). The low number of hotspots detected by the MODIS data during this time period is likely a result of the reduced fuel load susceptible to burning in the years immediately following the fire crisis. The increased number of hotspots detected in the 2011–2015 time band capture the prolonged El Niño conditions that culminated in the 2015–2016 fire crisis.

Social sustainability

Villages neighbouring certified plantations were expected to have distributed fewer SKTM certificates than non-certified plantations due to the social provisioning outlined by RSPO principle 6. However, the number of SKTM letters per capita increased in villages neighbouring both certified and non-certified plantations. This result is in line with the findings of Jagger and Rana (2017) who found an increase in SKTM letters when evaluating the social benefits provided by REDD+ initiatives in Kalimantan. It is plausible that the overall increase in the number of SKTM letters distributed is due to increased access to STKM related services, rather than an increase in poverty per se (Priebe and Howell 2014, Jagger and Rana 2017).

All villages neighbouring certified and non-certified plantations experienced a decline in the number of healthcare facilities per capita available. This is surprising, as Indonesia has experienced overall growth in both public and private health infrastructure since 1990. Nationwide, the number of health centres (Puskesmas) and hospitals per capita is considered adequate, with 3.5 health centres per 100 000 people and 2.5 hospital beds per 10 000 people (Rokx *et al* 2010). However, on a provincial level, large disparities in provision and access exist. The decline in the number of health facilities per capita may, therefore, reflect population growth in villages surrounding palm oil concessions and the continued tendency for health care facilities to be concentrated in large urban centres (Gunawan and Aungsuroch 2017, Sparrow *et al* 2017).

Economic sustainability

RSPO certification showed economic benefits for plantation companies. Share prices of publicly listed palm oil companies increased overall between 2011–2016. RSPO certified companies showed the greatest increase with an average share price of $2.69 SGD, $0.60 SGD more than those of non-certified companies. This difference is reflected at a finer temporal scale within individual company portfolios. For example, the expulsion of IOI corporation from the RSPO in March 2016 and subsequent loss of contracts resulted in a 16% decrease in share value. Whilst RSPO certification may not have delivered higher price premiums (Edwards and Laurance 2012), it is plausible that membership and certification may add value through improved public perceptions of corporate identity Giovannucci *et al* (2014). Similarly, import commitments for Certified Sustainable Palm Oil (CSPO) such as the European Union palm oil and deforestation resolution for 100% CSPO by 2020, has created exclusive market segments for the RSPO licensees, that in turn may lead to higher share prices for certified companies.

Although not significantly different, Fresh Fruit Bunch yields tended to be higher in certified plantations than non-certified plantations. This result may reflect improved suitability of land selected for concessions as well as better plantation management. Mangrove and flooded forest land have been shown to be unsuitable for plantation development (Abram *et al* 2014). As eligibility for RSPO certification requires concession owners to avoid establishing new plantations on substandard land (RSPO P&C 7 and 7.4), our results likely reflect the improved viability of preferable production areas. Since 2010, the oil palm industry has been able to produce more fruit than available labour forces are able to harvest Sayer *et al* (2012). It is also plausible that companies with the capital to afford RSPO certification may also be able to hire more employees than smaller competitors (Sanderson 2016).

Our study provides the first assessment of RSPO in delivering improved environmental, social and economic sustainability. Whilst our analysis shows no significant difference between certified and non-certified concessions, there are limitations to our assessment that should be considered. Primarily, our assessment utilizes six proxies (orangutan density, fire occurrence, poverty levels, access to health facilities, profits and yield) to assess broad, complex and dynamic facets of sustainability. Proxies were selected based on published criticisms of the RSPO, relevance to the schemes P&C as well as data availability. These proxies therefore serve as useful indicators of the schemes performance, particularly in regards to the specific criteria summarized in table S1, however they are not comprehensive enough to allow for definitive conclusions. In addition, although our analysis accounted for major confounding variables, there are certainly additional confounding factors that we were unable to account for and are likely to influence both the decision to participate in RSPO as well as concession performance. Upon the availability of more, fine scale and transparent data, a broader range of RSPO sustainability criteria should be assessed controlling for additional confounding factors.

Summary and recommendations

Certification offers a valuable opportunity for improving practices in a frequently and highly criticised industry (Koh and Wilcove 2007, Fitzherbert *et al* 2008, Wilcove and Koh 2010, Wicke *et al* 2011, Abram *et al* 2017). However, our analysis demonstrates that desired goals of the program are not being realised

and considerable modifications need to be made to RSPO certification criteria and their monitoring and evaluation, particularly in regards to environmental and social sustainability. The high degree of variation in environmental and social conditions between palm oil concessions prior to certification are poorly accounted for in RSPO policies, conflating participation and performance in the scheme. For example, deforested concessions are more easily able to meet zero deforestation targets (Carlson *et al* 2018) and less likely to have resident populations of threatened species that require management (Meijaard *et al* 2017). Similarly, concessions without peat soil are less vulnerable to fire than concessions with large proportions of, or in close proximity to, degraded peat soils (Turetsky *et al* 2015). In lieu of fixed figure targets (i.e 'zero deforestation', 'zero burning') and ambiguous targets ('maintain populations', 'promote positive impacts'), it may be advisable for RSPO P&C to adopt quantitative proportion based performance indicators to account for variation in baseline conditions and monitor performance relative to a concessions initial condition. Proportion based indicators also allow for performance to be monitored relative to each countries legal framework and interpretations of RSPO P&C.

At present, the estate level focus of RSPO appears to limit the ability of the scheme to deliver broad benefits. For example, the specification to 'maintain and enhance' high conservation value species ignores the biology and behavior of many species the scheme is trying to protect, such at the orangutan. Orangutans are known to have large home ranges and utilise parts of these ranges depending on seasonal food availability (van Schaik *et al* 2009). Given this, landscape level coordination between plantations known to overlap with existing orangutan populations is needed. Similarly, aims of contributing to local sustainable development and improve social impacts of plantation and mill operation, necessitates coordination between multiple stakeholders. The delivery of social benefits and infrastructure should therefore be developed and implemented at a larger village level rather than a per concession basis. Better alignment between scales of management and scales of the sustainability concerns, will not only increase program efficacy, but may also encourage smaller concession owners who lack the capacity to completely address large and complex goals, to contribute to collaborative endeavors. New jurisdictional approaches that aim at certifying entire administration units, such as the Malaysian State of Sabah or the Indonesian Province of Central Kalimantan in Borneo may address this critical and complex issue.

The 2018 revision of RSPO P&C and the implementation of the advanced certification scheme, 'RSPO next' provides an important opportunity to adopt critical changes to strengthen the certification scheme. Opportunities for improvement within the RSPO P&C include clarification around key terms and concepts as well as additional practitioner support. Vague concepts and terminology within RSPO P&C leave critical components of the sustainability program open to interpretation. Explicit definitions and standards for concepts such as 'indirect or secondary social and environmental impacts' and terms including 'high conservation value' and 'high carbon stock' need to be established by the RSPO with less reliance upon 'national guidelines'. The provision of greater support and guidance for concession owners on how to meet RSPO P&C's should be provided throughout the planning, implementation and reporting phases of development and operation. Environmental and social organisations are likely able to offer valuable knowledge and support in this regard through expert surveying, community consultation and landscape planning.

Industrial oil palm plantations are predicted to expand from 17–26 million hectares by 2050, with South America and Africa the new frontiers for development (Corley 2009, Sayer *et al* 2012, Pirker *et al* 2016). To prevent the adverse social and biodiversity impacts witnessed in South East Asia, plantation managers are encouraged to adopt RSPO management practices (Wich *et al* 2014). Given the effectiveness of RSPO to date, however, it is unlikely that current RSPO standards would achieve outcomes significantly better than 'business as usual'. For RSPO to meet the founding objective of 'promoting the growth and use of sustainable palm oil' within South East Asia and across the globe, considerable reform of the scheme is needed. The adoption of specific and measurable targets in particular, will not only assist in meeting this objective and improve RSPO, but will likely be of benefit environmental certification schemes overall.

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