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LETTER

Assessing the potential additionality of certification by the Round table on Responsible Soybeans and the Roundtable on Sustainable Palm Oil

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Abstract

Multi-stakeholder roundtables offering certification programs are promising voluntary governance mechanisms to address sustainability issues associated with international agricultural supply chains. Yet, little is known about whether roundtable certifications confer additionality, the benefits of certification beyond what would be expected from policies and practices currently in place. Here, we examine the potential additionality of the Round table on Responsible Soybeans (RTRS) and the Roundtable on Sustainable Palm Oil (RSPO) in mitigating conversion of native vegetation to cropland. We develop a metric of additionality based on business as usual land cover change dynamics and roundtable standard stringency relative to existing policies. We apply this metric to all countries with RTRS ($n = 8$) and RSPO ($n = 12$) certified production in 2013–2014, as well as countries that have no certified production but are among the top ten global producers in terms of soy ($n = 2$) and oil palm ($n = 2$). We find RSPO and RTRS both have substantially higher levels of stringency than existing national policies except in Brazil and Uruguay. In regions where these certification standards are adopted, the mean estimated rate of tree cover conversion to the target crop is similar for both standards. RTRS has higher mean relative stringency than the RSPO, yet RSPO countries have slightly higher enforcement levels. Therefore, mean potential additionality of RTRS and RSPO is similar across regions. Notably, countries with the highest levels of additionality have some adoption. However, with extremely low adoption rates (0.41% of 2014 global harvested area), RTRS likely has lower impact than RSPO (14%). Like most certification programs, neither roundtable is effectively targeting smallholder producers. To improve natural ecosystem protection, roundtables could target adoption to regions with low levels of environmental governance and high rates of forest-to-cropland conversion.

1. Introduction

Oilseed agriculture is expanding rapidly, with global production growing 79% between 2000 and 2014 [1]. These crops produce both meal and oil, which are used to feed a growing global appetite for cooking oils, livestock feeds, cosmetics, paints, biofuels, and industrial processes. Expansion of soy and oil palm, the leading oilseeds, is currently concentrated in tropical countries. This increased production has fueled economic growth by generating income, employment, tax revenues, and foreign exchange [2, 3]. However, expansion into forests, savannas, and community lands has also resulted in land conflict, biodiversity loss, and greenhouse gas (GHG) emissions [4–8].

To address these negative externalities, the World Wildlife Fund for Nature initiated multi-stakeholder discussions in the early 2000s that led to the formation of the Roundtable on Sustainable Palm Oil (RSPO) and the Round table on Responsible Soy (RTRS). Roundtables are voluntary environmental programs developed by voting members from industry and civil society that define social, environmental, and economic guidelines for crop production.

Although these roundtables are not democratically legitimate in the sense that members are not publicly elected officials, they meet additional legitimacy criteria such as participation, transparency, and accountability [9], particularly compared to unilateral private governance mechanisms (e.g. company-specific codes of conduct). Roundtables provide a forum for all value chain actors and civil society organizations to participate in deliberations about the sustainability of a commodity sector and share good practices. This forum may also be used to develop voluntary certification programs. Both the RSPO and the RTRS offer certification that requires oversight by independent third-party accredited auditors. Roundtables are ruled by principles of equal rights, common purpose, open dialogue, and decision-making by consensus [10, 11]. Since roundtable members who develop and approve certification standards are audited under the standard's principles and criteria, decision-making requires greater buy-in than a standard developed exclusively by governments, companies, or civil society.

In terms of transparency and accountability, roundtables enable interested parties to access information regarding standard-setting procedures. They offer the opportunity for public consultation during standard revision, and publically disclose information regarding certified producers, processors, and chains of custody. Yet, industry participation in the standard setting process may generate reduced stringency compared to civil society certification systems, since industry is likely to resist standards with costly compliance [12].

A critical question associated with all environmental programs, including certification by roundtables, is whether and under what circumstances such interventions generate *additionality*, defined as outcomes beyond business as usual [13]. Such additionality depends on the interaction between local circumstances and program goals and implementation, and therefore may vary widely across space and time. Since voluntary agreements are typically adopted where costs of adoption are lowest, not where benefits are greatest [14, 15], increasing adoption in regions with high potential additionality could greatly improve the overall impact of certification. Identifying regions with high potential additionality supports improved targeting of recruitment to environmental programs.

At the producer or farmer level, an additional outcome is achieved if certification requires the producer to adopt improved practices. Such producer-level additionality can be measured with careful study design and counterfactual analysis [16]. At regional to global scales, additionality is achieved only when certification leads to total reductions in negative externalities after accounting for leakage of undesirable practices into other regions and commodities [17].

Here we develop a set of indicators to assess and compare *potential additionality* of certification systems with respect to land cover change and smallholder adoption at a regional scale. We apply these indicators to soy and oil palm producing countries using data compiled from literature reviews, RTRS and RSPO audit reports, and deforestation assessments. We examine whether certification is being adopted in places that have high risk for converting native vegetation to agriculture. We aim to address the following questions:

(1) How does potential additionality vary between RTRS and RSPO certification systems and across regions?

(2) Are RTRS and RSPO certification systems adopted in regions with the greatest potential additionality?

2. Study design

Soy and oil palm provide excellent case studies to examine the additionality of roundtable certification because of their shared importance as globally traded commodities, but divergent land cover trajectories and supply chain characteristics. Together soy and oil palm compose 64% of 2013 global oilseed production, compared to 55% in 2000 [1]. From 2000 to 2008, these crops expanded rapidly into tropical forests, through direct forest conversion as well as crop and pasture displacement [18]. Since 2008, improved governance in the Brazilian Amazon has led to reduced soy expansion in tropical humid forest ecosystems and more expansion in South America's savannas and dryland forests [19, 20]. Oil palm expansion continues to rapidly convert humid tropical forests, mainly in Southeast Asia [6, 21].

RTRS and RSPO are the leading multi-stakeholder sustainability certifiers for oil palm and soy [22]; in ~2013–2014, RTRS certified <1% of soy production and RSPO certified 18% of global oil palm production (figure 1, www.responsiblesoy.org, www.rspo.org, faostat3.fao.org). RSPO was founded in 2004 and started certifying in 2008, while RTRS was established in 2006 and issued its first certificates in 2011. Data regarding the number, size, and location of certified producers are available from roundtable websites. Such information enables a detailed analysis of the

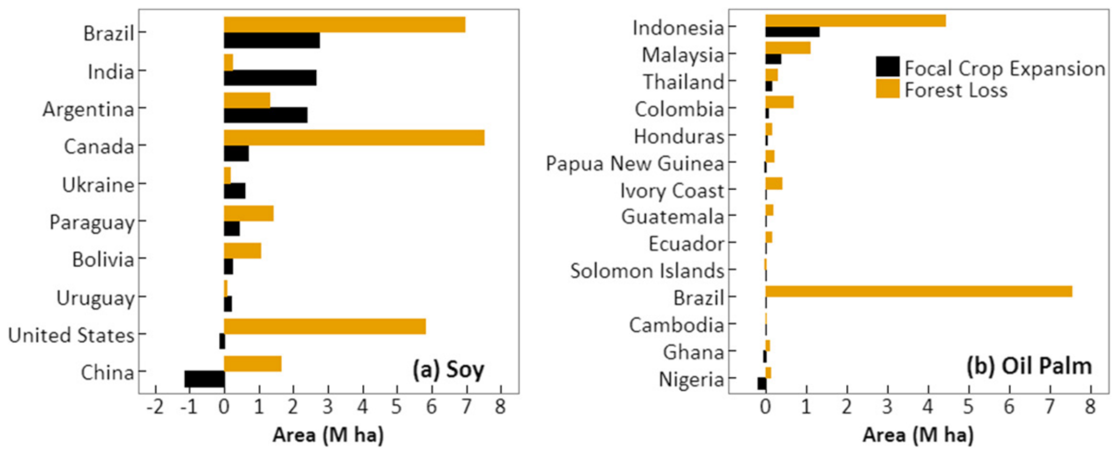

Figure 1. Gross tree cover loss and focal crop expansion during a business as usual period across focal countries with Round table on Responsible Soy (RTRS, (a)), and Roundtable on Sustainable Palm Oil (RSPO, (b)) certified production, ranked in order of focal crop expansion. Tree cover loss data are derived by applying a 30% canopy cover threshold to annual Landsat-derived percent tree cover data [21], while focal crop expansion data were downloaded from FAOSTAT [1]. The business as usual period is considered to be the three years prior to initial certifcation in a country, or in cases where a country did not contain certified production, the 2010–2013 period.

spatio-temporal patterns of these certification schemes, and assessments of the potential effects of multi-stakeholder certification systems on land use.

In this study we focus on additionality with respect to natural vegetation loss because conversion to croplands has substantial impacts on biodiversity, GHG emissions, and human livelihoods, and therefore serves as a rough proxy for these other outcomes [6, 7, 23–26]. Standardized metrics of satellite-derived land cover are readily available across space and time in all certified production regions [21]. We do not examine additionality with respect to other social issues, such as land conflict, income inequality, or labor abuses due to a lack of comparable data at the global scale.

3. Framework

Diverse economic, cultural, environmental, and political factors influence the potential additionality of voluntary environmental programs with regard to native vegetation conversion to agriculture. For this global comparative study, we computed additionality by combining two globally-available indicators identified by previous research [16, 27–29]:

(1) *Standard stringency* denotes behaviors required by the standard compared to behaviors required by existing policies and their enforcement [30]. Behaviors required by a voluntary standard should be complementary, rather than redundant or antagonistic, with other regional laws and statutes [31].

(2) *Business as usual land cover dynamics* include the rate at which natural ecosystems are converted to the crop in question, either directly or through displacement. Certification will have a higher likelihood of additionality in regions with high forest-to-crop conversion rates [14, 29].

These two indicators are both substitutes and complements in terms of potential additionality. If a high stringency standard is adopted in a region with low business as usual forest-to-crop conversion rates, then additionality will be low. Yet, if a stringent standard is adopted in a place with high forest-to-crop conversion, then additionality will be high. The overall impact of a standard in a particular region is a function of potential additionality and total adoption [32]. If a standard is adopted by a substantial proportion of producers in a region with low potential additionality, certification could still generate a large impact on land conversion.

One of the biggest barriers to achieving additionality through certification is high adoption among farmers with low opportunity costs (i.e., those farmers already near compliance with the standard) and low adoption among farmers with high opportunity costs. If a certification program is able to target socio-economic groups that are overlooked by pre-existing policies or incentive programs and have higher opportunity costs of certification, then certification could generate substantial behavior change and additionality [27, 33–36]. Here we focus on whether the RTRS and RSPO are targeting smallholders, since these producers are often unable to participate in certification schemes due to high upfront costs and certification complexity [30, 37–39]. Moreover, enforcement of land cover policies tends to be more difficult among smallholders [40], and regulatory approaches to govern smallholder environmental behavior are often politically infeasible in comparison to the incentive-based approaches offered by certification [41].

4. Methods

4.1. Spatial units of analysis

Our spatial unit of analysis is all countries with RTRS ($n = 8$ regions) and RSPO ($n = 12$) certified production from January 2013 through December 2014, as well as countries that had no certified production but were among the top ten global producers in terms of soy ($n = 2$) and oil palm ($n = 2$) in 2014 [1]. The countries considered in our analysis composed >95% of 2014 global soy and oil palm production. We also apply a subnational approach in Brazil and Indonesia, where subnational data on the focal crop and total agricultural areas are available, to examine the extent to which spatial scale influences our conclusions. In this analysis, we exclude administrative units with no Indonesian oil palm area in 2010 and no Brazilian soy production in 2014. Since means and significance tests presented in the results are weighted by the proportion of total global certified area in a country, these statistics only consider countries with some certification; unweighted means are presented in tables. Statistical tests were performed in R.

4.2. Estimating potential additionality

Potential additionality with respect to land cover (A, equation (1)) is a function of: (1) required protection of natural vegetation under the certification standard relative to existing policies and enforcement (relative stringency, S); and (2) business as usual land cover dynamics (BAU):

$$A = S \times \mathrm{BAU}. \tag{1}$$

Stringency is a basic requirement for additionality; if a standard has zero stringency, then additionality will also be zero. The relative stringency (S) of any standard in a particular region depends on the standard's absolute stringency (the natural vegetation protection required by standard in all regions, s), land cover policies in each region (p) and the degree of enforcement of such policies in each region (e):

$$S = 1 - p \times e/s,$$
$$S = 0 \text{ where } s < p \text{ or } s = 0. \tag{2}$$

We multiply $p \times e$ since enforcement is a necessary complement to any policy. We divide the combined numerator by absolute standard stringency (s) to examine how close existing policies duplicate standard protections. Since relative stringency (S) diminishes as $p \times e$ approaches s, this fraction is subtracted from 1.

To evaluate p and s we use three criteria: clear cutting restrictions (X); riparian buffer requirements (Y); and endangered species protections (Z) on agricultural properties (table S1). The extent to which a policy satisfies these three criteria is ranked on a scale of 1 to 3, with 1 being the lowest. For example, for X a score of 1 indicates no restrictions on clear cutting, 2 indicates partial restrictions, and 3 indicates full restrictions (no clearing allowed). Values of 1, 2, and 3 are weighted according to the type (t) of restriction/rule: specific-mandatory (full weight), procedural-mandatory (75% weight), or specific-voluntary (75% weight). Since clear cutting restrictions are most directly related to forest protection, this category is weighted most heavily (three times the weight of Y and Z). The raw score is then scaled between 0 to 1 by subtracting the minimum score of 5 and dividing the total by 10. The final equation for calculating the raw stringency score is as follows:

$$p, s = (3 \times X_t + Y_t + Z_t - 5)/10. \tag{3}$$

To capture different enforcement levels in each region (e), we combine the Transparency International Corruption Perception Index (www.transparency.org/cpi2014/results) and Forest Cover Monitoring Capacity metrics produced by by Romijn *et al* [42]. We convert each to a 0–1 scale, and multiply the two metrics to generate e.

To determine the fraction of tree cover loss attributable to soy or oil palm expansion (BAU) we assess the proportion of total tree cover loss (L_{tot}, ha) due to expansion of all crops (L_{crops}, ha), and the contribution of soy or oil palm expansion (E_{focal}, ha) to total crop expansion, (E_{tot}, ha). To calculate the contribution of crop expansion to tree cover loss, we consider two scenarios, similar to the approach applied by Koh *et al* [43]. Our low bound estimate assumes that crop expansion first occurs in already-cropped lands, represented by crops that experienced net contraction during the time period of interest, followed by clearing of natural ecosystems. Our high-bound estimate assumes that crops first expand into areas of natural vegetation, followed by existing croplands. We compute the mean of low- and high-bound estimates to represent L_{crops}. This metric does not account for crop expansion into land uses besides forests and croplands (e.g., pastures, grasslands), and is therefore most robust in regions dominated by forests and croplands (e.g., Indonesia). We assume BAU of zero in cases with focal crop contraction or net tree cover gain:

$$\mathrm{BAU} = E_{\mathrm{focal}}/E_{\mathrm{tot}} \times L_{\mathrm{crops}}/L_{\mathrm{tot}},$$
$$\mathrm{BAU} = 0 \text{ where } E_{\mathrm{focal}} \leqslant 0 \text{ or } L_{\mathrm{tot}} \leqslant 0. \tag{4}$$

Ideally, BAU would represent the fraction of total natural vegetation loss converted (directly or via displacement) to the crop in question [44]. Yet, such conversion data are rarely available [18].

For subnational analysis, individual metrics of crop expansion and contraction across all crop types were unavailable; we were only able to obtain data on net cropland change. Therefore, we calculate BAU as the average of low and high estimates of crop contribution to deforestation (C_{focal}, ha):

$$\mathrm{BAU} = C_{\mathrm{focal}}/L_{\mathrm{tot}},$$
$$\mathrm{BAU} = 0 \text{ where } C_{\mathrm{focal}} \leqslant 0 \text{ or } L_{\mathrm{tot}} \leqslant 0. \tag{5}$$

The high bound estimate of C_{focal} is focal crop expansion, or total deforestation if focal crop expansion is greater than forest loss. If net cropland change is less than zero, the low bound estimate is the sum of net cropland change and focal crop expansion. If net cropland change is greater than zero and focal crop expansion is greater than net cropland expansion, the low bound estimate is net crop expansion. Otherwise, the low bound estimate is equal to the high bound estimate.

4.3. Estimating adoption and impact

We compute regional adoption rates (U) by comparing certified crop area within a region (C_{cert}) to total crop area in that region (C_{all}):

$$U = C_{cert} / C_{all}. \quad (6)$$

Finally, we multiply adoption (U) and additionality (A) to compute the potential impact of certification (I) in a given region:

$$I = U \times A. \quad (7)$$

To quantify regional distribution of roundtable certification (C_{cert}) we downloaded tabular summaries of certified area and production from roundtable websites (www.responsiblesoy.org, www.rspo.org). Data on total crop area in each region (C_{all}) were obtained from FAOSTAT [1]. In most cases, we examine adoption in 2014, since this is the last year for which certification data and crop area are both available. Since the United States had RTRS certified production only in 2013, in this case we compare 2013 overall production to 2013 certified production. For subnational analysis, we use publically available audit reports to identify the location of certified production at the province (Indonesia) or state (Brazil) level for 2014, and compare this to total oil palm area in 2010 (Indo-DAPOER), or total soy area in 2013 (IBGE). While these dates do not align, more temporally resolved data are not available to refine this analysis.

4.4. Estimating smallholder targeting

To examine whether certification is targeting smallholders (T), we compare mean certified farm size in 2014 (F_{cert}) to mean country farm size (F_{all}):

$$T = F_{cert} / F_{all}. \quad (8)$$

Audit reports contain data on individual farms for individual and multi-site certifications. For RTRS group certifications, when the details for each individual farm are not listed, average farm sizes are provided. For RTRS multi-site certifications, we divide total certified area by the number of certified sites to obtain mean farm area. We include only productive area rather than total farm area, which may include conservation areas. For RSPO grower (i.e., corporate) certifications, we assume that planted area is equivalent to farm size. For RSPO group (i.e., smallholder) certifications, we divide the total planted area by the number of group members to generate farm size. Mean country farm sizes were collected from FAO's 2000 World Census of Agriculture [45] and the Brazilian Institute of Geography and Statistics' 2006 Agricultural Census [46].

4.5. Business as usual baselines

To define BAU we collate data on tree cover loss and crop expansion in the 3 year period prior to initial issuance of certificates in each country or subnational region. If an administrative area did not contain a certified farm or plantation in 2014, we calculate loss and expansion from 2010 to 2013. In Indonesia, subnational oil palm extent was available only through 2010. Therefore, we estimate BAU from 2007 to 2010 in cases with no certification, or when initial certification occurred after 2010. Country crop areas were obtained from FAOSTAT [1]. For subnational Brazil analysis, we obtained soy and total perennial and annual crop area from the annual Municipal Agricultural Surveys from the Brazilian Institute for Geography and Statistics [47]. In Indonesia, we obtained province-scale oil palm area from Indo-DAOPER [48], and annual crop data from Indonesia's Central Bureau of Statistics [49]. To examine the sensitivity of potential additionality to the BAU baseline we also present results for the 2 to 7 year periods prior to initial certification.

Tree cover change data were derived from Hansen *et al* [21]. We consider 30% tree cover in year 2000 to represent natural forest or savanna vegetation, while reduction of tree cover to ~0% constitutes tree cover loss. This approximation of natural vegetation is prone to both over and underestimation depending on the ecosystem, since it excludes savanna and grassland ecosystems, but includes tree plantations [50].

5. Results

5.1. Potential additionality (*A*)

RSPO and RTRS are being adopted in regions with similar potential additionality with respect to native vegetation conversion (RSPO—weighted mean $A = 0.14$; RTRS—weighted mean $A = 0.15$, table 1). These differences are not significant (weighted linear regression, $p = 0.73$).

RTRS and RPSO have identical standard stringency with respect to native vegetation conversion (table S2). Standard stringency (s) exceeds policy stringency for native vegetation conversion (p) in all regions included in the study (table S2). The difference between s and p is smallest in the Brazilian Amazon, China, and Uruguay, where a combination of policies strictly protects native forests from conversion to agriculture and also safeguards riparian zones. However, additional protections for biodiversity habitat in these countries are minimal [51–53]. Argentina (Cordoba, La Pampa, and Santa Fe), India (Madya Pradesh),

Table 1. Characteristics of Round table on Responsible Soy (RTRS) or Roundtable on Sustainable Palm Oil (RSPO) certification in focal countries. Stringency (*S*) is assessed from existing national policies compared to roundtable standard stringency (table 1). Targeting (*T*) indicates the degree to which certified producer farm sizes match mean country farm sizes. Business as Usual (BAU) estimates the degree to which the focal crop is responsible for deforestation in a country. Additionality (*A*) is a function of Stringency and BAU. Adoption (*U*) is presented as a percentage. The overall impact (*I*) of certification in a country is a function of additionality and adoption.

Focal crop—soy						
Country	Stringency (*S*)	Targeting (*T*)	BAU	Additionality (*A*)	Adoption (*U*)	Impact (*I*)
Argentina	0.96	0.35	0.18	0.17	0.83	0.0014
Bolivia	0.90	0.0	0.13	0.12	0.00	0.0
Brazil	0.79	0.037	0.20	0.15	0.83	0.0013
Canada	1.0	0.081	0.039	0.039	0.15	0.0
China	0.75	0.0	0.0	0.0	0.59	0.0
India	0.94	0.73	0.10	0.093	0.11	0.000 10
Paraguay	0.96	0.012	0.18	0.18	0.43	0.000 76
Ukraine	1.0	0.0	0.15	0.15	0.0	0.0
United States	0.85	0.46	0.0	0.0	0.010	0.0
Uruguay	0.53	0.59	0.18	0.094	0.027	0.000 025
Mean	0.87	0.23	0.12	0.10	0.30	0.000 37
Focal crop—oil palm						
Country	Stringency (*S*)	Targeting (*T*)	BAU	Additionality (*A*)	Adoption (*U*)	Impact (*I*)
Brazil	0.79	0.0057	0.000 087	0.000 07	74	0.000 050
Cambodia	0.98	0.000 067	0.0	0.0	0	0.0
Colombia	1.0	0.0039	0.049	0.049	2.4	0.0012
Ecuador	0.99	0.0038	0.0063	0.0062	1.8	0.000 11
Ghana	0.95	0.0019	0.0	0.0	1.7	0.0
Guatemala	0.94	0.000 56	0.033	0.031	11	0.0
Honduras	1.00	0.0	0.054	0.054	0	0.0
Indonesia	0.80	0.000 090	0.23	0.18	15	0.028
Ivory Coast	0.85	0.000 43	0.0094	0.0079	3.4	0.000 27
Malaysia	0.74	0.000 11	0.16	0.12	24	0.028
Nigeria	1.0	0.0	0.0	0.0	0	0.0
Papua New Guinea	1.0	0.000 10	0.072	0.072	93	0.067
Solomon Islands	1.0	0.000 13	0.14	0.14	48	0.069
Thailand	1.0	0.0024	0.058	0.058	2.7	0.0016
Mean	0.93	0.0014	0.058	0.051	20	0.014

Indonesia, Malaysia, and Paraguay have some combination of moderate to high restrictions on clear cutting, and low to moderate protections for riparian buffers. In other regions legal frameworks typically prohibit clearing forests in state-controlled protected areas and forest estates, but allow clearing on private land, and/or fail to protect riparian buffers. Few countries have strong habitat protections for biodiversity with the exception of Canada (Ontario) and the United States. Yet, these two regions have weak protections for forest conversion on private agricultural properties.

RSPO countries have slightly higher enforcement levels (weighted mean $e = 0.41$) than RTRS countries (weighted mean $= 0.37$, table 2). Canada and the United States rank highest in terms of enforcement ($e > 0.70$), with very good monitoring capacity and low corruption. Honduras, Nigeria, and the Solomon Islands all score <0.1 on our enforcement index. As a result, RSPO has lower relative stringency levels than RTRS (RSPO—weighted mean $S = 0.79$; RTRS—weighted mean $S = 0.85$, table 1).

Across oil palm countries, our proxy metric suggests that oil palm expansion composed 0%–32% of net tree cover loss, while soy expansion totaled 0%–24% of tree cover loss (table 3). Thus, RSPO has slightly greater BAU (weighted mean $= 0.18$) than RTRS (weighted mean $= 0.17$). In the soy sector, Brazil receives the highest BAU score (0.20) because soy accounted for 24% of all crop expansion, and 63%–100% of tree cover loss is associated with crop expansion either directly or through displacement (table 3, figure 1). Soy area contracted in China, so this country receives a BAU score of zero. For oil palm, Indonesia had high BAU (0.23), with 25% of total crop expansion attributed to oil palm, and 84%–100% of tree cover loss potentially due to crop expansion. During the BAU period from 2006 to 2009, Indonesia had high levels of oil palm expansion (1.3 M ha) and tree cover loss (4.4 M ha). Malaysia also stands out with a BAU of 0.16. The Brazilian Amazon had negligible oil palm expansion compared to tree cover loss rates, with the lowest non-zero BAU in the oil palm sector.

Table 2. Policies and enforcement governing forest protection on private lands in focal countries compared to Round table on Responsible Soy (RTRS) or the Roundtable on Sustainable Palm Oil (RSPO) certification standards. The stringency of existing policies (p) is estimated from data collected in a literature review (table S1); the stringency of both RSPO and RTRS standards is computed to be 1. Enforcement (e) is the product of monitoring capacity (Romijn *et al* [42]) and Transparency International's corruption index [79], where higher numbers signify greater monitoring capacity and lower corruption, respectively.

Focal standard—RTRS				
Country	Monitoring capacity	Corruption index	Enforcement (e)	Existing policy (p)
Argentina	0.8	0.34	0.27	0.15
Bolivia	1.0	0.35	0.35	0.3
Brazil	1.0	0.43	0.43	0.5
Canada	1.0	0.81	0.81	0.0
China	1.0	0.36	0.36	0.70
India	1.0	0.38	0.38	0.15
Paraguay	0.60	0.24	0.14	0.30
Ukraine	0.81	0.74	0.21	0
United States	1.0	0.26	0.74	0.20
Uruguay	0.8	0.73	0.58	0.80
Mean	0.90	0.46	0.43	0.31
Focal standard—RSPO				
Country	Monitoring capacity	Corruption index	Enforcement (e)	Existing policy (p)
Brazil	1.0	0.43	0.43	0.50
Cambodia	1.0	0.21	0.21	0.10
Colombia	1.0	0.37	0.37	0
Ecuador	0.8	0.33	0.26	0.050
Ghana	0.8	0.48	0.38	0.13
Guatemala	1.0	0.32	0.32	0.20
Honduras	0.2	0.29	0.06	0
Indonesia	1.0	0.34	0.34	0.60
Ivory Coast	0.80	0.32	0.256	0.60
Malaysia	1.0	0.52	0.52	0.50
Nigeria	0.20	0.27	0.054	0
Papua New Guinea	0.60	0.25	0.15	0
Solomon Islands	0.20	0.40	0.080	0
Thailand	0.80	0.38	0.30	0
Mean	0.74	0.35	0.27	0.19

Potential for land cover additionality from adopting certification varies greatly among countries. Paraguay and Argentina have the greatest potential additionality when adopting RTRS because of high rates of forest to cropland conversion (BAU) and high relative stringency of certification. In contrast, Uruguay has relatively low additionality compared to its BAU score due to extremely low relative standard stringency. Considering countries with RSPO certified production, only Indonesia, Malaysia, and the Solomon Islands have potential additionality >0.10, driven largely by high rates of forest to cropland conversion. China and the United States (RTRS), and Ghana and Nigeria (RSPO) have zero potential additionality due to declining area under soy and oil palm cultivation.

5.2. Adoption (U) and impact (I)

In 2014, RTRS-certified production totaled 1.4 M tons ((table 4) or <1% of global soy production. Brazil accounted for ~50% of total certified soy area, followed by Argentina with 33%. By 2014, RSPO had certified 10.6 M tons or ~20% of global crude palm oil production (figure 2), with ~90% of the certified area concentrated in Indonesia and Malaysia. While RTRS adoption is extremely low in all countries (<1%), RSPO adoption rates range from 1.1% in Ecuador to 74% in Papua New Guinea.

Examining relationships between potential land cover additionality and adoption by region, we note that certification has been adopted in all countries with higher levels of additionality >0.10–0.15, (table 1, figures 3 and 4). At lower levels of additionality zero adoption occurs more frequently. Due to high adoption rates, RSPO has much higher potential impact (weighted mean $I = 0.029$) than RTRS (weighted mean $I = 0.0012$). This difference is significant at a 99% confidence level (weighted linear regression, $p < 0.01$, table 1). RSPO impact is particularly high in Papua New Guinea and the Solomon Islands.

Table 3. Land cover change in focal countries. We calculate low and high estimates of the fraction of total tree cover loss due to crop expansion, as well as the fraction of tree cover loss attributable to soy or oil palm expansion (BAU). Tree cover loss data are derived by applying a 30% canopy cover threshold to annual Landsat-derived percent tree cover data [21], while crop expansion data were downloaded from FAOSTAT [1]. Oil palm area for Cambodia was not available from FAOSTAT. Some countries had no certified (NC) area in 2013 or 2014.

Focal crop—soy											
Country	Initial cert. Year	Total crop contraction (ha)	Total crop expansion (ha)	Focal crop expansion (ha)	Net crop expansion (ha)	Tree cover loss (ha)	Fraction of tree cover loss from crop expansion (low-high)		Fraction of total crop expansion from focal crop	BAU (low-high)	
Argentina	2011	−948 237	13 116 004	12 167 767	2377 412	1315 908	1.00	1.00	0.18	0.18	0.18
Bolivia	NC	−60 016	1804 472	1744 456	241 121	1055 279	1.00	1.00	0.13	0.13	0.13
Brazil	2011	−6933 553	11 291 627	4358 074	2722 361	6951 270	0.63	1.00	0.24	0.15	0.24
Canada	2014	−9308 887	8785 630	−523 257	692 700	7513 780	0.00	1.00	0.08	0.00	0.08
China	2014	−119 147 355	14 368 026	−104 779 329	−1158 387	1644 697	0.00	1.00	0.00	0.00	0.00
India	2012	−12 646 040	26 925 962	14 279 922	2645 810	234 611	1.00	1.00	0.10	0.10	0.10
Paraguay	2011	−177 981	2216 272	2038 291	408 941	1409 710	1.00	1.00	0.18	0.18	0.18
Ukraine	NC	−2234 650	3918 263	1683 613	572 400	153 743	1.00	1.00	0.15	0.15	0.15
United States	2013	−10 478 262	11 754 086	1275 824	−144 470	5795 360	0.22	1.00	0.00	0.00	0.00
Uruguay	2012	−17 586	1139 797	1122 211	201 200	77 224	1.00	1.00	0.18	0.18	0.18
Mean	2012	−17 992 776	10 464 482	−7528 293	928 654	2897 151	0.65	1.00	0.12	0.10	0.12
Focal crop—oil palm											
Country	Initial cert. Year	Total crop contraction (ha)	Total crop expansion (ha)	Focal crop expansion (ha)	Net crop expansion (ha)	Tree cover loss (ha)	Fraction of tree cover loss from crop expansion (low-high)		Fraction of total crop expansion from focal crop	BAU (low-high)	
Brazil	2011	−3160 828	25 390 198	22 229 370	2215	7531 120	1.00	1.00	0.00	0.00	0.00
Colombia	2010	−455 042	294 955	−160 087	65 000	666 311	0.00	0.44	0.22	0.00	0.10
Ecuador	2013	−284 584	479 107	194 523	3028	134 675	1.00	1.00	0.01	0.01	0.01
Ghana	2014	−367 014	318 786	−48 228	−41 240	92 392	0.00	1.00	0.00	0.00	0.00
Guatemala	2014	−8020	305 822	297 802	10 000	184 358	1.00	1.00	0.03	0.03	0.03
Honduras	NC	−282 606	175 082	−107 524	19 000	137 184	0.00	1.00	0.11	0.00	0.11

Table 3. (Continued.)

Focal crop—soy											
Country	Initial cert. Year	Total crop contraction (ha)	Total crop expansion (ha)	Focal crop expansion (ha)	Net crop expansion (ha)	Tree cover loss (ha)	Fraction of tree cover loss from crop expansion (low-high)		Fraction of total crop expansion from focal crop	BAU (low-high)	
Indonesia	2009	−1569 142	5258 790	3689 648	1300 000	4411 628	0.84	1.00	0.25	0.21	0.25
Ivory Coast	2012	−6357 908	645 893	−5712 015	12 090	396 500	0.00	1.00	0.02	0.00	0.02
Malaysia	2008	−1512 828	1135 275	−377 553	363 321	1080 660	0.00	1.00	0.32	0.00	0.32
Nigeria	NA	−5419 169	16 915 673	11 496 504	−200 000	121 642	1.00	1.00	0.00	0.00	0.00
Papua New Guinea	2008	−13 402	108 788	95 386	15 000	195 227	0.49	0.56	0.14	0.07	0.08
Solomon Islands	2011	−424	21 073	20 649	3000	15 785	1.00	1.00	0.14	0.14	0.14
Thailand	2012	−286 818	2364 295	2077 477	137 362	276 689	1.00	1.00	0.06	0.06	0.06
Mean	2011	−1516 753	4108 749	2591 996	129 906	1172 629	0.56	0.92	0.10	0.040	0.085

Table 4. Soy and oil palm area and mean farm size across focal countries, including those with 2013 or 2014 production certified by the Round table on Responsible Soy (RTRS) or the Roundtable on Sustainable Palm Oil (RSPO). Certified area and producer size were collated from certification audit reports and Roundtable websites, while crop area data was sourced from FAOSTAT [1]. Mean country farm size is derived from the FAO World Census of Agriculture and Brazilian Institute of Geography and Statistics [45, 46]. Overall statistics represent sums of crop area, and means of producer and farm size. Some countries had no certified (NC) area in 2013 or 2014.

Focal Standard—RTRS					
Country	Certified area (ha)	Crop area (ha)	Contribution to total certified area (%)	Mean certified producer size (ha)	Mean country farm size (ha)
Argentina	160 177	19 252 552	33	1650	583
Bolivia	0	1358 683	0	NC	1.5
Brazil	250 774	30 273 763	52	3564	131
Canada	3374	2235 100	0.70	3374	273
China	39 436	6730 000	8.2	4930	0.60
India	11 619	10 908 000	2.4	1.8	1.3
Paraguay	15 009	3500 000	3.1	6481	78
Ukraine	0	1792 900	0.0	NC	75
United States[a]	3074	30 858 830	0.67	384	178
Uruguay	356	1321 400	0.074	487	287
Overall RTRS	483 819	108 231 228	101	2512	104
Focal standard—RSPO					
Country	Certified area (ha)	Crop area (ha)	Contribution to total certified area (%)	Mean certified producer size (ha)	Mean country farm size (ha)
Brazil	93 286	126 559	3.6	23 322	133
Cambodia	14 947	NA	0.58	14 947	1.0
Colombia	6474	270 000	0.25	6474	25
Ecuador	3916	214 570	0.15	3916	15
Ghana	5979	349 040	0.23	5979	12
Guatemala	7989	70 000	0.31	7989	4.5
Honduras	0	130 650	0.0	NC	11
Indonesia	1131 621	7407 090	44	8901	0.80
Ivory Coast	9323	277 090	0.36	9323	4.0
Malaysia	1115 140	4689 321	44	8865	1.0
Nigeria	0	3025 950	0.0	NC	2.3
Papua New Guinea	146 291	157 100	5.7	10 449	1.0
Solomon Islands	7475	15 510	0.29	7475	1.0
Thailand	18 022	663 707	0.70	1328	3.2
Overall RSPO	2560 463	17 396 587	100	8427	3.6

[a] Since the United States had no RTRS certified production in 2014, United States certified area, crop area, and contribution to total certified area represent 2013 conditions.

5.3. Targeting smallholders (*T*)

Certification is predominantly adopted by large producers (table 4, figure 5). The median farm size for RSPO certified producers is 8427 ha compared to a median farm size of 3.6 ha in oil palm producing countries. The median farm size for RTRS certified farms is 2 512 ha compared to a median farm size of 104 ha in the soy producing countries. Only India and Uruguay have certified farm sizes that approach country-wide farm sizes. In RSPO countries, smallholder targeting tends to be lower in places with higher potential land cover additionality (figure 6). In RTRS countries targeting and additionality are uncorrelated.

5.4. Changing BAU baselines

To assess the sensitivity of our findings to the choice of BAU period, we generate BAU baselines from 2 to 7 years prior to initial certification. We find that relative additionality between countries depends strongly on the choice of baseline years (figure S1). For RSPO, the coefficient of variation (CV) across all potentially additionality scores ($n = 5$) by country ranges from 9 (Solomon Islands) to 245 (Ghana). For the RTRS, the CV ranges from 8 (Paraguay) to 146 (United States).

5.5. Subnational additionality analysis

We present results from our subnational analysis in supplementary tables 3–4. In Brazil, existing policy stringency and BAU forest to cropland conversion rates vary substantially between states. Although states within the Legal Amazon have substantially more restrictive existing policies than states in other ecological biomes, Mato Grosso and Tocantins (both within

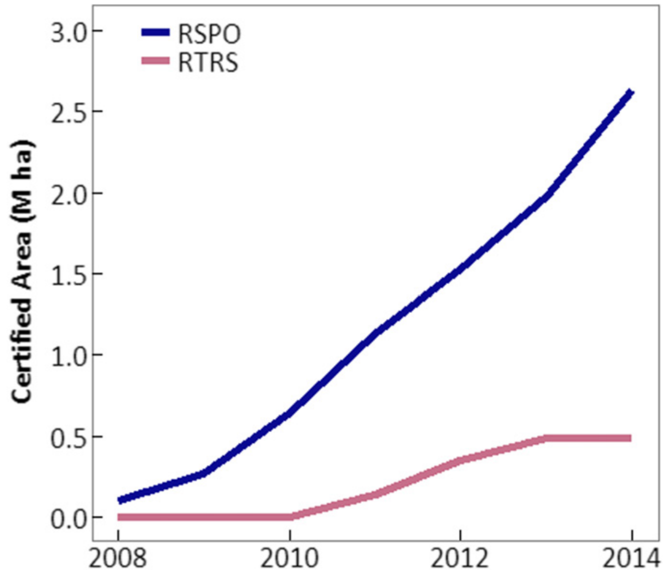

Figure 2. Total area certified by the Round table on Responsible Soy (RTRS) and the Roundtable on Sustainable Palm Oil (RSPO) from 2008 to 2014.

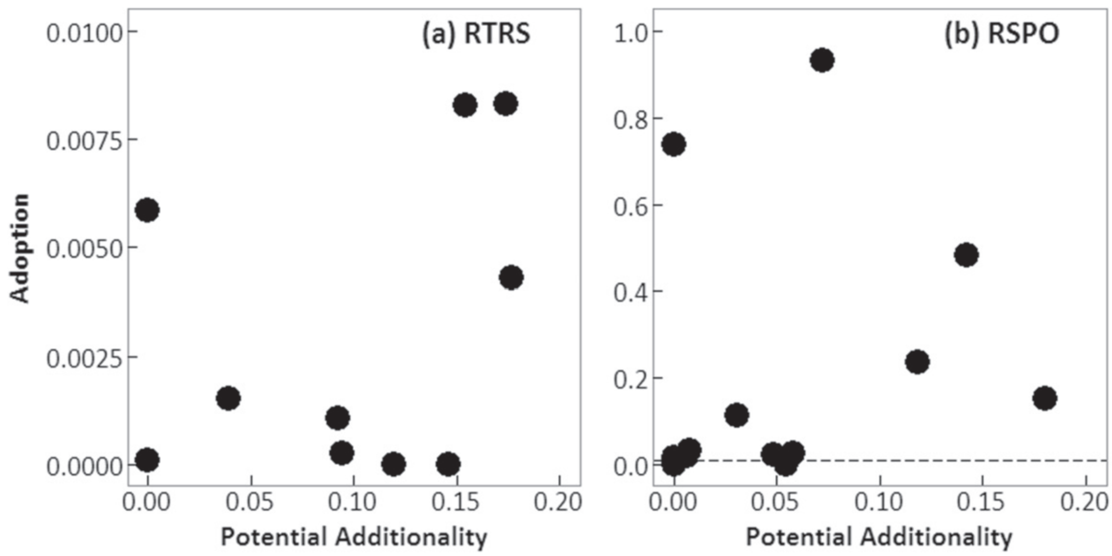

Figure 3. Potential additionality with respect to land cover change versus adoption of Round table on Responsible Soy ((a), RTRS), and the Roundtable on Sustainable Palm Oil ((b), RSPO) certification in 2014. Each point denotes a country, while horizontal line in (b) indicates the limit of the *y* axis in (a).

the Legal Amazon) have very high BAU scores >0.70 and therefore have relatively high potential additionality >0.30. Nevertheless, high potential additionality is not associated with RTRS certification in Brazil, as two states (Piauí and Paraná) with the highest levels of potential additionality had zero certification. In Indonesia, subnational variation is driven entirely by BAU conditions, since policy stringency is identical across all provinces. In contrast to the Brazilian case, we find that high levels of potential additionality are associated with RSPO certification; the six provinces with the highest potential additionality >0.25 all contained some certified plantations.

6. Discussion

6.1. Relationship between adoption and potential additionality

When examining RTRS and RSPO certification patterns, we find that countries with higher potential additionality >0.10–0.15 typically have some certification adoption. This result is somewhat surprising given that low levels of existing governance and high crop expansion into natural ecosystems likely inflate the costs of meeting certification requirements [33]. However, benefits of certification may also be greater in regions with high potential additionality. Multinational oilseed traders operating in regions with rapid

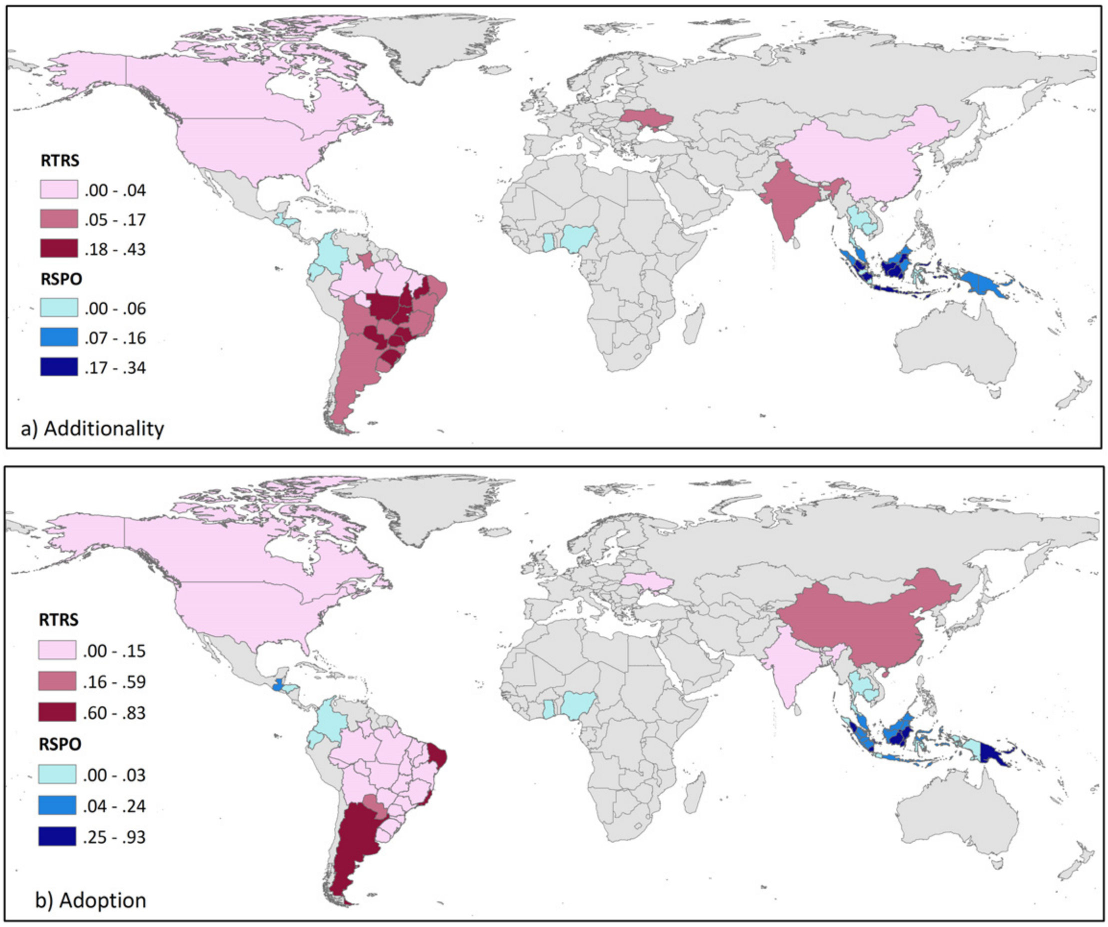

Figure 4. Potential additionality with respect to land cover change (a) and 2014 certification adoption (b) by country (or region) for the Round table on Responsible Soy (RTRS) and the Roundtable on Sustainable Palm Oil (RSPO). Dark colors indicate high potential additionality or adoption, while light colors indicate low potential additionality or adoption. Gray indicates countries not included in the study. Subnational resolution is included for Brazil and Indonesia; in 2014, Brazil had overall RTRS adoption of 0.83% and RSPO adoption of 74%, while Indonesia has overall RSPO adoption of 15%.

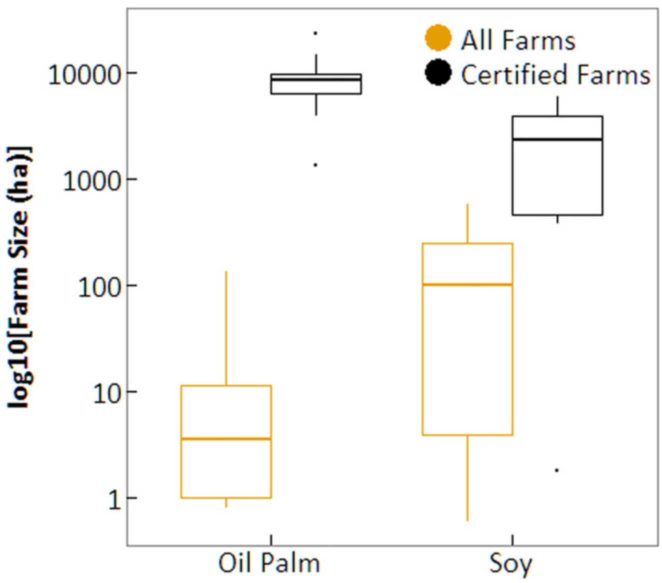

Figure 5. Mean farm size (ha) across countries with soy and oil palm producers certified by the Round table on Responsible Soy (RTRS) and the Roundtable on Sustainable Palm Oil (RSPO) in 2013–2014 [45]. Mean farm size is log-transformed.

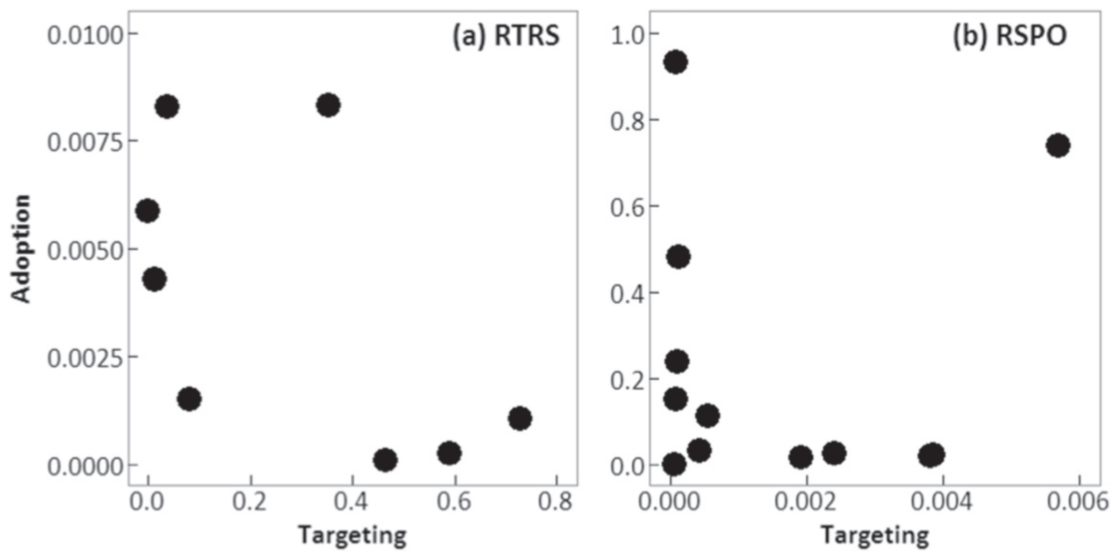

Figure 6. Relationship between smallholder targeting and certification adoption for countries with Round table on Responsible Soy ((a), RTRS), and Roundtable on Sustainable Palm Oil ((b), RSPO) certified production in 2014. Each point denotes a country.

deforestation are under substantial pressure from environmental groups to eliminate deforestation from their supply chains [54, 55]. Producers in such high-risk regions may seek certification to differentiate themselves and reduce the likelihood of market exclusion [19, 56]. Yet, our highly aggregated analysis is unable to examine the precise locations of certified and non-certified producers, nor their contributions to natural vegetation clearing. Even within regions where crops are expanding into natural ecosystems, producers seeking certification may be those who cleared land prior to RTRS and RSPO cutoff dates for forest clearing, and their costs of meeting the certification requirements would be relatively lower.

RSPO certification has been adopted at much higher rates than RTRS. While this effect is likely related to the age of these roundtables (RSPO issued its first certificates in 2008, RTRS in 2011), elevated adoption in the oil palm sector may also be explained by differences in soy and oil palm supply chains. Soy production occurs on thousands of individual farms, and each producer has little or no brand identity [57, 58]. If soy traders and retailers want to reduce reputational risk associated with tropical deforestation, they can source more soy from temperate regions. In contrast, palm oil plantations are frequently controlled by large multinational corporations, for whom brand identity and deforestation risk are important [59]. Moreover, the vast majority of palm oil is grown in just two tropical countries with high deforestation rates (Indonesia and Malaysia) [60]. Therefore, oil palm companies must directly address tropical deforestation on their own lands in order meet sustainability demands. The high rate of RSPO adoption is particularly remarkable given oil palm's high level of processing, since product visibility is expected to influence certification uptake [12].

High levels of adoption may be more important than high additionality for conserving natural ecosystems. Due to uniformly low adoption rates, RTRS is likely to have minimal effect on land cover dynamics despite adoption in regions with similar potential additionality. For example, soy production is increasing rapidly in the tropical Chaco forests of Argentina as investors flee more stringent environmental regulations in other regions [20, 61]. Here, RTRS could have large impact if adopted at a wide scale, yet current RTRS adoption stands at <1% of Argentina's soy area. In contrast, RSPO may be having a substantial effect especially in Papua New Guinea (93% adoption), despite medium potential additionality in this region.

6.2. Targeting of smallholders and developing countries

Based on large differences between mean certified producer size and mean country farm size, our analysis shows that neither roundtable is successfully targeting small farmers. An exception is India, where most certified farms are <2 ha due to the strong presence of social NGOs aimed at improving livelihoods for small farmers [62]. Inability to reach small farms is a common failure among certification programs [27, 33–36], due to high fixed costs and complexity [30, 37, 38]. One exception is Fairtrade International, which aims to increase equity across all global commodity chains and traditionally has offered preferential certification to small farms [63, 64]. Restricting RTRS and RSPO certification access to any group of producers would not support the goal of protecting natural ecosystems through certification. Yet, smallholders are playing an increasing role in land cover change in both Brazil [40] and Indonesia [65] and should therefore be included in these certifications, despite the fact that large capitalized producers account for the vast majority of deforestation across tropical soy and oil palm sectors [40, 65, 66]. Both roundtables now offer group certification and smallholder funding programs [67], which could lead to higher smallholder certification rates via lowered transaction costs and informational barriers [68–70]. Such programs have already been implemented by organic certifiers and the Sustainable Agriculture Network Certification, with some success in increasing smallholder participation and benefits [71, 72].

RTRS and RSPO certifications are being adopted primarily in less-developed countries (figure 4). This pattern is distinct from dynamics observed in forest and fish certification programs, which tend to have higher adoption rates in developed countries [27, 73, 74], but consistent with coffee, cocoa and banana certification programs that are concentrated in tropical countries. In the soy sector, the United States and Canada produce 37% of global soy [1] but <2% of RTRS certified soy. Low RTRS adoption in Canada and the United States might be related to higher costs of adoption relative to Brazil and other South American countries, or to reduced targeting by NGOs focused on tropical ecosystem preservation. RSPO adoption in less-developed countries is expected, since oil palm is only grown in the tropics.

6.3. Increasing relative standard stringency

While RTRS and RSPO standards are substantially more stringent than land-cover policies in most soy and oil palm producing regions, certification standards do not extend full protection to non-primary-forest vegetation types, such as secondary forest, savannas and grasslands. RTRS defines native forest as areas of native vegetation >1 ha with canopy cover >35% and where >9 trees per ha reach 10 m in height, including forests in the humid tropical Amazon basin, the Atlantic Forest biome, and arid Chaco and Chiquitano regions of South America. This definition may fail to protect non-forest ecosystems and secondary forests. RSPO defines primary forest as forest that has never been logged and that has developed following natural disturbances and processes, or one that is used 'inconsequentially' by indigenous communities. Since Southeast Asia's extensive logged forests and agroforests do not qualify as primary forest, converting these land covers could be permissible by the RSPO. Thus, RTRS and RSPO relative standard stringency could be greatly increased by including land covers that are largely unprotected in soy and oil palm producing regions.

6.4. Limitations

Several uncertainties limit the empirical conclusions of our study. While the additionality metric was developed from a critical reading of the literature, results depend on the metric's functional form and predictor variables, as well as weights given to each variable. Leakage is not considered in our analysis, but could reduce additionality through displacement effects. The broader effects of certification programs, such as induced changes in national policies, are not considered here.

Using countries as our basic units of analysis allows us to present an initial global overview of the potential additionality of roundtable certifications with respect to land cover change. However, our highly aggregated analysis is unable to account for variation in land cover dynamics, producer behavior, and policy enforcement at the farm or plantation scale. As evidenced by our subnational results, trends identified at the aggregate scale may not match those at finer scales. By applying a national scale analysis using a proxy dataset representing natural ecosystems, we also generate high uncertainty around rates of natural ecosystem conversion to the target crop. Since the 30% tree cover loss threshold excludes native grasslands and some savannas, and includes highly managed tree plantations, applying this threshold to regions with high rates of grassland or savanna conversion to croplands will underestimate BAU; applying it to regions with tree-like land cover conversion will generate artificially high BAU levels. Thus, our metric is problematic in regions such as the Brazilian Cerrado, rubber plantations in Indonesia, and North American grasslands [50]. Subnational analyses using refined land cover datasets would represent significant improvements to this initial evaluation. Given that our potential additionality metric is highly sensitive to the selection of BAU baseline years, we also recommend that future analyses pay careful attention to the time period over which BAU is calculated. To aid comparisons between studies, authors should minimize differences in baseline years.

Since the area certified by RTRS is quite small compared to global soy area, small increases in adoption could substantially alter the adoption and additionality patterns identified here. The positive trend between additionality and adoption could intensify if RTRS and RSPO follow the patterns of forestry certification, with increasing adoption in temperate-developed regions over time, since most temperate countries included in our analysis have very weak native vegetation protections on agricultural properties. However, further refinement of the BAU vegetation conversion metrics might also reveal that temperate-developed regions have experienced very low rates of direct forest conversion to cropland in recent years. In this case, greater adoption in temperate-developed countries would weaken the positive additionality-adoption relationship.

Although previous studies have identified the potential for corruption among certifiers [64], in this study we do not measure the degree of enforcement of RTRS and RSPO standards. Interviews with auditors and analysis of land cover and management practices before and after certification are required to assess standard enforcement. If data on standard enforcement were available, degree of enforcement could be multiplied by standard stringency to further refine our additionality metric.

Critically, results with respect to additionality of land cover change should not be taken as an indicator of the contribution of RSPO and RSTS to societal well-being. RSPO and RTRS are subject to intense criticism because the interests of groups directly affected by the expansion of certified crops (i.e., traditional land users) and by the standards themselves (i.e. smallholders and landless workers) have not been fully incorporated in the standard-setting procedures [12, 75–78]. Our analysis does not examine these outcomes.

7. Conclusion

Here, we develop a metric to assess the potential additionality of roundtable certification in terms of native vegetation conversion; we then apply this metric to compare potential additionality conferred by the RTRS and RSPO in major soy and oil palm producing countries. Our results suggest that countries with higher additionality tend to have some adoption of RTRS or RSPO certification. This finding implies that the net benefits of certification are highest in regions with higher rates of crop expansion into natural ecosystems and less stringent environmental policies. Nevertheless, we also find that certain countries have relatively high certification adoption rates despite low or zero estimated additionality. When certification is adopted in such regions, roundtables may do little more than reward companies or farmers who cleared natural vegetation in the past or have low likelihood of clearing in the future. Such an outcome does not address the major environmental impacts of soy and oil palm production in tropical regions.

This analysis engages the tension between standard stringency and adoption that challenge most certification programs [12]. RTRS and RSPO offer higher protections for native vegetation than existing policies in all regions where they are adopted, yet additional provisions for grasslands, savannas, and logged forests, or other forms of tenure, such as community agroforests, would increase standard stringency and potential additionality in all regions, possibly leading to lower rates of adoption. Global additionality of RTRS and RSPO could be further improved by better targeting countries with low levels of native vegetation protection, high rates of forest to crop conversion, or low protection and moderate forest to crop conversion. The RSPO could focus on increasing adoption by smallholder farmers, while the RTRS needs higher overall adoption levels to improve standard impact.

This research provides a simple framework allowing businesses, NGOs, and consumers to assess whether certification is likely to yield additionality. Discerning the factors that enhance additionality can support improvements to standard design and implementation [69]. To stay relevant, commodity roundtables must ensure that their standards keep pace with improvements in regional governance and industry-wide practices.

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