ENVIRONMENTAL RESEARCH
LETTERS

TOPICAL REVIEW • OPEN ACCESS

Environmental and socioeconomic effects of Roundtable on Sustainable Palm Oil certification: a systematic review and meta-analysis

To cite this article: Kibrom T Sibhatu and Matin Qaim 2026 *Environ. Res. Lett.* **21** 133003

ENVIRONMENTAL RESEARCH
LETTERS

OPEN ACCESS

RECEIVED
21 February 2024

REVISED
1 June 2026

ACCEPTED FOR PUBLICATION
22 June 2026

PUBLISHED
1 July 2026

TOPICAL REVIEW

Environmental and socioeconomic effects of Roundtable on Sustainable Palm Oil certification: a systematic review and meta-analysis

Kibrom T Sibhatu[1,*] and **Matin Qaim**[2,3]

[1] International Centre of Insect Physiology and Ecology (icipe), Nairobi, Kenya
[2] Center for Development Research (ZEF), University of Bonn, 53113 Bonn, Germany
[3] Institute for Food and Resource Economics, University of Bonn, 53113 Bonn, Germany
[*] Author to whom any correspondence should be addressed.

E-mail: ktsibhatu@gmail.com

Keywords: sustainability standards, tropical deforestation, biodiversity, human welfare

Supplementary material for this article is available online

Abstract

Palm oil is the most widely produced and consumed vegetable oil worldwide, but its production is associated with deforestation and other environmental and social problems. Roundtable on Sustainable Palm Oil (RSPO) is the only internationally-recognized voluntary certification standard aimed at mitigating such problems. Many studies examine RSPO's effects on particular outcomes in specific contexts, but a consolidated global assessment is lacking. Here, we systematically review the literature and identify 53 original studies covering RSPO effects in various countries of Asia, Africa, and Latin America. Where data availability permits, we also conduct meta-analysis. Results reveal that RSPO can lead to environmental improvements, such as reduced peatland use and greenhouse gas emissions, but these effects are context-dependent and not consistently achieved. RSPO reduces deforestation within certified concessions, but this is largely offset by leakage to non-certified land, such that the overall effect on deforestation is insignificant. RSPO contributes to improved oil palm yields, especially for large-scale producers, and often also to higher profits and incomes. Yet, RSPO seems to exacerbate asymmetric power structures. Certification of independent smallholders remains limited due to technical and institutional constraints. While RSPO has certain positive effects in specific situations, further development of the standard and other policies are needed to make palm oil production more sustainable. Another important finding is that the methodological approaches of the original studies vary considerably. Rigorous impact studies consistently show smaller effects than less-rigorous ones, suggesting that uncontrolled confounding factors may lead to exaggerated reports about RSPO benefits.

1. Introduction

Palm oil is the most widely produced and consumed vegetable oil worldwide. Over the last six decades, the global oil palm area has expanded 8-fold (3.6 million ha—29.1 million ha), while oil palm fruit production has increased more than 30-fold (13.6 million tons in 1961–418.7 million tons in 2024) (FAO 2025). Palm oil is extracted from the fruits of the oil palm (*Elaeis guineensis*), a tropical palm native to West and Central Africa, now widely cultivated in Asia and Latin America as well (Corley and Tinker 2015). Palm oil's versatility makes it an essential ingredient in a variety of food and non-food products, including biodiesel and cosmetics (Murphy *et al* 2012). However, the rapid expansion of oil palm plantations has been linked to severe environmental and social issues in tropical regions, including large-scale deforestation, greenhouse gas (GHG) emissions, biodiversity loss, and conflicts over land rights (Qaim *et al* 2020, Abram *et al* 2017). The clearing of tropical forests for oil palm cultivation has not only contributed significantly to carbon emissions but has also threatened the habitats of many endangered mammal and bird species (Vijay *et al* 2016). These environmental concerns, combined with social issues, such as land tenure disputes and the exploitation of workers, have placed palm oil production at the center of public debates and policy discussions around sustainable agricultural practices (Meijaard *et al* 2020, Qaim *et al* 2020, Xin *et al* 2022, Xu *et al* 2022, Bicknell *et al* 2023, Sibhatu 2023).

Several national and international sustainability standards have been established as mechanisms to reduce the negative effects and encourage more responsible practices within the palm oil sector. Existing standards include voluntary sustainability standards, like organic palm oil and Roundtable on Sustainable Palm Oil (RSPO), as well as mandatory ones, like Indonesian Sustainable Palm Oil (ISPO) and Malaysian Sustainable Palm Oil (MSPO) (Qaim *et al* 2020, Bok *et al* 2022, De Rosa *et al* 2022, Nursyamin *et al* 2023). Among these standards, RSPO is the most prominent and the only internationally-recognized certification scheme aimed at addressing environmental and socioeconomic issues associated with palm oil production (Furumo *et al* 2020, Qaim *et al* 2020, Tey *et al* 2022).

RSPO was established in 2004 through a cooperation between the World Wide Fund for Nature and several companies and stakeholders in the palm oil industry (RSPO 2011). The scheme brings together producers, processors, traders, retailers, financial institutions, and non-governmental organizations to develop and implement sustainability standards across the entire palm oil value chain. RSPO's main objectives include promoting practices that reduce deforestation, safeguard biodiversity, and prevent the clearance of areas with high conservation value (HCV) and high carbon stock (Scriven *et al* 2019). Socioeconomically, RSPO aims to improve living conditions of farmers and workers, with a particular emphasis on respecting the rights of indigenous communities (RSPO 2011, Scriven *et al* 2019). The RSPO principles are summarized in table 1.

Oil palm growers can attain RSPO certification for either specific plantations or whole land concession areas that may include multiple plantations, forested areas, and conservation zones within their boundaries. In either case, growers must demonstrate compliance with RSPO principles, adhere to all applicable laws and regulations, maintain bookkeeping, and report on agro-chemical input use and yield. RSPO certification involves annual auditing by an independent body, and growers incur costs related to certification, auditing fees, and compliance (Levin *et al* 2012). Over the last 20 years, RSPO has gained considerable market share, with RSPO-certified palm oil accounting for approximately 20% of all internationally-traded palm oil in 2023 (RSPO 2023). This involves over 5.2 million hectares of certified oil palm land, producing 14.5 million tons of palm oil processed in over 6400 certified processing mills (RSPO 2023).

Voluntary sustainability standards, like RSPO, aim to drive change through a combination of different mechanisms, including market-based incentives, regulatory pressures, and multi-stakeholder engagement (Blackman and Naranjo 2012, Ruben and Fort 2012, van der Ven *et al* 2018, Meemken *et al* 2021). Certified producers may gain access to different markets that prioritize sustainable sourcing, enjoy an enhanced reputation and brand image, and benefit from increased productivity and higher prices for their products, thereby incentivizing the adoption of sustainable agricultural management practices (Levin *et al* 2012). Access to differentiated markets, higher prices, and increased yields through RSPO certification may translate into higher incomes of producers, which can lead to greater investment in rural infrastructure and improved household welfare. Moreover, RSPO certification may serve as a platform for knowledge sharing, capacity building, and collaboration among diverse stakeholders, contributing to the incremental improvement of practices within the palm oil sector. However, the effectiveness of RSPO certification is likely context-dependent, influenced by factors such as the scale of production (e.g. smallholders versus large commercial plantations), the type of land use replaced by oil palm cultivation (e.g. forest versus degraded land), regional variations in government policies, and access to technical and financial resources (Lee *et al* 2011, Hidayat *et al* 2015). Smallholder farmers, for instance, frequently encounter financial, technical, and institutional barriers to RSPO certification, limiting their ability to participate and benefit (Qaim *et al* 2020). Even when certification is achieved, structural features of certified supply chains can exclude independent smallholders (ISHs) from actually selling through these channels (Ekaputri *et al* 2025). When these challenges are combined with increased costs of production, the possible gains from certification may be offset, potentially hindering significant welfare improvements among smallholders. In contrast, larger plantations may face lower fixed costs of certification per unit of output, and may have more influence on the exact shape of certified concession areas. Therefore, examining the contextual factors that facilitate or hinder RSPO's success in different settings is crucial.

A growing body of literature evaluates effects of RSPO on environmental outcomes (e.g. Saswattecha *et al* 2015, Carlson *et al* 2018, Schmidt and De Rosa 2020), oil palm yield (e.g. Beall 2012, Saswattecha *et al* 2015, Veriasa *et al* 2024), and human wellbeing (e.g. Levin *et al* 2012, Santika *et al* 2021, Córdoba *et al* 2022, Richartz and Abdulai 2025). Some studies find positive effects in certain situations, whereas others do not. Most studies focus on specific outcomes and countries or subnational regions, making it difficult

Table 1. RSPO principles and criteria.

	Principles	Explanation: certified members are required to…
1	Commitment to transparency	Be transparent and accountable in their operations and provide regular reports on their performance against the RSPO's principles and criteria.
2	Compliance with applicable laws and regulations	Comply with all relevant laws and regulations, including those relating to the environment, labor rights, and human rights.
3	Commitment to long-term economic and financial viability	Promote economic and social development in the communities where they operate, including the provision of education and training opportunities.
4	Use of appropriate best practices by growers and millers	Promote sustainable management of oil palm plantations, including using best practices for agroforestry and integrated pest management.
5	Environmental responsibility and conservation of natural resources and biodiversity	Conserve biodiversity and promote the sustainable use of natural resources.
6	Responsible consideration of employees as well as individuals and communities affected by growers and mills	Respect the human rights of workers and local communities, including the rights of indigenous people (including fair wages and safe working conditions).
7	Responsible development of new plantings	Ensure that new plantings are developed responsibly and sustainably, avoiding the conversion of high conservation value areas and peatlands.
8	Commitment to continuous improvement in key areas of activity	Continuously improve their performance against RSPO's principles and criteria and engage in a continuous dialogue with stakeholders to address any concerns or issues that arise.
9	Protection of high conservation value (HCV) areas	Avoid or minimize the impact of their operations on HCV areas, including forests, wetlands, and other areas of high biodiversity value.

Sources: (RSPO 2011, 2023, Nupueng *et al* 2022).

to draw generalizable conclusions in the absence of a systematic synthesis. Here, we provide a systematic review of the literature on RSPO effects.

A few earlier reviews have addressed various aspects of palm oil certification, but none of them has specifically focused on RSPO effects from a comprehensive perspective. Abidin *et al* (2024) focus on the adoption dynamics of the MSPO standard. Majid *et al* (2021) and Rosdin *et al* (2023) analyze the frameworks of different certification schemes and their socioeconomic implications, without systematically covering the environmental effects of RSPO. Tey *et al* (2021) restrict their synthesis to the financial costs and benefits of RSPO compliance. Ogahara *et al* (2022) review studies on smallholder palm oil sustainability and the role of certification and other policies, but their analysis does not systematically evaluate RSPO effects, nor does it cover large-scale plantations. A global assessment of RSPO's effects on the various environmental and socioeconomic dimensions, as we provide here, has been lacking up till now.

We systematically review the literature on RSPO's effects under different conditions, identifying 53 original studies. Our review makes three contributions. First, by synthesizing evidence simultaneously across environmental, yield, and wellbeing dimensions, we provide a more comprehensive picture of RSPO's effects than any single-domain analysis can offer. Second, we stratify findings by methodological rigor, treating evidence from studies with control groups and regression approaches as the main results, while using less-rigorously derived evidence only for comparison and to provide more context. Third, we analyze important contextual conditions, including producer scale, land-use type, regional governance, and supply chain structure, which helps explain why RSPO's effects vary across settings. We complement this synthesis with an assessment of smallholder participation in RSPO certification and the constraints that commonly limit it.

Given the heterogeneity in methods, outcome variables, and study contexts, much of the evidence compiled from the original studies is not suitable for full meta-analysis, so we rely primarily on narrative synthesis combined with structured tabular comparison. Yet, where subsets of studies report sufficiently comparable quantitative estimates, we additionally conduct exploratory meta-analyses. We restrict our review to RSPO and do not cover other standards because—as mentioned—RSPO is the only comprehensive, internationally-recognized sustainability standard in the palm oil industry. Some of the insights may also be useful for the evaluation of other standards.

2. Materials and methods

We follow the PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines to ensure transparency and reproducibility of our systematic review of the literature on effects of RSPO on various dimensions of sustainable development (Moher *et al* 2009, Haddaway *et al* 2018, O'Dea *et al* 2021).

2.1. Search and selection criteria

We searched PubMed, Science Direct, Scopus, Web of Science, Google Scholar, ResearchGate, Agris, AgEcon Search, Academia, and JSTOR, using 'RSPO', 'Roundtable on Sustainable Palm Oil', 'Oil Palm Certification', and 'Palm Oil Certification' in the title, abstract, and keywords. We selected original studies following the inclusion and exclusion criteria summarized in table 2, considering articles in peer-reviewed journals, books, and conference proceedings published until February 2026. We did not include editorials, perspectives, and opinion pieces. Duplicates were extracted, recorded, and removed using Zotero reference manager (Roy Rosenzweig Center for History and New Media 2016).

2.2. Analysis

To ensure robust conclusions, we evaluate the methodological rigor of the original studies included. In line with established frameworks (Blackman and Rivera 2011), we assess the extent to which each study controls for confounding factors in its analysis of RSPO impacts. Detailed information about the study categorization is provided in Supplementary table A1. Specifically, we categorize studies into two tiers of methodological rigor, namely '*higher rigor*' and '*lower rigor*'. Studies with higher rigor are those that control for confounding factors and use non-certified comparison groups, typically through regression analysis, difference-in-differences, propensity score matching, or life cycle assessment (LCA), thereby offering more reliable insights into RSPO effects. Although LCAs combine modelling with empirical inventories, we include them in the higher-rigor category because they build on processes empirically observed in RSPO-certified versus non-certified plantations and mills and use counterfactual scenarios that allow systematic comparison (Saswattecha *et al* 2015, Schmidt and De Rosa 2020, Schmidt and Weidema 2026). Studies with lower methodological rigor are primarily descriptive or qualitative, lacking control groups and with little or no attempt to control for confounding factors. These include case studies, narrative reviews, interviews, and simple before-after comparisons without matched counterfactuals. Note that we do not try to judge on the quality or value of the studies, but simply on the reliability of interpreting results as causally-identified effects. In all result tables and figures, we clearly indicate to which methodological rigor category particular findings belong.

The large heterogeneity of methods used and outcome variables covered means that most findings across original studies are not suitable for formal meta-analysis. The included studies span LCA, village-level quasi-experimental panel regressions, propensity score matching, qualitative case studies, and household surveys, with different outcome variables, sample populations, and geographic contexts. Pooling effect sizes across such heterogeneous designs would require unjustifiable assumptions and would pretend misleading precision. We therefore employ narrative synthesis and a structured tabular approach to analyze and classify the findings.

Nevertheless, for four outcome domains (deforestation, GHG emissions, oil palm yield, and farm income) a subset of studies reports sufficiently comparable quantitative estimates to permit exploratory pooling. For these subsets, we conduct DerSimonian–Laird random-effects meta-analyses (DerSimonian and Laird 1986, 2015) to complement the narrative synthesis with standardized effect sizes and examine whether the direction and magnitude of certification effects are confirmed quantitatively. Given the small number of studies in each domain and the high between-study heterogeneity, all pooled estimates should be interpreted with caution. Full methodological details, forest plots, funnel plots, and sensitivity analyses are provided in supplementary material B; the raw extracted effect sizes are documented in supplementary material C.

For evaluating the original studies' results, we compiled a comprehensive summary of each study, focusing on the reported effects of RSPO on various environmental outcomes, oil palm yield, and human wellbeing (e.g. profit, income, poverty, worker conditions). Each individual finding is categorized by assigning one of the following possible labels. '*Positive or desirable effect*' if RSPO certification leads to a statistically significant improvement in sustainability outcomes, such as reduced deforestation, lower pollution, higher yield, higher human wellbeing, etc. '*Negative or undesirable effect*' if certification leads to a worse sustainability outcome. '*No effect*' if no significant effect on the particular sustainability outcome is reported in the original study. Where a study reports divergent results across distinct sub-indicators, subgroups, or geographic regions, these are presented as separate entries in the summary tables rather than

Table 2. Study inclusion and exclusion criteria.

	Inclusion	Exclusion
Peer-review	• Books, peer-reviewed journals, conference proceedings	• Opinion articles, editorials, and NGO reports
Focus areas	• RSPO	• Non-RSPO related studies
Language	• English	• Languages other than English
Year	• Published between 01/2005 and 02/2026	• Published after 02/2026
Keywords	• RSPO mentioned in title, abstract, or keywords • Reported effect of RSPO on any indicator of environment, yield of oil palm, human wellbeing	• RSPO not mentioned in title, abstract, or keywords
Alternative keywords	• Oil palm (palm oil) certification	• Alternative keywords not mentioned
Methodology	• Research with empirical data • Reported original findings on the effects of RSPO	• Without empirical data and without clear research method • Pure opinion pieces

collapsed into a single mixed category, enabling more precise reading of the evidence.

3. Results

We identified 53 original studies for inclusion in our systematic review. We describe general characteristics of these studies in section 3.1, and synthesize results in terms of environmental and socioeconomics effects of RSPO in sections 3.2 and 3.3. This is followed by results of the meta-analysis for subsets of outcomes in section 3.4. In section 3.5, we focus specifically on smallholder farmers and their inclusion in RSPO certification.

3.1. Descriptive characteristics of original studies

The study selection procedure is illustrated in the PRISMA flow diagram in supplementary material A (figure 1(A)). A summary of the 53 original studies included is presented in Supplementary table A1. Four studies focus on Latin America (two on Ecuador, one each on Colombia and Brazil), two on Africa (both on Ghana), and 37 on Southeast Asia, namely Indonesia (24 studies), Malaysia (eight studies), Thailand (four studies), and Brunei Darussalam (one study). The ten remaining studies report findings from two or more countries, primarily in Southeast Asia, with some also including evidence from Africa and Latin America. This regional distribution reflects the disparity in geography of RSPO certification. Indonesia and Malaysia are by far the largest palm oil producers worldwide, where oil palm cultivation is highly commercialized and primarily geared towards international export markets (Qaim *et al* 2020). In Africa, overall production volumes of palm oil are larger than in Latin America, but most of the oil palm land in Africa is cultivated by smallholders (Qaim *et al* 2020, Tabe-Ojong *et al* 2023), who are not yet involved much in RSPO certification. Of the 53 original studies included, 22 provide evidence from smallholders only (in spite of low rates of smallholder participation in RSPO, many studies focus on smallholder situations), eight from large-scale plantation companies and mills, and the rest from a mixture of smallholders, large-scale plantations, forest estates, and other stakeholders.

Of the 53 studies included, 34 (64.2%) are classified as having lower methodological rigor, and 19 (35.8%) meet the criteria for higher methodological rigor (figure 1). The predominance of lower-rigor studies indicates that a substantial portion of the existing literature on RSPO certification does not use methods of impact evaluation needed to make robust causal statements about RSPO's effects. In our presentation of results, evidence from higher-rigor studies is treated as primary, while findings from lower-rigor studies are used mainly for comparison and for providing more context for meaningful interpretation.

Many of the original studies look at specifically-defined outcomes, whereby the indicators used are not always congruent. Several studies include more than one indicator. Systematic coding of the studies yielded 149 indicator-level observations, distributed across three thematic domains: environmental outcomes ($n = 61$), oil palm yield ($n = 18$), and human wellbeing ($n = 70$). RSPO effects on each of these domains are synthesized below.

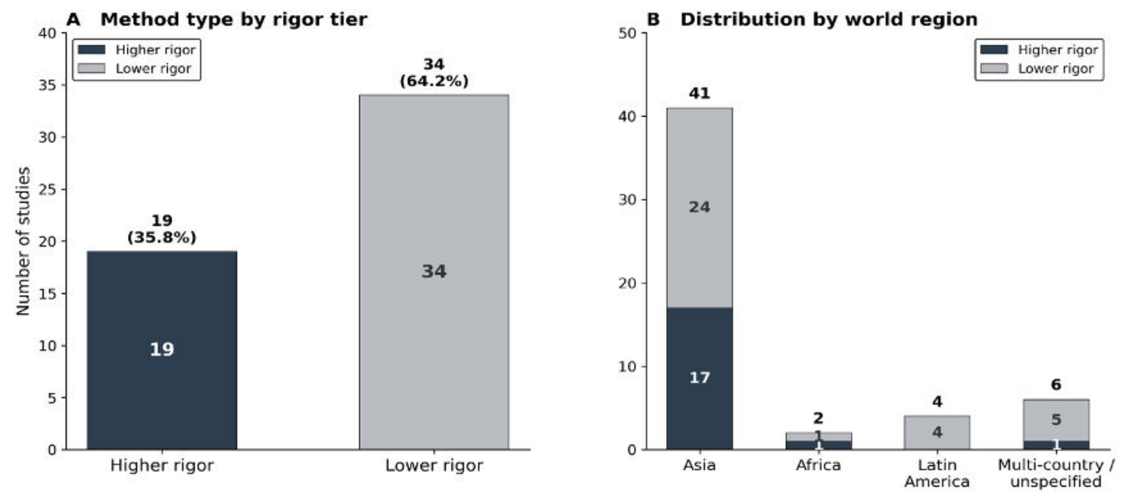

Figure 1. Distribution of studies by methodological rigor category and world region.

3.2. Environmental effects

Many studies examine to what extent RSPO certification helps reduce environmental problems related to oil palm cultivation. The results are synthesized in table 3, where each entry shows the concrete outcome and indicator analyzed per original study, the direction of the RSPO effect, and the study's methodological rigor category. Key findings are further explained below.

3.2.1. Environmental pollution

Depending on cultivation practices and input intensity, oil palm production can have negative effects on soil, water, and air quality. As shown in table 3, several studies investigate effects of RSPO certification on different types of environmental pollution. For example, one higher-rigor study in Thailand finds that RSPO-certified production has lower negative environmental impacts than non-certified production (Saswattecha *et al* 2015). Specifically, RSPO certification has led to the adoption of improved wastewater management techniques, better weed control, and a reduction of nitrogen-based fertilizers, contributing to lower GHG emissions and reduced photochemical ozone formation. Lower fertilizer use in Thailand also reduces acidification, eutrophication, human toxicity, and freshwater ecotoxicity (Saswattecha *et al* 2015). These findings align with RSPO's principle of reducing environmental impacts through improved management practices.

A few studies in Indonesia also suggest that RSPO reduces land, water, and air pollution (Lee *et al* 2020, Santika *et al* 2021). However, the effects vary by context, including farmers' knowledge and environmental awareness. In some parts of Indonesia and Malaysia, RSPO-certified producers use more fertilizer than their non-certified counterparts, leading to higher water pollution and human toxicity in the vicinity of RSPO-certified plantations (Schmidt and De Rosa 2020). It should be noted that RSPO's principles specify qualitative pollution-management requirements without setting quantitative thresholds for most pollutants. This means that higher pollutant levels in certified plantations do not necessarily represent non-compliance with RSPO.

In spite of higher fertilizer use, Schmidt and De Rosa (2020) show that RSPO-certified palm oil is associated with 35% lower GHG emissions, which is achieved through higher yields and thus lower land requirements per unit of product, less oil palm grown on peat soil, and increased use of biogas capture technologies. Schmidt and Weidema (2026) also show lower GHG emissions and peatland use through RSPO in five countries, namely Indonesia, Malaysia, Thailand, Colombia, and Nigeria. However, not all studies confirm that RSPO consistently reduces peatland use for oil palm cultivation (Carlson *et al* 2018).

3.2.2. Deforestation

As mentioned, the expansion of oil palm plantations has long been associated with deforestation in tropical regions, contributing to habitat loss, carbon emissions, and biodiversity decline. RSPO certification aims to address this issue by promoting the conservation of HCV areas and enforcing policies against clearing primary forests.

Several studies explore whether RSPO helps reduce deforestation and protect HCV areas (table 3). For instance, one higher-rigor study in Indonesia finds that RSPO reduces deforestation significantly within certified concessions, yet without fully eliminating it (Carlson *et al* 2018). Another higher-rigor study in Indonesia confirms that RSPO reduces deforestation in lowland areas, but not on steeper slopes where deforestation seems to increase (Lee *et al*

Table 3. Effects of RSPO certification on environmental indicators.

Study	Rigor	Association	Effect	Indicator/outcome
Greenhouse gas emissions and climate change				
Carlson *et al* (2018)	Higher	/	Not significant	Peatland forest clearing (% concession area on peat): no statistically significant reduction in peat
Saswattecha *et al* (2015)	Higher	—	Desirable	GHG emissions (kg CO_2-eq per t FFB): scenario-based LCA found RSPO practices reduce global warming potential
Schmidt and Weidema (2026)	Higher	—	Desirable	GHG emissions (kg CO_2-eq per t CPO): updated 2021 five-country LCA confirmed certified production maintains lower emissions
Schmidt and De Rosa (2020)	Higher	—	Desirable	GHG emissions (kg CO_2-eq per t refined palm oil): attributional LCA found 36% lower emissions for RSPO-certified production
Schmidt and De Rosa (2020)	Higher	—	Desirable	Peatland area under cultivation (share of estate area on peat): certified estates had lower peatland use
Schmidt and De Rosa (2020)	Higher	—	Desirable	GHG emissions (kg CO_2-eq, consequential LCA): RSPO 3.41 vs non-certified 5.34 (36.1% lower, NHST = yes)
Air quality and atmospheric emissions				
Lee *et al* (2020)	Higher	/	Not significant	Air pollution incidence (village PODES indicator): NOT significant in Kalimantan (coeff = 0.05, SE = 0.17) or Sumatra (coeff = 0.09, SE = 0.14)
Santika *et al* (2021)	Higher	—	Desirable	Air pollution incidence (village-level PODES census indicator): reduced in market-oriented villages
Saswattecha *et al* (2015)	Higher	—	Desirable	Acidification potential (g SO_2-eq per t FFB): lower under RSPO scenarios; reduced open burning and input use
Saswattecha *et al* (2015)	Higher	—	Desirable	Photochemical ozone formation (m^3 ppm h per t FFB): reduced under RSPO scenarios
Schmidt and Weidema (2026)	Higher	/	Not significant	Respiratory inorganics (g $PM_{2.5}$-eq per kg RBDPO, consequential): RSPO 2.80 vs non-certified 2.81 (negligible)
Schmidt and Weidema (2026)	Higher	—	Desirable	Photochemical ozone formation (mg ozone-eq/$m^3 \cdot$h, consequential): RSPO 21.8 vs non-certified 24.9 (12.4% lower)
Schmidt and Weidema (2026)	Higher	/	Not significant	Acidification ($m^2 \cdot$UES, consequential): RSPO 0.297 vs non-certified 0.292 (1.7% higher, negligible)
Schmidt and De Rosa (2020)	Higher	/	Not significant	Acidification potential (g SO_2-eq per t refined palm oil, consequential LCA): negligible difference (0.159 vs 0.160)
Schmidt and De Rosa (2020)	Higher	—	Desirable	Photochemical ozone formation (m^3 ppm h per t refined palm oil): attributional LCA found lower in certified production
Schmidt and De Rosa (2020)	Higher	—	Desirable	Respiratory inorganics/particulate matter (kg PM_{10}-eq per t refined palm oil): lower in certified production
Schmidt and De Rosa (2020)	Higher	—	Desirable	Acidification potential (g SO_2-eq, attributional LCA): RSPO 0.180 vs non-certified 0.193 (6.7% lower, NHST = no)

(Continued.)

Table 3. (Continued.)

Study	Rigor	Association	Effect	Indicator/outcome
Water quality, ecotoxicity, and human toxicity				
Lee *et al* (2020)	Higher	/	Not significant	Water pollution incidence (village PODES indicator): NOT significant in Kalimantan (coeff = −0.48, SE = 0.41) or Sumatra (coeff = −0.05, SE = 0.04)
Lee *et al* (2020)	Higher	−	Desirable	Land pollution incidence (village PODES indicator): reduced near certified concessions in Kalimantan coeff = −0.21** (SE = 0.09);
Lee *et al* (2020)	Higher	/	Not significant	Land pollution incidence (village PODES indicator): not significant in Sumatra
Santika *et al* (2021)	Higher	−	Desirable	Water pollution incidence (village PODES indicator): reduced in market-oriented villages; worsened in subsistence-oriented villages
Saswattecha *et al* (2015)	Higher	−	Desirable	Eutrophication potential (g PO_4-eq per t FFB): reduced through improved POME treatment under RSPO
Saswattecha *et al* (2015)	Higher	−	Desirable	Freshwater ecotoxicity (kg 1,4-DCB-eq per t FFB): lower under RSPO due to reduced herbicide/pesticide use
Saswattecha *et al* (2015)	Higher	−	Desirable	Human toxicity, carcinogenic (g C_2H_6Cl-eq per t FFB): lower under RSPO scenarios
Saswattecha *et al* (2015)	Higher	−	Desirable	Human toxicity, non-carcinogenic (g $C_3H_6NO_2$-eq per t FFB): N-RSPO = 42, P-RSPO = 92, C-RSPO = 36 (14% lower for C-RSPO)
Schmidt and Weidema (2026)	Higher	−	Desirable	Eutrophication, aquatic (kg NO_3-eq, consequential): RSPO 0.096 vs non-certified 0.109 (11.9% lower)
Schmidt and Weidema (2026)	Higher	+	Undesirable	Ecotoxicity, aquatic (kg TEG-eq, consequential): RSPO 73.7 vs non-certified 69.4 (6.2% higher)
Schmidt and Weidema (2026)	Higher	−	Desirable	Ecotoxicity, terrestrial (kg TEG-eq, consequential): RSPO 4.25 vs non-certified 4.55 (6.6% lower)
Schmidt and De Rosa (2020)	Higher	−	Desirable	Eutrophication potential (g PO_4-eq per t refined palm oil, attributional LCA): lower for certified production
Schmidt and De Rosa (2020)	Higher	+	Undesirable	Eutrophication potential (g PO_4-eq, consequential LCA): system-wide expansion increased eutrophication
Schmidt and De Rosa (2020)	Higher	+	Undesirable	Freshwater ecotoxicity, aquatic (kg 1,4-DCB-eq per t refined palm oil, attributional LCA): higher for certified production
Schmidt and De Rosa (2020)	Higher	/	Not significant	Terrestrial ecotoxicity (kg 1,4-DCB-eq per t refined palm oil): negligible difference (3.16 vs 3.18)
Schmidt and De Rosa (2020)	Higher	/	Not significant	Human toxicity, carcinogenic (g C_2H_6Cl-eq per t refined palm oil): negligible difference (13.3 vs 13.3)
Schmidt and De Rosa (2020)	Higher	+	Undesirable	Human toxicity (consequential LCA): system-wide expansion increased human toxicity for certified production
Schmidt and De Rosa (2020)	Higher	+	Undesirable	Human toxicity, non-carcinogenic (g C_2H_6Cl-eq, attributional LCA): RSPO 35.5 vs non-certified 34.8 (2% higher, NHST = no)

(Continued.)

Table 3. (Continued.)

Study	Rigor	Association	Effect	Indicator/outcome
Agrochemical use and input intensity				
Renner *et al* (2024)	Higher	−	Desirable	Toxic herbicide (paraquat) application: reduced by certified smallholders (coeff = −0.37***, SE = 0.06 in 2017; −0.37***, SE = 0.09 in 2018)
Renner *et al* (2024)	Higher	+	Undesirable	Glyphosate application rate: increased by certified smallholders (coeff = +0.29***, SE = 0.05 in 2017; +0.16**, SE = 0.06 in 2018)
Renner *et al* (2024)	Higher	+	Undesirable	Triclopyr application rate: increased by certified smallholders (coeff = +0.32***, SE = 0.02 in 2017; not significant 2018)
Renner *et al* (2024)	Higher	+	Undesirable	Nitrogen fertilizer application rate: increased by certified smallholders
Richartz and Abdulai (2025)	Higher	−	Desirable	Hazard quotient (pesticide toxicity): ATT = −0.357, $t = -1.568^*$ (84.6% reduction in toxicity)
Deforestation and land use change				
Carlson *et al* (2018)	Higher	−	Desirable	Deforestation rate (annual tree cover loss %): PSM-DiD found 33% reduction on certified concessions
Heilmayr *et al* (2020)	Higher	−	Desirable	Deforestation inside certified supply bases (pixel-level logit with FE): coeff = −0.0165*** (SE = 0.0017, n = 553 019 pixels); certification significantly reduced deforestation probability within certified concession boundaries
Heilmayr *et al* (2020)	Higher	+	Undesirable	Deforestation spillover to non-certified areas (pixel-level logit): coeff = +0.0147* (SE = 0.0072); certification increased deforestation probability in nearby non-certified agricultural land (leakage effect)
Lee *et al* (2020)	Higher	−	Desirable	Primary forest loss (village PODES indicator): reduced on gentle slopes in Sumatra; increased on steep slopes
Schmidt and Weidema (2026)	Higher	−	Desirable	Land occupation (PDF·m^2·a per t CPO): updated 2021 LCA confirmed lower land occupation across five countries
Schmidt and De Rosa (2020)	Higher	−	Desirable	Land occupation (PDF·m^2·a per t refined palm oil): certified had 20% lower biodiversity-adjusted land use
Gatti and Velichevskaya (2020)	Lower	+	Undesirable	Tropical forest conversion (1984–2020 time series): 92.3% of 1984 forests in current certified supply bases were converted
Gatti *et al* (2019)	Lower	+	Undesirable	Tree cover loss (Hansen >30% canopy): ∼40% of certified area lost cover 2001–2016; loss rate 38.3% equivalent to non-certified areas
Garrett *et al* (2016)	Lower	/	Not significant	Certification additionality (stringency × targeting × BAU scores): low targeting scores indicate certification predominantly adopted by large producers with already low deforestation baselines

(Continued.)

Table 3. (Continued.)

Study	Rigor	Association	Effect	Indicator/outcome
Meijaard *et al* (2017)	Lower	−	Desirable	Forest loss rate (ha yr^{-1}, Borneo): RSPO concessions lost 9.0% of 2000 forest cover vs 17.2% for non-RSPO; $n = 464$ concessions
Ruysschaert and Salles (2014)	Lower	+	Undesirable	Forest area loss (qualitative): RSPO failed to halt deforestation due to five structural shortcomings
Fire incidence and fire-driven forest loss				
Carlson *et al* (2018)	Higher	/	Not significant	Fire detection rate (fires per km^2 y^{-1}): no significant reduction on certified concessions ($P = 0.08$)
Cattau *et al* (2016)	Higher	−	Desirable	Fire density (MODIS active fires per km^2): significantly lower on certified during wet years on mineral soils
Lee *et al* (2020)	Higher	/	Not significant	Fire density (MODIS fires/village area): not significant in Kalimantan (coeff = −0.11, SE = 0.19) or Sumatra (coeff = 0.02, SE = 0.05)
Morgans *et al* (2018)	Higher	/	Not significant	Fire hotspot density (MODIS detections per concession, PSM-matched): no significant difference
Noojipady *et al* (2017)	Lower	−	Desirable	Fire-driven forest loss and fire detection density: fire-driven loss comparable; fire detection 66%–75% lower on certified during El Niño events
Biodiversity, habitat, and landscape ecology				
Morgans *et al* (2018)	Higher	/	Not significant	Orangutan population density (individuals per km^2, ANCOVA with PSM): no significant difference between certified and non-certified
Azhar *et al* (2015)	Lower	−	Undesirable	Landscape heterogeneity (patch number, mean patch area, edge density; ANCOVA): certified plantations showed lower landscape diversity
Gatti and Velichevskaya (2020)	Lower	−	Undesirable	Large mammal habitat overlap (spatial intersection with 1990s orangutan, tiger, elephant, rhino range maps)
Meijaard *et al* (2017)	Lower	/	Not significant	Orangutan population decline rate (% y^{-1}): RSPO 2.2% vs non-RSPO 2.1%; comparable decline
Ruysschaert and Salles (2014)	Lower	−	Undesirable	Orangutan habitat conservation (qualitative): RSPO ineffective due to insufficient compensation and enforcement
Scriven *et al* (2019)	Lower	+	Desirable	Habitat connectivity (graph-theoretic metrics for HCV set-asides): RSPO set-asides improved modelled connectivity

Notes and Abbreviations: GHG = greenhouse gas; CO_2-eq = carbon dioxide equivalent; FFB = fresh fruit bunch; CPO = crude palm oil; RPO = refined palm oil; RBDPO = refined, bleached, and deodorized palm oil; LCA = life cycle assessment; PODES = Potensi Desa (Village Potential Statistics, Indonesia); POME = palm oil mill effluent; PSM = propensity score matching; DiD = difference-in-differences; IPTW = inverse probability of treatment weighting; FE = fixed effects; NHST = null hypothesis significance test; HCV = high conservation value; MODIS = Moderate Resolution Imaging Spectroradiometer; ESA = European Space Agency; PDF = potentially disappeared fraction (biodiversity impact unit); UES = unweighted ecologically scaled (acidification unit); TEG-eq = triethylene glycol equivalent (ecotoxicity unit); DCB-eq = dichlorobenzene equivalent (toxicity unit); BAU = business as usual; ATT = average treatment effect on the treated; MESR = multinomial endogenous switching regression; OLS = ordinary least squares; ANCOVA = analysis of covariance. Association symbols: + = positive/increase; − = negative/decrease;/= no significant effect. Significance levels: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Rigor: Higher = studies using control groups with regression, PSM, DiD, IPTW, or ISO-compliant LCA; Lower = descriptive, qualitative, or before–after without counterfactual. Effect classification: Desirable = RSPO association in the expected beneficial direction; Undesirable = association in the opposite direction; Not significant = no statistically significant association detected.

2020). RSPO's principles place particular emphasis on peatlands, which are typically located in lowland areas. Moreover, lowland areas were the first to be deforested—often more than 20 years ago—and are therefore disproportionately represented within currently certified concessions. In some regions, much of the remaining forest is concentrated on steeper terrain, to which the current clearance pressure has shifted. It should be noted that the RSPO standard itself has no specific provisions in terms of land slopes. Also, the fact that some deforestation still occurs within certified concessions does not necessarily mean non-compliance with RSPO standards, as RSPO's objective is to reduce or minimize deforestation.

The picture gets more complex when spillovers or leakage effects of RSPO to non-certified areas are also considered. Heilmayr *et al* (2020) have analyzed the broader deforestation effects in Kalimantan. Within certified concessions, RSPO reduces deforestation, whereas on some of the nearby non-certified land it increases deforestation. Considering this leakage, the overall effect of RSPO on deforestation in Kalimantan is small and statistically insignificant (Heilmayr *et al* 2020).

3.2.3. Forest fires

Fire-driven deforestation is prohibited in Indonesia, Malaysia, and many other countries, but still widely observed. Not all forest fires are set deliberately, some occur naturally due to high temperatures (Carlson *et al* 2018). Nevertheless, fire is commonly used to clear tropical rainforests for oil palm cultivation, because it is less expensive than alternative methods and saves time. It is estimated that in Indonesia, fire-driven deforestation recently accounted for 25% of the total forest loss for oil palm expansion (Noojipady *et al* 2017). Forest fires contribute to carbon emissions and loss of biodiversity. A few studies analyze the effects of RSPO on the incidence of forest fires with inconclusive results (table 3).

Two higher-rigor studies in Indonesia find no significant effect of RSPO on forest fire rates (Carlson *et al* 2018, Morgans *et al* 2018). Another higher-rigor study in Indonesia reports that fire activity is noticeably lower in RSPO-certified concessions in regions and during periods of low fire risk, such as non-peatlands and particularly wet years (Cattau *et al* 2016). However, this difference is smaller when the risk of fire is higher, which includes non-peatlands in dry years and peatlands in general. Possibly, frequent natural fires in the locality make it easier to conceal setting fire deliberately for oil palm expansion, even with RSPO certification, if careful monitoring is not maintained.

3.2.4. Wildlife and biodiversity

Oil palm plantations are often established on degraded forestland. Research in Indonesia suggests that 40% of the current RSPO concession areas had been degraded in the last 15 years before being converted to oil palm plantations (Gatti *et al* 2019). Some of this area is home to various emblematic species, including orangutans, tigers, rhinos, and elephants. RSPO aims to protect such habitats, but studies suggest that the effectiveness is limited (table 3). For example, a few studies show that the habitat of orangutans and other emblematic species is still diminishing to make way for oil palm expansion (Ruysschaert and Salles 2014, Morgans *et al* 2018, Gatti and Velichevskava 2020). Research also shows that the orangutan population declined between 2009 and 2014 in Kalimantan (Morgans *et al* 2018) and between 2000 and 2015 in Borneo (Meijaard *et al* 2017), both in RSPO-certified and non-certified areas. These results indicate that—despite specific RSPO guidelines—habitat loss and fragmentation persist, possibly due to ineffective enforcement or inadequate attention to wildlife corridors.

Agricultural land harbors less wildlife and biodiversity than natural forests, but the type of land use also plays an important role. Higher landscape heterogeneity, referring to the quantity, proportion, and spatial arrangement of different land-cover types, supports a greater diversity of organisms (Tscharntke *et al* 2012). One study with data from Malaysia analyzes the relationship between RSPO certification and landscape heterogeneity in oil palm plantations (Azhar *et al* 2015). The data reveal that certified large-scale plantations still exhibit lower landscape diversity (fewer and larger patches) than smallholder oil palm landscapes that are mostly not RSPO-certified. More diverse landscapes and management systems on large-scale plantations could be possible in principle, but are not yet explicitly promoted by RSPO.

3.3. Socioeconomic effects

3.3.1. Oil palm yield

One of the key principles of RSPO is to improve the quantity and quality of oil palm yield. Interestingly, almost all original studies on the effects of RSPO on yield refer to smallholder farmers, who—regardless of their certification status—tend to have significantly lower oil palm yields than large-scale plantations (Qaim *et al* 2020). One exception is a study by Morgans *et al* (2018), assessing yields on industrial plantations. The different study results are synthesized in table 4.

Most studies suggest that RSPO certification helps to increase oil palm yields. It is possible that higher-yielding producers self-select into certification. However, the higher-rigor studies try to control for possible selection bias, suggesting that real yield gains exist. RSPO-related yield gains can be explained through farmers in certified channels having better access to credit, inputs, and extension services (Saswattecha *et al* 2015, Hutabarat *et al* 2019, Veriasa *et al* 2024).

Table 4. Effects of RSPO certification on oil palm yield.

Study	Rigor	Association	Effect	Indicator/outcome
Fresh fruit bunch (FFB) yield per hectare				
Hutabarat *et al* (2019)	Higher	+	Desirable	FFB yield (kg ha^{-1} yr^{-1}, OLS regression): CERT coefficient = +3,479.7*** (t = 6.537, n = 829); certified smallholders produce ∼3.5 t ha^{-1} more
Morgans *et al* (2018)	Higher	+	Desirable	FFB yield (t FFB ha^{-1} of planted area, PSM + DiD): certified concessions produced approximately 5 t FFB ha^{-1} more than matched non-certified concessions
Renner *et al* (2024)	Higher	+	Desirable	FFB yield per hectare: higher-rigor OLS with controls (coeff = +0.476***, SE = 0.145)
Richartz and Abdulai (2025)	Higher	+	Desirable	Yield (metric tons ha^{-1}): ATT = 0.09, t = 1.727** (1.1% increase vs non-certified)
Saswattecha *et al* (2015)	Higher	+	Desirable	FFB yield (t FFB ha^{-1} yr^{-1}, scenario-based LCA): N-RSPO = 19.2, P-RSPO (partial) = 21.2, C-RSPO (complete) = 23.5 t FFB ha^{-1} yr^{-1}
Schmidt and De Rosa (2020)	Higher	+	Desirable	FFB yield, mature palms (t FFB ha^{-1} yr^{-1}, LCA inventory): certified estates = 21.1 t ha^{-1} vs non-certified = 17.5 t ha^{-1}
Veriasa *et al* (2024)	Higher	+	Desirable	Oil palm smallholder productivity (panel regression, district-level): certification associated with higher productivity
Hutabarat *et al* (2018)	Lower	+	Desirable	FFB yield (t FFB ha^{-1} yr^{-1}, before–after comparison): 17.9 t ha^{-1} before certification → 19.7 t ha^{-1} after certification
Malini and Aryani (2012)	Lower	+	Desirable	FFB yield (t FFB ha^{-1} yr^{-1}, Cobb–Douglas production function): certified plasma farmers = 27.14 t ha^{-1}yr^{-1} vs non-certified = 20.58 t ha^{-1}yr^{-1}
Napitupulu and Rafiq (2019)	Lower	+	Desirable	FFB production (farmer perception score, hypothesis testing): certified farmers scored 2.41/3.0 vs non-certified 1.87/3.0
Oil extraction rate (OER) and CPO yield				
Hutabarat *et al* (2019)	Higher	+	Desirable	Oil extraction rate (%, OLS regression): scheme smallholders (PIR-TRANS, PIR-KKPA) achieved 20%–22% OER
Saswattecha *et al* (2015)	Higher	+	Desirable	Oil extraction rate (%, scenario-based LCA): C-RSPO mills = 18% vs N-RSPO = 17%; CPO input efficiency higher for certified mills
Schmidt and De Rosa (2020)	Higher	+	Desirable	Oil extraction rate (%, LCA inventory): RSPO certified mills = 20.8% OER vs non-certified = 20.0% (insignificant difference)

(Continued.)

Table 4. (Continued.)

Study	Rigor	Association	Effect	Indicator/outcome
Agricultural practice quality and process efficiency				
Renner *et al* (2024)	Higher	+	Desirable	Agricultural practice quality (certified smallholder survey, $n = 3{,}869$ in 2017–2018): certified smallholders achieved higher profit per ha, higher yield, and substituted toxic paraquat with less harmful alternatives
Saswattecha *et al* (2015)	Higher	+	Desirable	Process efficiency and waste reduction (LCA): C-RSPO mills produced 5.8% less empty fruit bunch waste per t FFB
Schmidt and De Rosa (2020)	Higher	+	Desirable	POME biogas capture rate (%, LCA inventory): certified mills = 10.5% vs non-certified = 3.5% (industry-leading practice)
Zachlod *et al* (2025)	Higher	−	Undesirable	Satellite-based plantation oil-palm canopy coverage used as proxy for plantation production efficiency
Beall (2012)	Lower	+	Desirable	Productivity improvement (qualitative case study): certification linked to improved smallholder access to inputs and training
Hidayat *et al* (2015)	Lower	+	Desirable	Farmer-perceived production change (livelihood framework survey): 80% of 66 certified smallholders perceived production increase
Levin *et al* (2012)	Lower	+	Desirable	CPO yield (t CPO ha^{-1}, cost–benefit review): RSPO global average = 5.1 t CPO ha^{-1} vs industry global average = 3.8 t CPO/ha

Notes and Abbreviations: FFB = fresh fruit bunch; CPO = crude palm oil; OER = oil extraction rate; LCA = life cycle assessment; PSM = propensity score matching; DiD = difference-in-differences; OLS = ordinary least squares; POME = palm oil mill effluent; ATT = average treatment effect on the treated; MESR = multinomial endogenous switching regression; N-RSPO = non-RSPO certified; P-RSPO = partially RSPO certified; C-RSPO = completely RSPO certified. PIR-TRANS, PIR-KKPA = Indonesian smallholder partnership schemes (Perkebunan Inti Rakyat). Association symbols: + = positive/increase; − = negative/decrease;/= no significant effect. Significance levels: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Rigor: Higher = studies using control groups with regression, PSM, DiD, or ISO-compliant LCA; Lower = descriptive, qualitative, or before–after without counterfactual. Effect classification: Desirable = RSPO association in the expected beneficial direction.

3.3.2. Farm revenues and profits

Several studies analyze effects of RSPO certification on farmers' output prices, revenues, and profits (table 5). Again, most of these studies refer to smallholder farmers. Studies with data from Indonesia suggest that RSPO certification significantly increases the prices that smallholder farmers receive for their fresh fruit bunches sold, due to better market access and the ability to sell their produce at premium prices (Hutabarat *et al* 2018, Napitupulu and Rafiq 2019). Higher output prices and higher yields also lead to higher revenues (Malini and Aryani 2012, Hutabarat *et al* 2018).

For farm profits and income, a few studies also show positive effects. Richartz and Abdulai (2025) use data from Ghana to show that RSPO-certified farmers have significantly higher incomes than their non-certified counterparts. A study in Malaysia finds that RSPO certification is financially viable on average, even though the smallest farms and those with below-average yields face substantial financial risk (Tey *et al* 2022). A few lower-rigor studies from Indonesia report negative profit effects because RSPO is associated with higher production, and administrative costs, which can outweigh the higher revenues achieved (Beall 2012, Hutabarat *et al* 2018). The findings suggest that profit effects are context-dependent and sensitive to farm scale, cost structure, and possibly other factors.

3.3.3. Market access

A few studies examine to what extent RSPO certification is associated with better producer access to markets and credit, revealing mixed results (table 5). Studies with qualitative data from Indonesia reveal that farmers producing under contract with a company do not feel that RSPO has affected their access to output markets in any way, whereas smallholders without a contract feel that certification has improved their market access noticeably (Hidayat *et al* 2015,

Table 5. Effects of RSPO certification on human wellbeing.

Study	Rigor	Association	Effect	Indicator/outcome
Farm income and revenue				
Morgans *et al* (2018)	Higher	+	Desirable	Share value profit (SGD): DiD = 1.12 (pre RSPO 1.15 → post 2.10); comparison with non-certified
Richartz and Abdulai (2025)	Higher	+	Desirable	Net farm income (MESR)
Richartz and Abdulai (2025)	Higher	+	Desirable	Output (metric tons FFB): ATT = 1.09, $t = 5.55^{***}$ (41.5% increase vs non-certified)
Richartz and Abdulai (2025)	Higher	+	Desirable	Net household income (GHS): ATT = 50.53, $t = 10.479^{***}$ (9.2% increase)
Richartz and Abdulai (2025)	Higher	+	Desirable	Yield (metric tons ha^{-1}): ATT = 0.09, $t = 1.727^{**}$ (1.1% increase)
Tey *et al* (2022)	Higher	+	Desirable	Net farm income per hectare
Tey *et al* (2022)	Higher	+	Desirable	Net present value (NPV) of certification
Beall (2012)	Lower	−	Undesirable	Net profit after certification costs
Hutabarat *et al* (2018)	Lower	+	Desirable	Farm revenue per hectare
Hutabarat *et al* (2018)	Lower	−	Undesirable	Net farm income per hectare
Malini and Aryani (2012)	Lower	+	Desirable	Net farm revenue
Napitupulu and Rafiq (2019)	Lower	+	Desirable	Farm revenue from FFB sales
Nupueng *et al* (2022)	Lower	+	Desirable	Oil palm income: RSPO certified = 2900 THB ha^{-1} yr^{-1} vs non-certified = 2335 THB ha^{-1} yr^{-1} (19.2% higher); $n = 723$ Thai smallholders
Rodthong *et al* (2020)	Lower	+	Desirable	Annual farm income (cross-sectional comparison, $n = 723$ Thai smallholders): RSPO adopters US$11 919 yr^{-1} vs non-adopters US$8239 yr^{-1} (44.7% higher)
FFB price premium				
Richartz and Abdulai (2025)	Higher	+	Desirable	Prices received per metric ton (GHS): ATT = 0.47, $t = 6.59^{***}$ (19.2% increase)
Renner *et al* (2024)	Higher	−	Undesirable	FFB price per kilogram
Tey *et al* (2022)	Higher	+	Desirable	FFB price premium
Hutabarat *et al* (2018)	Lower	+	Desirable	FFB price per ton
Napitupulu and Rafiq (2019)	Lower	+	Desirable	FFB price per ton
Total farm production costs				
Tey *et al* (2022)	Higher	−	Desirable	Total production costs per hectare
Hutabarat *et al* (2018)	Lower	+	Undesirable	Total production costs per hectare
Social infrastructure (healthcare and education)				
Lee *et al* (2020)	Higher	+	Desirable	Healthcare facilities—count
Lee *et al* (2020)	Higher	+	Desirable	Educational facilities—count
Morgans *et al* (2018)	Higher	/	Not significant	Healthcare facilities
Santika *et al* (2021)	Higher	/	Not significant	Healthcare facilities—count and access
Santika *et al* (2021)	Higher	+	Desirable	Educational facilities—count
Santika *et al* (2021)	Higher	−	Desirable	Educational facilities—distance
Poverty and village well-being				
Morgans *et al* (2018)	Higher	/	Not significant	Village poverty index
Richartz and Abdulai (2025)	Higher	−	Desirable	Food insecurity (HFIAs): ATT = −0.902, $t = -4.323^{***}$ (59% reduction)

(Continued.)

Table 5. (Continued.)

Study	Rigor	Association	Effect	Indicator/outcome
Santika *et al* (2021)	Higher	+	Desirable	Multidimensional village well-being index (market-oriented villages): positive association with RSPO presence in commercially integrated areas; panel regression with village FE
Santika *et al* (2021)	Higher	−	Undesirable	Multidimensional village well-being index (subsistence-oriented villages): negative association with RSPO presence in subsistence-oriented areas; panel regression with village FE
Santika *et al* (2021)	Higher	−	Desirable	Village poverty rate
Labor, employment, and capacity building				
Santika *et al* (2021)	Higher	+	Desirable	Agricultural wage employment
Beall (2012)	Lower	+	Desirable	Knowledge sharing
Beall (2012)	Lower	+	Desirable	Workplace safety and health
Córdoba *et al* (2022)	Lower	−	Undesirable	Traditional labor arrangements
Levin *et al* (2012)	Lower	+	Desirable	Employee motivation and morale
Napitupulu and Rafiq (2019)	Lower	+	Desirable	Capacity building and empowerment
Land rights, tenure, and conflict resolution				
Afrizal *et al* (2023)	Lower	−	Undesirable	Land conflict resolution effectiveness
Genoud (2020)	Lower	−	Undesirable	Customary land rights protection
Johnson (2014)	Lower	−	Undesirable	Land governance legitimacy
Khatun *et al* (2020)	Lower	−	Undesirable	Land tenure security
McCarthy (2012)	Lower	−	Undesirable	Land access equity
Nesadurai (2013)	Lower	+	Desirable	Food security safeguards via land governance
De Vos *et al* (2023)	Lower	−	Undesirable	Land legality documentation burden: 10/31 certified groups lack full legal documentation; major barrier for independent smallholders
Stakeholder power dynamics and governance equity				
Chalil and Barus (2019)	Lower	−	Undesirable	RSPO criteria implementation score (multinomial regression): managed smallholders scored 26%–39% implementation; independent 1.8–2.1 out of 5
Cheyns (2014)	Lower	−	Undesirable	Stakeholder voice equity
Johnson (2014)	Lower	−	Undesirable	Green-grabbing dynamics
Johnson (2019)	Lower	−	Undesirable	Smallholder procedural inclusion
Kadarusman and Herabadi (2018)	Lower	−	Undesirable	Reward distribution equity
Khatun *et al* (2020)	Lower	−	Undesirable	Governance accessibility
Martens *et al* (2020)	Lower	−	Undesirable	Institutional context for RSPO implementation (net-map analysis, Jambi): independent smallholders not recognized as essential stakeholders
Market access and supply-chain inclusion				
Ekaputri *et al* (2025)	Higher	−	Undesirable	Supply-chain inclusion of smallholders
Renner *et al* (2024)	Higher	+	Desirable	Farm profit per hectare
Renner *et al* (2024)	Higher	−	Undesirable	FFB price per kilogram
Renner *et al* (2024)	Higher	+	Desirable	FFB yield per hectare
Renner *et al* (2024)	Higher	+	Desirable	Nitrogen fertilizer application
Renner *et al* (2024)	Higher	−	Desirable	Toxic herbicide (paraquat) use
Santika *et al* (2021)	Higher	+	Desirable	Credit access
Hidayat *et al* (2015)	Lower	−	Undesirable	Market access—barriers
Hidayat *et al* (2015)	Lower	+	Desirable	Market access—improved linkages
Hidayat *et al* (2015)	Lower	−	Undesirable	Credit access—barriers

(Continued.)

Table 5. (Continued.)

Study	Rigor	Association	Effect	Indicator/outcome
Hidayat *et al* (2015)	Lower	+	Desirable	Credit access—improved
Hidayat *et al* (2015)	Lower	/	Not significant	FFB price volatility
Hou *et al* (2024)	Lower	−	Undesirable	Smallholder certification burden
Hou *et al* (2024)	Lower	−	Undesirable	Inequality consolidation
Hou *et al* (2024)	Lower	−	Undesirable	Food security under certification
Hutabarat *et al* (2018)	Lower	+	Desirable	Market access—guaranteed purchase
Nupueng *et al* (2022)	Lower	+	Desirable	Certification adoption intensity (fractional logit, $n = 723$): land title ($\beta = 0.188^{**}$), training sessions ($\beta = 0.580^{*}$), extension services ($\beta = 0.095^{***}$) significantly increase adoption; debt ($\beta = -0.257^{***}$) and tree age ($\beta = -0.106^{***}$) decrease it; RSPO adopters had 84% larger farms (5.53 vs 3.01 ha)
De Vos *et al* (2023)	Lower	−	Undesirable	Certification accessibility for independent smallholders: high barriers from cost, legality, knowledge gaps (77% certified are former scheme smallholders)

Notes and Abbreviations: FFB = fresh fruit bunch; SGD = Singapore dollars; GHS = Ghanaian cedis; THB = Thai baht; NPV = net present value; MESR = multinomial endogenous switching regression; HFIAs = Household Food Insecurity Access Scale; PODES = Potensi Desa (Village Potential Statistics, Indonesia); FE = fixed effects; ATT = average treatment effect on the treated; CSR = corporate social responsibility; OLS = ordinary least squares; IDR = Indonesian rupiah. Association symbols, direction of the statistical tests in the original studies: + = positive/increase; − = negative/decrease;/= no significant effect. Significance levels: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$. Rigor: Higher = studies using control groups with regression, PSM, DiD, IPTW, or ISO-compliant LCA; Lower = descriptive, qualitative, or before–after without counterfactual. Effect classification: Desirable = RSPO association in the expected beneficial direction; Undesirable = association in the opposite direction; Not significant = no statistically significant association detected.

Hutabarat *et al* 2018). In contrast, farmers with a contract state that RSPO has facilitated their access to credit, which is not the case for certified farmers without a contract (Hidayat *et al* 2015). The effects also seem to differ regionally. In more market-oriented settings of Indonesia, RSPO tends to increase the number of credit facilities, whereas in more subsistence-oriented settings no effect is observed (Santika *et al* 2021).

3.3.4. Living conditions

Beyond direct profit and income effects, RSPO may also influence living conditions of local communities through various indirect pathways, such as local market developments or the provision of rural services (Levin *et al* 2012). Several studies look into such broader social effects of RSPO with mixed results (table 5). In Kalimantan, RSPO certification is positively associated with the availability of healthcare centers in local villages (Lee *et al* 2020). However, these benefits of RSPO are not uniformly experienced across all regions of Indonesia (Morgans *et al* 2018, Lee *et al* 2020, Santika *et al* 2021). Regional differences are also observed for the association between RSPO certification and the local availability of schools and other educational facilities (Lee *et al* 2020).

A few studies in Indonesia compare broader indicators of socioeconomic wellbeing between regions with and without RSPO concessions, or before and after RSPO certification (table 5). One higher-rigor study finds a lower prevalence of poverty in or near locations with RSPO concessions than in locations without RSPO concessions (Morgans *et al* 2018). Another higher-rigor study shows that RSPO certification is associated with lower poverty in market-oriented communities, but not in communities with more subsistence-oriented livelihoods (Santika *et al* 2021). This variation may be influenced by regional differences in infrastructure, government support, and the extent to which certification bodies engage with local communities.

3.3.5. Labor and land rights

RSPO aims at promoting fair labor practices and protecting land rights. Several studies examine the effects of RSPO on local labor and land rights, mainly referring to large company concession areas (table 5). A few studies in Indonesia and Malaysia find positive associations between RSPO certification and labor rights of company workers, worker motivation, as well as capacity-building and empowerment among smallholder farmers contracted by RSPO-certified companies (Levin *et al* 2012, Napitupulu and Rafiq 2019). In some cases, RSPO also supports the land rights of rural and indigenous communities, which are otherwise often overlooked by governments and palm oil companies (Nesadurai 2013).

However, different findings on land-related aspects also exist. In Indonesia, RSPO-certified companies do not always effectively address land conflicts between palm oil companies and local communities Afrizal *et al* 2023). Negative effects are observed in several African and Latin American countries. One study in Ghana argues that RSPO certification has contributed to land reforms that prioritize export orientation over domestic and local-scale palm oil production, with potentially negative effects for smallholders (Khatun *et al* 2020). In Colombia, RSPO-certified companies expropriated farmers' lands (Genoud 2020). In Ecuador, an RSPO land-titling scheme worsened social and environmental conflicts and promoted unequal land ownership (Johnson 2014).

3.3.6. Decision-making power

Several studies suggest that RSPO has negative effects on the decision-making power of vulnerable groups (table 5). Smallholder farmers and local communities are often excluded from important discussions and decision-making processes in RSPO-certified supply chains (Cheyns 2014). These groups are not represented on the RSPO Executive Board, so their ideas and perspectives are sometimes overlooked. Palm oil companies, investors, global buyers, and NGOs have much more decision-making power in RSPO, resulting in asymmetrical power dynamics (Johnson 2014, Kadarusman and Herabadi 2018, Khatun *et al* 2020). RSPO certification can also influence local community structures and gender relations. Studies in Indonesia and Brazil find that RSPO-certified plantation companies have a negative social effect on traditional family farming because the company protocols and contracts mostly focus on male farmers and male family members, thus weakening women's role and agency (Santika *et al* 2021, Córdoba *et al* 2022).

3.4. Meta-analysis

As explained, we conduct DerSimonian–Laird random-effects meta-analyses on subsets of indicators, relying mostly on the higher-rigor studies. Lower-rigor studies are considered for comparison but not included in the pooled estimates shown in figures 2–5. The pooled data estimates should be interpreted with some caution, given the small number of studies in each domain.

3.4.1. Deforestation

Three higher-rigor studies report deforestation-related effect sizes that can be converted to log odds ratios (Carlson *et al* 2018, Heilmayr *et al* 2020, Lee *et al* 2020). The pooled estimate from these studies is not statistically significant (lnOR $= -0.157$, 95% CI $[-0.334, +0.020]$, OR $= 0.85$, $p = 0.081$), suggesting that RSPO does not reduce overall deforestation (figure 2; supplementary material C, panel (A). Heterogeneity within this subset of studies is moderate ($I^2 = 67.0\%$), driven largely by the contrast between Heilmayr *et al* (2020), which contributes the largest weight (44.2%) with a precisely estimated but small effect, and Carlson *et al* (2018) and Lee *et al* (2020), which report substantially larger reductions but with wide confidence intervals.

Three additional lower-rigor studies are available for complementary pooling (Meijaard *et al* 2017, Noojipady *et al* 2017, Gatti *et al* 2019). When all seven studies are combined, the full-sample estimate reaches statistical significance (pooled lnOR $= -0.198$, OR $= 0.82$, $p = 0.030$), but between-study heterogeneity is substantial ($I^2 = 74.0\%$), and the lower-rigor studies show more dispersed effects, with Gatti *et al* (2019) being the only study reporting a positive (i.e. undesirable) point estimate (supplementary material B, figures B1–B5). Egger's regression test indicates significant funnel plot asymmetry (intercept $= -1.425$, $p = 0.003$), consistent with small-study effects.

3.4.2. GHG emissions

Four higher-rigor studies report GHG emission reductions attributable to RSPO certification, expressed as percentage reductions in CO_2-equivalent emissions per unit of output (supplementary material C, panel B). The pooled estimate indicates a statistically significant 34.1% reduction in GHG emissions through RSPO certification (95% CI: 28.5–39.7%, $p < 0.001$; figure 3). The three multi-country estimates (Schmidt and De Rosa 2020, attributional and consequential, Schmidt and Weidema 2026) cluster between 35.8% and 36.1% reduction, while Saswattecha *et al* (2015) report a lower estimate of 21.1% for Thailand. Heterogeneity is negligible ($I^2 = 0.3\%$), and leave-one-out sensitivity analysis confirms that the pooled finding is robust to the exclusion of any individual study (supplementary material B, figures B7–B9). Egger's test yields a significant result (intercept $= -4.469$, $p = 0.019$), though the small number of studies ($K = 4$) limits the interpretability of this test; the asymmetry is driven primarily by the separation between the three Schmidt and colleagues estimates and the single Saswattecha *et al* estimate rather than by classical publication bias.

3.4.3. Oil palm yield

Three higher-rigor studies report yield effects that can be converted to Hedges' g (Saswattecha *et al* 2015, Morgans *et al* 2018, Schmidt and De Rosa 2020). The pooled estimate is positive and statistically significant ($g = 0.486$, 95% CI $[0.335, 0.638]$, $p < 0.001$), indicating a moderate yield advantage for RSPO-certified production with complete internal consistency ($I^2 = 0.0\%$; figure 4; supplementary material C, panel C).

Three additional lower-rigor studies are available for complementary analysis (Levin *et al* 2012, Malini and Aryani 2012, Hutabarat *et al* 2018). When all six studies are pooled, the combined estimate is larger ($g = 0.777$, 95% CI $[0.421, 1.134]$), but heterogeneity rises sharply ($I^2 = 86.1\%$), driven by the lower-rigor

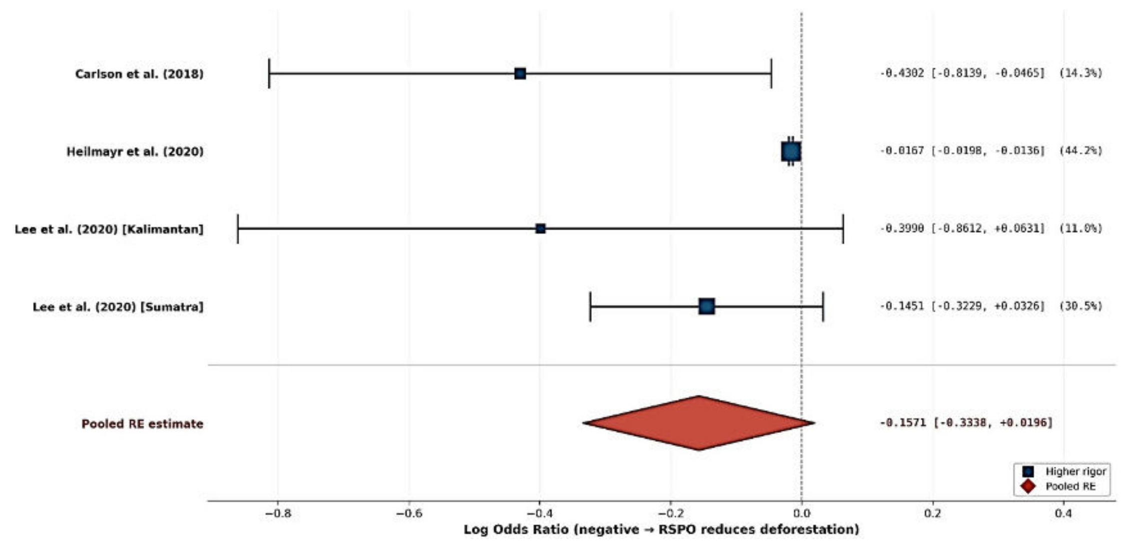

Figure 2. Forest plot of higher-rigor deforestation studies. $K = 4$, DerSimonian–Laird random-effects model. The pooled log odds ratio is -0.157 (OR = 0.85, 95% CI [0.72, 1.02], $p = 0.081$), providing no statistically significant evidence that RSPO certification reduces deforestation at the conventional significance level.

subgroup which produces a pooled effect of $g = 1.242$ ($I^2 = 94.1\%$), approximately 2.6 times the higher-rigor estimate (supplementary material B, figures B10–B14). Egger's test does not indicate significant funnel plot asymmetry (intercept = 2.656, $p = 0.385$), though the small number of studies limits the power of this test.

3.4.4. Farm income and revenue

Two higher-rigor studies report income or revenue comparisons that can be poolable as Hedges' g (Tey *et al* 2022, Richartz and Abdulai 2025) (supplementary material C, panel D). The pooled estimate indicates a small but statistically significant positive income effect ($g = 0.216$, 95% CI [0.067, 0.366], $p = 0.005$), with complete internal consistency ($I^2 = 0.0\%$; figure 5).

Four additional lower-rigor studies are available for complementary pooling (Levin *et al* 2012, Malini and Aryani 2012, Hutabarat *et al* 2018, Napitupulu and Rafiq 2019). The full-sample estimate is substantially larger ($g = 0.871$, 95% CI [0.402, 1.340]), but heterogeneity is very high ($I^2 = 92.0\%$), driven almost entirely by the lower-rigor subgroup ($g = 1.219$, $I^2 = 91.0\%$), which produces an effect approximately 5.6 times larger than the higher-rigor estimate (supplementary material B, figures B15–B19). This is the most pronounced rigor gradient observed across the four meta-analyzed domains. Egger's test does not indicate significant asymmetry (intercept = 4.951, $p = 0.731$), but the leave-one-out analysis confirms that the pooled estimate is most sensitive to the exclusion of the lower-rigor studies with the most extreme positive effects (supplementary material B, figure B19).

In summary, the higher-rigor meta-analytic evidence confirms statistically significant effects of RSPO certification on three outcome domains: GHG emissions, oil palm yield, and farm income. For deforestation, the higher-rigor subgroup of studies does not reach statistical significance. In all four domains, the lower-rigor estimates are systematically larger than the higher-rigor estimates, with rigor gradient ratios ranging from 1.6:1 (deforestation) to 5.6:1 (farm income). Also, heterogeneity rises sharply when lower-rigor studies are included (supplementary material B, table B1). These patterns suggest that a non-trivial share of the positive effects attributed to RSPO in the existing literature reflects uncontrolled confounding factors or selection bias in lower-rigor designs rather than genuine certification impacts.

3.5. RSPO and smallholder farmers

Understanding how smallholder farmers are affected by sustainability standards in agricultural supply chains is important, as smallholder farmers are a particularly vulnerable group (Grabs *et al* 2021). Globally, around half of the oil palm land is managed by smallholders (Qaim *et al* 2020). While there is no uniform threshold for the maximum size of a smallholder farm, most of the farms in Southeast Asia and Africa have less than 10 hectares of oil palm land (Ruml *et al* 2022). Apart from clear differences in the size of the operations, a key distinguishing factor between smallholder farms and large-scale plantations is that the former are owned and managed by local families, whereas the latter are not.

In principle, both large-scale palm oil companies and smallholder farmers can be RSPO-certified. If smallholders are part of a contract scheme, RSPO certification is organized through the contracting company. ISHs without a company contract can obtain RSPO certification either alone or as part of a farmer group under the ISH Standard (RSPO 2025b).

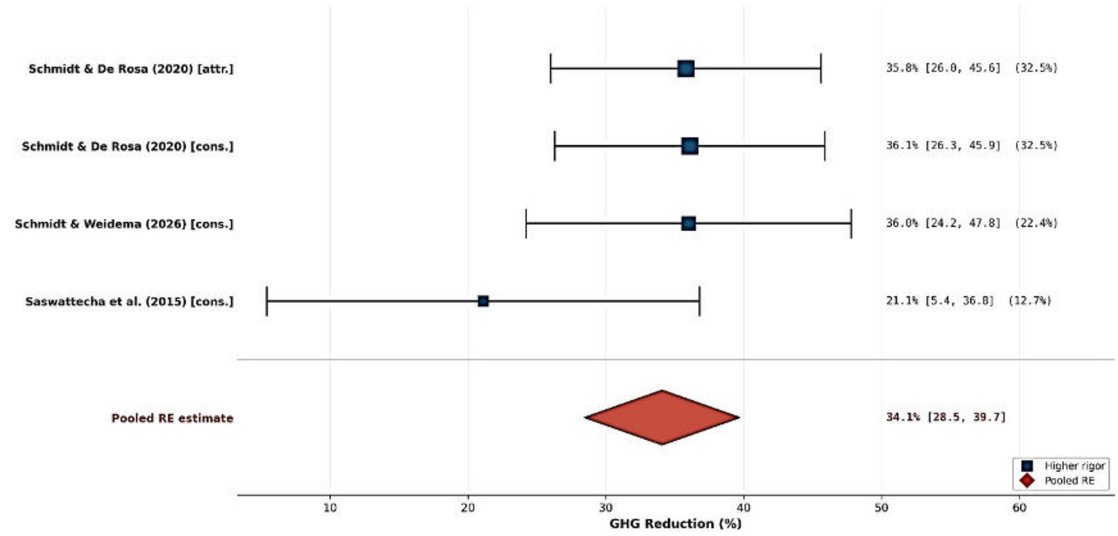

Figure 3. Forest plot of higher-rigor GHG emissions studies. $K = 4$, DerSimonian–Laird random-effects model. All four studies are classified as higher rigor (life cycle assessment). The pooled estimate indicates a 34.1% reduction in GHG emissions for RSPO-certified production (95% CI: 28.5%–39.7%).

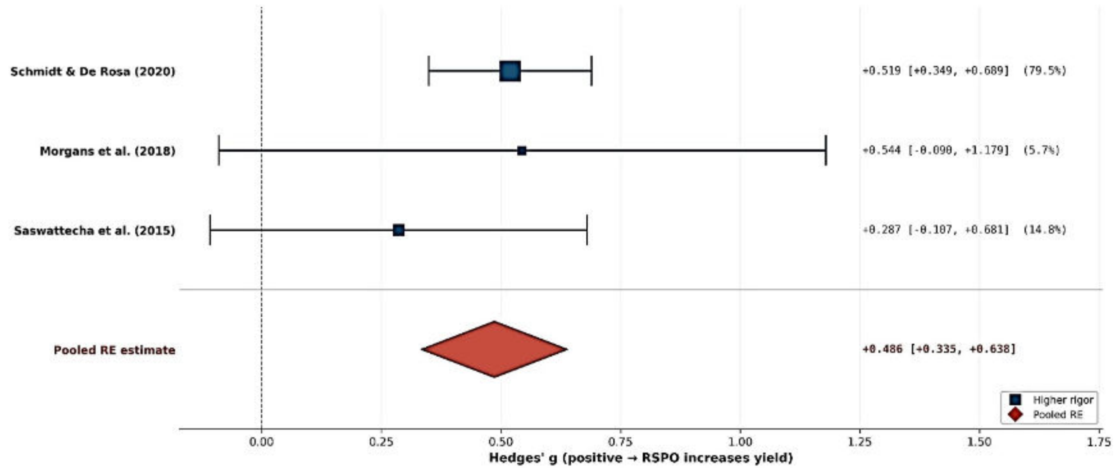

Figure 4. Forest plot of higher-rigor oil palm yield studies. $K = 3$, DerSimonian–Laird random-effects model. The pooled Hedges' g is 0.486 (95% CI [0.335, 0.638], $p < 0.001$), indicating a moderate positive yield effect with complete consistency across estimates.

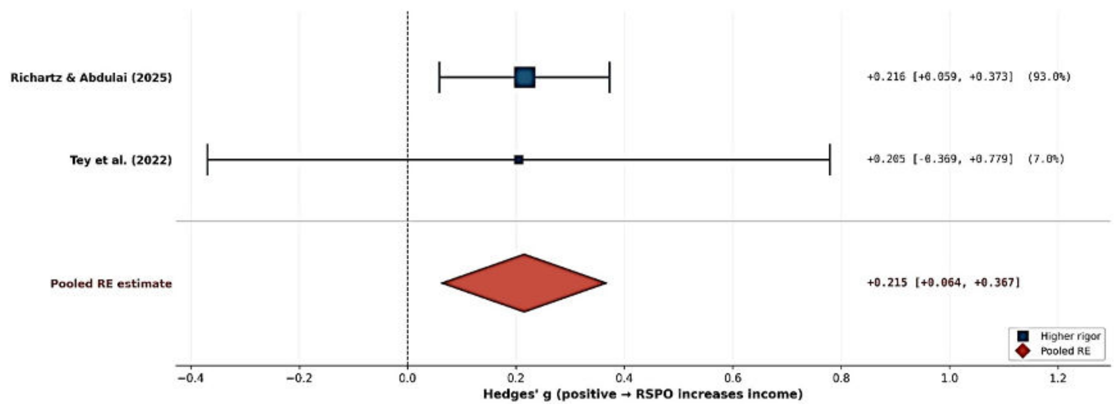

Figure 5. Forest plot of higher-rigor farm income studies. $K = 2$, DerSimonian–Laird random-effects model. The pooled Hedges' g is 0.215 (95% CI [0.064, 0.367], $p = 0.005$), indicating a small but statistically significant positive income effect.

However, up till now RSPO certification in the small farm sector has been very limited (Qaim *et al* 2020, Bok *et al* 2022, RSPO 2023, 2025a). In 2024, only 2.1% of the estimated 7 million smallholders growing oil palm globally were certified (table 6). Moreover, the total number of certified smallholders declined by approximately 12% between 2021 and 2024, suggesting that retention poses a challenge at least as important as initial adoption.

This overall decline in the number of certified smallholders conceals a pronounced divergence between certification pathways. The number of RSPO-certified smallholders in contract schemes fell sharply, from 143 445 in 2021 to 99 597 in 2024, a reduction of more than 30%. In contrast, ISHs with RSPO certificate more than doubled over the same period, rising from 22 017 to 46 248. The drivers of the decline in contract-scheme certification are not yet well understood and warrant further investigation, as contract arrangements are typically assumed to lower the costs and barriers of RSPO certification. It appears that some mills with smallholder contract schemes have recently dropped out of RSPO certification.

Regional trends are similarly heterogeneous: certified smallholder numbers declined markedly in Indonesia (−14.1%), Latin America (−90.8%), and the rest of the world (−13.0%), while Africa recorded a notable increase (+37.1%), and Malaysia saw growth in independent certification despite the complete disappearance of contract-scheme certified smallholders. Based on the original studies identified (supplementary tables A1), we analyze various reasons for the low adoption of RSPO among smallholder farmers. Further analysis of relevant factors is shown in supplementary table A2.

3.5.1. RSPO conditions

Smallholder farmers may face challenges with RSPO certification due to several issues associated with the certification scheme itself. In order to be eligible for certification, farmers in most situations need formal land titles, which many smallholders do not have (Brandi *et al* 2015, Rietberg and Slingerland 2016). Obtaining formal land titles is sometimes possible for smallholders but is typically costly and time-consuming (Krishna *et al* 2017, Córdoba *et al* 2022). Additionally, RSPO requires farmers to have business permits and to submit expert environmental and social impact assessments on a regular basis. Most smallholders lack the financial means and expertise to obtain such permits and assessment reports (Rietberg and Slingerland 2016, Hutabarat *et al* 2019). Moreover, smallholders often find the regular bookkeeping and documentation requirements challenging (Beall 2012, Brandi *et al* 2015, Rietberg and Slingerland 2016). The cost of RSPO certification, auditing, and adhering to the standards can also be prohibitive for smallholders (Martens *et al* 2020), and sometimes even for large-scale producers (Bishop 2017, Bishop and Carlson 2022).

Beyond the initial certification hurdles, De Vos *et al* (2023) find that the ability to sustain RSPO certification over time depends critically on pre-certification conditions: among 18 certified ISH groups in Indonesia, those with secure land rights, stronger organizational capacity, and higher-quality facilitator support were significantly more likely to maintain compliance, while groups lacking these preconditions often struggled to retain certification after the initial audit.

3.5.2. Farm, household, and regional characteristics

Studies in Thailand and Indonesia show that farm size is positively associated with RSPO certification (Rodthong *et al* 2020, Nupueng *et al* 2022). This is plausible because the fixed costs of certification and auditing are more difficult to bear for smaller than for larger farms. Additionally, the age of oil palm plantations is positively associated, whereas distance to palm oil mills and forest cover in the region are negatively associated with RSPO certification (Carlson *et al* 2018, Rodthong *et al* 2020). RSPO tries to protect forests and avoid deforestation for the establishment of new oil palm plantations, so farmers' decision to get certified is easier when the remaining forest in their location is small anyway.

Oil palm smallholders with a company contract are more likely to be RSPO-certified than independent farmers (Kadarusman and Herabadi 2018) because the companies often encourage and facilitate certification in their outgrower schemes. It should be noted that the aggregate decline in the number of contracted smallholders with certification, as discussed above, is often not driven by individual farmers' decisions but by mills exiting contract-scheme certification. Up till now, RSPO certification is still more widely observed among contracted than among ISHs.

Farmers' oil palm yields, prices, and revenues are positively associated with RSPO certification (Hidayat *et al* 2015, Rietberg and Slingerland 2016, Rizal *et al* 2021, Tey and Brindal 2021, Nupueng *et al* 2022). Farming experience and household income seem to have positive effects on RSPO certification (Chalil and Barus 2019, Nupueng *et al* 2022). Younger farmers are more likely to be certified than older farmers (Hutabarat *et al* 2019). For education, no consistent effects are observed (Nupueng *et al* 2022).

3.5.3. Technical support and group membership

For many smallholders, the lack of technical and organizational support is a barrier to RSPO certification and compliance with the standards (Rietberg and Slingerland 2016, Johnson 2019, Rodthong *et al* 2020). Farmers who are members of farmer groups are more likely to be RSPO-certified (Chalil and Barus 2019, Nupueng *et al* 2022). Group certification and

Table 6. Number of RSPO-certified and non-certified smallholders (2021 and 2024).

		Certified smallholders								
		Contract scheme			Independent			Both		
Region	Total smallholders	2021	2024	2024–2021	2021	2024	2024-2021	2021	2024	2024–2021
Indonesia	2700 000	119 856	83 511 (3.1)	−36 345	10 953	28 822 (1.1)	17 869	130 809	112 333 (4.2)	−18 476 (−14.1)
Malaysia	650 000	30	0 (0)	−30	1324	2912 (0.4)	1588	1354	2912 (0.4)	1558 (115.1)
Latin America	150 000	1708	15 (0)	−1693	0	142 (0.1)	142	1708	157 (0.1)	−1551 (−90.8)
Africa	3100 000	899	3184 (0.1)	2285	4983	4883 (0.2)	−100	5882	8067 (0.3)	2185 (37.1)
Rest of the world	450 000	20 952	12 887 (2.9)	−8065	4757	9489 (2.1)	4732	25 709	22 376 (5)	−3333 (−13)
Total	7050 000	143 445	99 597 (1.4)	−43 848	22 017	46 248 (0.7)	24 231	165 462	145 845 (2.1)	−19 617 (−11.9)

Notes: Numbers in parentheses are percentages relative to total smallholders.Source*: Data from* (*RSPO* 2023), *RSPO* (2025a).

auditing are easier and less costly than individual certification. Moreover, certification as a group can strengthen social interactions, knowledge exchange, shared identity, and trust among farmers and stakeholders in palm oil supply chains (Rizal *et al* 2021).

Where certification is mandated at the jurisdictional level rather than adopted voluntarily, these barriers can become even more consequential. In Malaysia, qualitative fieldwork on the mandatory RSPO program finds that ISHs face compounded equity, food security, and compliance barriers: mandatory certification requirements without adequate support structures risk excluding the most vulnerable smallholders from sustainable supply chains and can threaten food security among those who depend on oil palm as a subsistence crop alongside commercial production (Hou *et al* 2024). These findings suggest that expanding RSPO through mandatory jurisdictional approaches requires targeted institutional support to avoid exacerbating inequalities.

4. Discussion

We have systematically reviewed the extant literature on the environmental and socioeconomic effects of RSPO certification. Most of the original studies provide evidence from Southeast Asia; fewer studies refer to Latin America and Africa. This regional distribution of studies reflects the disparity in the geography of oil palm cultivation and RSPO certification.

Overall, RSPO has desirable (positive) effects on various facets of sustainable development, but the results are context-dependent. In some situations, no significant effects of RSPO are observed. In a few studies, undesirable (negative) outcomes are observed, meaning that RSPO may even have adverse environmental and socioeconomic effects in particular situations.

4.1. Environmental effects

RSPO certification seems to reduce illegal deforestation, especially in peatland and HCV areas, aligning with RSPO's primary goal of conserving biodiversity and reducing habitat loss. However, our meta-analysis reveals that—when only higher-rigor studies are considered—the pooled estimate is not statistically significant, providing no evidence that RSPO certification really reduces overall deforestation. The estimate reaches significance only when lower-rigor studies are also included, suggesting that the reported deforestation-reducing effect may partly reflect uncontrolled confounding factors.

Several higher-rigor studies show that RSPO reduces but does not eliminate deforestation within certified concessions. However, in nearby non-certified land, deforestation for oil palm cultivation sometimes increases. Such leakage effects were particularly shown in Indonesia, leading to a small and statistically insignificant impact of RSPO on overall deforestation. As the increased deforestation largely occurs on non-certified land, the issue is not primarily one of non-compliance with RSPO. Stricter rules and more effective monitoring and enforcement may help to address the remaining issues of deforestation on RSPO-certified land, but not the leakage effects. This underlines that RSPO alone cannot solve the issue of deforestation associated with palm oil, which holds true also for other voluntary certification schemes. In other words, RSPO and other voluntary sustainability standards can address issues of deforestation only to a limited extent (Meemken *et al* 2021).

We also find mixed effects of RSPO on other environmental indicators, such as water pollution and human toxicity. These effects are influenced by geographic and land-cover conditions, local farming practices, and farmers' access to input markets and technical support. In this respect, improved designs of the RSPO standard and the institutional context can help achieve more consistent positive outcomes. Clear positive environmental effects of RSPO were identified in several studies in terms of lower GHG emissions. Specifically, our meta-analysis of higher-rigor studies confirms a mean RSPO reduction in GHG emissions of 34% per unit of palm oil produced.

We also show a significant positive effect of RSPO on oil palm yields. In principle, higher yields help to save land, even though under certain conditions they may also lead to more natural land being converted to palm oil production. The growing profitability of the crop may incentivize further land expansion, which is a rebound effect, sometimes also referred to as Jevons' Paradox (Sorrell 2009). Given the global rising demand for palm oil, such a rebound effect is plausible especially in contexts where remaining forests are not effectively protected. While yield improvements are important, they will have to be accompanied by national nature conservation policies to reduce or stop further deforestation. As mentioned, RSPO alone will not be able to solve this problem.

4.2. Socioeconomic effects

The positive yield effects of RSPO are mostly achieved through enhanced producer access to credit, inputs, and extension. Coupled with better output market access and higher output prices, higher yields have also contributed to higher revenues for RSPO-certified producers. In terms of profit and income, RSPO effects depend on the context. One study with data from farmers in Africa shows positive income effects (Richartz and Abdulai 2025), whereas evidence from Southeast Asia is mixed. A few studies in Indonesia suggest that the higher revenues with RSPO are sometimes offset by higher production and certification costs (Beall 2012, Hutabarat *et al* 2018).

RSPO's broader socioeconomic effects on local communities (e.g. healthcare and educational infrastructure) appear to be positive in market-oriented settings but not in more subsistence-oriented settings. This variation underscores the need for RSPO to adapt its approach to different socioeconomic contexts to ensure that the benefits are equitably distributed. In terms of labor and land rights, while RSPO certification has improved worker rights and capacity-building in some situations, evidence also points to persistent power asymmetries in decision-making processes, often marginalizing local communities and smallholder farmers.

4.3. Smallholder inclusion

Our research reveals that RSPO certification is predominantly concentrated in the large-plantation sector, with limited participation by smallholder farmers. Only around 2% of all smallholder oil palm producers worldwide are RSPO-certified. Against this background, it may be surprising that approximately 42% (22 out of 53) of the original studies on RSPO effects focus on smallholders. On the one hand, this may possibly be due to researchers being more concerned about the social situation of smallholder farmers. On the other hand, the focus on smallholders in impact research also relates to the quasi-experimental approaches often used, which require large samples to obtain meaningful and statistically significant results. Large samples are difficult to obtain when surveying large-scale commercial oil palm plantations.

The low rates of smallholder participation in RSPO can be explained by various factors. RSPO certification is costly and requires formal land titles, which many smallholders do not have. In addition, without specific support, smallholders often face technical and institutional constraints to obtain certification and comply with the RSPO standards. This is a well-known problem and also the reason why RSPO developed and adopted a smallholder strategy in 2017 with various support measures, including capacity building and supply chain partnership programs (RSPO 2017).

However, evidence suggests that obtaining certification is only part of the challenge. Even when being RSPO-certified, smallholders sometimes cannot reap the full benefits because structural features of certified supply chains exclude them from actually selling through these channels (Ekaputri *et al* 2025). Aggregation costs, documentation requirements, and traceability constraints mean that certified mills source predominantly from contracted farmers and plantations, passively bypassing ISHs despite their formal certification status. While the number of RSPO-certified ISHs has grown in recent years, they remain at a structural disadvantage in capturing the economic benefits of certification. Further adjustments in RSPO programs and institutional support could help to make certified supply chains more smallholder-inclusive.

4.4. Methodological rigor of original studies

It is important to emphasize that all of the original studies reviewed here rely on observational data. Many studies simply compare situations with and without or before and after RSPO certification, without reliable control groups and without always controlling for possible confounding factors. This is the reason why we differentiate between higher-rigor studies, which use statistical approaches to control for confounders as much as possible, and lower-rigor studies that do not. Of the 53 original studies included, 35.8% and 64.2% are classified as higher-rigor and lower-rigor studies, respectively. This is not an attempt to judge about the quality of each study, but to add transparency about which of the observed RSPO effects can be interpreted in a causal sense. In all result tables (tables 3–5), entries are clearly labeled according to this classification. The figures reporting the meta-analysis results (figures 2–5) only include eligible higher-rigor studies, whereas alternative results also including lower-rigor studies are discussed in the text for comparison.

The high proportion of lower-rigor studies in this body of literature underscores the need for more research using rigorous methods of impact evaluation to better understand the net sustainability effects of RSPO. Our meta-analysis supports this concern. When only considering higher-rigor studies, the effect size estimates are consistently smaller than wen also including lower-rigor studies. This suggests that a non-trivial share of the positive effects attributed to RSPO in the existing literature reflects uncontrolled confounding factors or selection bias in lower-rigor studies rather than genuine certification impacts.

5. Conclusion

A few broader lessons can be drawn from the evidence reviewed and synthesized here. First, concerning environmental effects, RSPO is a step in the right direction to mitigate some of the issues associated with palm oil production. RSPO's emphasis on preventing deforestation in HCV areas, reducing GHG emissions, and encouraging sustainable agricultural practices are welcome initiatives to promote more sustainability. Existing studies confirm that RSPO certification is associated with a significant reduction in GHG emissions per unit of output. However, for effects on deforestation the evidence is less clear. Higher-rigor studies show that RSPO reduces but does not always eliminate deforestation on certified land. In this respect, stricter rules and more effective enforcement would help. In addition, there is leakage to non-certified land, where deforestation increases as a result of RSPO. The deforestation reductions on certified land may be offset by this leakage effect on non-certified land, such that the overall effect of RSPO on deforestation in our meta-analysis with only the higher-rigor studies included is small and statistically insignificant. This is not primarily an issue of non-compliance; leakage effects cannot be addressed by stricter enforcement of RSPO rules. Buyers of RSPO-certified palm oil need to recognize that completely deforestation-free supply chains can hardly be achieved through voluntary certification programs alone. The same is true for other voluntary sustainability standards or for regulations that only apply to certain market segments, such as the EU Deforestation Regulation. Mandatory national standards, such as ISPO or MSPO, could be better suited to deal with leakage effects, but would need stricter rules on deforestation.

Second, while RSPO contributes to higher oil palm yields, the broader socioeconomic effects are not yet satisfactory, as evidenced by mixed outcomes in terms of profits and human wellbeing. The income and profit effects vary geographically, also when only considering the higher-rigor studies. This heterogeneity implies that profit outcomes are sensitive to local cost structures, market conditions, and institutional environments, and that general policy prescriptions should not be drawn from a single regional context. RSPO certification seems to exacerbate power asymmetries, particularly in decision-making processes concerning land rights, which disproportionately affect smallholder farmers and local communities. RSPO should prioritize more inclusive approaches, ensuring that the voices and perspectives of smallholder farmers and indigenous communities are adequately represented.

Third, smallholder farmers play a significant role in global oil palm production, yet up till now they are hardly included in RSPO certification. This needs more serious attention. If only large plantations are certified and smallholders cannot participate, rising inequality and further marginalization of vulnerable groups is possible, especially given that sustainability certification is increasingly required to access certain high-value markets. The barriers for smallholders operate at two levels. The first is getting certified in the first place, which requires access to finance, formal land titles, and technical and administrative support. The second relates to actually selling through certified channels, which involves additional costs and traceability requirements. Both types of barriers need to be addressed to make RSPO more inclusive.

Finally, future research should aim to apply more rigorous methodologies, such as randomized controlled trials or quasi-experimental approaches, to assess the true causal effects of RSPO. Our meta-analysis reveals potential biases in the existing literature. When only considering higher-rigor studies, the effect size estimates are consistently smaller than wen also including lower-rigor studies. This suggests that some studies may report benefits of RSPO that are inflated due to uncontrolled confounding factors. Future studies should explore the long-term impacts of RSPO on both environmental and socioeconomic sustainability dimensions, considering the dynamic and evolving nature of palm oil production landscapes. Equally important is to expand the geographic evidence. Most studies on RSPO impacts to date refer to Southeast Asia, even though certification is also increasing in other parts of the world. Our findings suggest that the geographic context matters due to differences in socioeconomic and institutional conditions.

Acknowledgments

We thank Susanne Vögele for research assistance and Tobias Bähr for helpful comments. We also thank the editors and anonymous reviewers of this journal for constructive comments on earlier versions of this manuscript. This study was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)–grant number 192626868–and Germany's Excellence Strategy (EXC-2070-390732324-PhenoRob).

Data availability statement

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

Supplementary data A available at https://doi.org/10.1088/1748-9326/ae803b/data1.

Supplementary data B available at https://doi.org/10.1088/1748-9326/ae803b/data2.

Supplementary data C available at https://doi.org/10.1088/1748-9326/ae803b/data3.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

Author contributions

Kibrom T Sibhatu 0000-0002-3063-8369
Conceptualization (lead), Funding acquisition (equal), Investigation (lead), Methodology (lead), Validation (lead), Writing – original draft (lead), Writing – review & editing (equal)

Matin Qaim 0000-0003-4143-0763
Conceptualization (supporting), Funding acquisition (equal), Investigation (supporting), Methodology (supporting), Validation (supporting), Writing – original draft (supporting), Writing – review & editing (equal)

References

Abidin M N Z, Abdul Fatah F, Noor W N W M and Aris N F M 2024 A review on adoption of the Malaysian sustainable palm oil (MSPO) certification scheme *IOP Conf. Ser.: Earth Environ. Sci.* **1397** 012035

Abram N K *et al* 2017 Oil palm–community conflict mapping in Indonesia: A case for better community liaison in planning for development initiatives *Appl. Geogr.* **78** 33–44

Afrizal A, Hospes O, Berenschot W, Dhiaulhaq A, Adriana R and Poetry E 2023 Unequal access to justice: an evaluation of RSPO's capacity to resolve palm oil conflicts in Indonesia *Agric. Hum. Values* **40** 291–304

Azhar B, Saadun N, Puan C L, Kamarudin N, Aziz N, Nurhidayu S and Fischer J 2015 Promoting landscape heterogeneity to improve the biodiversity benefits of certified palm oil production: evidence from peninsular *Malaysia. Glob. Ecol. Conserv.* **3** 553–61 (available at: www.sciencedirect.com/science/article/pii/S2351989415000232)

Beall E 2012 *Smallholders in global bioenergy value chains and certification* (FAO) (available at: www.fao.org/docrep/015/i2597e/i2597e00.pdf)

Bicknell J E *et al* 2023 Enhancing the ecological value of oil palm agriculture through set-asides *Nat. Sustain.* **6** 513–25

Bishop K J and Carlson K M 2022 The role of third-party audits in ensuring producer compliance with the roundtable on sustainable palm oil (RSPO) certification system *Environ. Res. Lett.* **17** 094038

Bishop K 2017 *Assessing the role of third-party audits in ensuring producer compliance with the roundtable on sustainable palm oil (RSPO) certification system Master's Thesis* (University of Hawai'i at Mānoa) (available at: http://hdl.handle.net/10125/62581)

Blackman A and Naranjo M A 2012 Does eco-certification have environmental benefits? Organic coffee in Costa Rica *Ecol. Econ.* **83** 58–66

Blackman A and Rivera J 2011 Producer-level benefits of sustainability certification *Conserv. Biol.* **25** 1176–85

Bok C H, Lim C H, Ngan S L, How B S, Ng W P Q and Lam H L 2022 Life cycle assessment and life cycle costing analysis for uncertified and Malaysia sustainable palm oil—MSPO-certified independent smallholders *J. Clean. Prod.* **379** 134646

Brandi C, Cabani T, Hosang C, Schirmbeck S, Westermann L and Wiese H 2015 Sustainability standards for palm oil: challenges for smallholder certification under the RSPO *Ournal Environ. Dev.* **24** 292–314

Carlson K M, Heilmayr R, Gibbs H K, Noojipady P, Burns D N, Morton D C, Walker N F, Paoli G D and Kremen C 2018 Effect of oil palm sustainability certification on deforestation and fire in Indonesia *Proc. Natl Acad. Sci. USA* **115** 121–6

Cattau M E, Marlier M E and DeFries R 2016 Effectiveness of roundtable on sustainable palm oil (RSPO) for reducing fires on oil palm concessions in Indonesia from 2012 to 2015 *Environ. Res. Lett.* **11** 105007

Chalil D and Barus R 2019 Analysis of smallholders' progress in implementing sustainable management in North Sumatra, Indonesia *Indones. J. Agric. Res.* **1** 246–59

Cheyns E 2014 Making "minority voices" heard in transnational roundtables: the role of local NGOs in reintroducing justice and attachments *Agric. Hum. Values* **31** 439–53

Córdoba D, Abrams J and Selfa T 2022 Achieving palm oil sustainability under contract: roundtable on sustainable palm oil and family farmers in the Brazilian Amazon *Curr. Res. Environ. Sustain.* **4** 100160

Corley R H V and Tinker P B 2015 *The oil palm* vol 5 (Wiley-Blackwell) (available at: www.wiley.com/en-ae/The+Oil+Palm,+5th+Edition-p-9781405189392)

De Rosa M, Schmidt J and Pasang H 2022 Industry-driven mitigation measures can reduce GHG emissions of palm oil *J Clean. Prod.* **365** 132565

De Vos R E, Suwarno A, Slingerland M, Van Der Meer P J and Lucey J M 2023 Pre-certification conditions of independent oil palm smallholders in Indonesia. Assessing prospects for RSPO certification *Land Use Policy.* **130** 106660

DerSimonian R and Laird N 1986 Meta-analysis in clinical trials *Control. Clin. Trials* **7** 177–88

DerSimonian R and Laird N 2015 Meta-analysis in clinical trials revisited *Contemp. Clin. Trials* **45** 139–45

Ekaputri A D, Gaveau D L A, Heilmayr R and Carlson K M 2025 Uneven participation of independent and contract smallholders in certified palm oil mill markets in Indonesia *Commun. Earth Environ.* **6** 721

FAO 2025 FAOSTAT statistical database: production/yield quantities of oil palm fruit in world (available at: www.fao.org/faostat/en/#data/QCL/visualize)

Furumo P R, Rueda X, Rodríguez J S and Parés Ramos I K 2020 Field evidence for positive certification outcomes on oil palm smallholder management practices in Colombia *J. Clean. Prod.* **245** 118891

Garrett R D, Carlson K M, Rueda X and Noojipady P 2016 Assessing the potential additionality of certification by the roundtable on responsible soybeans and the roundtable on sustainable palm oil *Environ. Res. Lett.* **11** 045003

Gatti R C, Liang J, Velichevskaya A and Zhou M 2019 Sustainable palm oil may not be so sustainable *Sci. Total Environ.* **652** 48–51

Gatti R C and Velichevskaya A 2020 Certified "sustainable" palm oil took the place of endangered Bornean and Sumatran large mammals habitat and tropical forests in the last 30 years *Sci. Total Environ.* **742** 140712

Genoud C 2020 Access to land and the round table on sustainable palm oil in Colombia *Globalizations* **18** 1–18

Grabs J, Cammelli F, Levy S A and Garrett R D 2021 Designing effective and equitable zero-deforestation supply chain policies *Glob. Environ. Change* **70** 102357

Haddaway N R, Macura B, Whaley P and Pullin A S 2018 ROSES RepOrting standards for systematic evidence syntheses: pro forma, flow-diagram and descriptive summary of the plan and conduct of environmental systematic reviews and systematic maps *Environ. Evid.* **7** 7

Heilmayr R, Carlson K M and Benedict J J 2020 Deforestation spillovers from oil palm sustainability certification *Environ. Res. Lett.* **15** 075002

Hidayat K N, Glasbergen P and Offermans A 2015 Sustainability certification and palm oil smallholders' livelihood: a comparison between scheme smallholders and independent smallholders in Indonesia *Int. Food Agribus. Manag. Rev.* **18** 25–48

Hou T M, Tamunaidu P, Padfield R and Huzir N M 2024 "Smile even if your burdens are heavy": smallholder challenges and the Sabah sustainable palm oil initiative *Sustain. Dev.* **32** 5488–98

Hutabarat S, Slingerland M and Dries L 2019 Explaining the "certification gap" for different types of oil palm smallholders in Riau Province, Indonesia *J. Environ. Dev.* **28** 253–81

Hutabarat S, Slingerland M, Rietberg P and Dries L 2018 Costs and benefits of certification of independent oil palm smallholders in Indonesia *Int. Food Agribus. Manag. Rev.* **21** 681–700

Johnson A 2014 Ecuador's national interpretation of the roundtable on sustainable palm oil (RSPO): green-grabbing through green certification? *J. Latin Am. Geogr.* **13** 183–204

Johnson A 2019 The roundtable on sustainable palm oil's national interpretation process in Ecuador: 'fitting' global standards into local contexts *J. Rural Stud.* **71** 125–33

Kadarusman Y B and Herabadi A G 2018 Improving sustainable development within Indonesian palm oil: the importance of the reward system *Sustain. Dev.* **26** 422–34

Khatun K, Maguire-Rajpaul V A, Asante E A and McDermott C L 2020 From agroforestry to agroindustry: smallholder access to benefits from oil palm in Ghana and the implications for sustainability certification *Front. Sustain. Food Syst.* **4** 29

Krishna V V, Kubitza C, Pascual U and Qaim M 2017 Land markets, property rights, and deforestation: insights from Indonesia *World Dev.* **99** 335–49

Lee J S H, Miteva D A, Carlson K M, Heilmayr R and Saif O 2020 Does oil palm certification create trade-offs between environment and development in Indonesia? *Environ. Res. Lett.* **15** 124064

Lee J S H, Rist L, Obidzinski K, Ghazoul J and Koh L P 2011 No farmer left behind in sustainable biofuel production *Biol. Conserv.* **144** 2512–6

Levin J, Ng G, Fortes D, Garcia S, Lacey S and Grubba D 2012 Profitability and sustainability in palm oil production: analysis of incremental financial costs and benefits of RSPO compliance (WWF, CDC and FMO) (available at: www.fao.org/sustainable-food-value-chains/library/details/ru/c/246693/)

Majid N A, Ramli Z, Md Sum S and Awang A H 2021 Sustainable palm oil certification scheme frameworks and impacts: a systematic literature review *Sustainability* **13** 3263

Malini H and Aryani D 2012 Efficiency analysis of palm plantation plasma farmers certified RSPO and without RSPO on sustainable palm plantation management in Musi Banyuasin Regency South Sumatera Indonesia *IPCBEE 2012 Int. Conf. on Environment, Energy and Biotechnology IPCBEE* vol 33 (IACSIT Press) pp 194–9 (available at: www.evidensia.eco/resources/731/efficiency-analysis-of-palm-plantation-plasma-farmers-certified-rspo-and-without-rspo-on-sustainable-palm-plantation-management-in-musi-banyuasin-regency-south-sumatera-indonesia/)

Martens K, Kunz Y, Rosyani I and Faust H 2020 Environmental governance meets reality: a micro-scale perspective on sustainability certification schemes for oil palm smallholders in Jambi, Sumatra *Soc. Nat. Resour.* **33** 634–50

McCarthy J F 2012 Certifying in contested spaces: private regulation in Indonesian forestry and palm oil *Third World Q.* **33** 1871–88

Meemken E-M, Barrett C B, Michelson H C, Qaim M, Reardon T and Sellare J 2021 Sustainability standards in global agrifood supply chains *Nat. Food* **2** 758–65

Meijaard E *et al* 2020 The environmental impacts of palm oil in context *Nat. Plants* **6** 1418–26

Meijaard E, Morgans C, Msi H, Abram N and Ancrenaz M 2017 *An Impact Analysis of RSPO Certification on Borneo Forest Cover and Orangutan Populations* (Pongo Alliance)

Moher D, Liberati A, Tetzlaff J and Altman D G 2009 Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement *BMJ* **339** b2535

Morgans C L, Meijaard E, Santika T, Law E, Budiharta S, Ancrenaz M and Wilson K A 2018 Evaluating the effectiveness of palm oil certification in delivering multiple sustainability objectives *Environ. Res. Lett.* **13** 064032

Murphy S, Burch D and Clapp J 2012 *Cereal Secrets: The World's Largest Grain Traders and Global Agriculture* (OXFAM)

Napitupulu D M and Rafiq E 2019 RSPO certification impacts on oil palm smallholders' welfare in Jambi Province *Anal. Kebijak. Pertan.* **15** 127–36 (available at: http://repository.pertanian.go.id/handle/123456789/6728)

Nesadurai H E S 2013 Food security, the palm oil–land conflict nexus, and sustainability: a governance role for a private multi-stakeholder regime like the RSPO *Pac. Rev.* **26** 505–29

Noojipady P, Morton D C, Schroeder W, Carlson K M, Huang C, Gibbs H K, Burns D, Walker N F and Prince S D 2017 Managing fire risk during drought: the influence of certification and El Niño on fire-driven forest conversion for oil palm in Southeast Asia *Earth Syst. Dyn.* **8** 749–71

Nupueng S, Oosterveer P and Mol A P J 2022 Global and local sustainable certification systems: factors influencing RSPO and Thai-GAP adoption by oil palm smallholder farmers in Thailand *Environ. Dev. Sustain.* **25** 6337–62

Nursyamin Z, Yahya M S, Atikah S N, Tohiran K A, Norhisham A R, Othman N W, Lechner A M and Azhar B 2023 Identifying indicator bird species for sustainable oil palm plantation certification *J. Clean. Prod.* **415** 137852

O'Dea R E *et al* 2021 Preferred reporting items for systematic reviews and meta-analyses in ecology and evolutionary biology: a PRISMA extension *Biol. Rev. Camb. Philos. Soc.* **96** 1695–722

Ogahara Z, Jespersen K, Theilade I and Nielsen M R 2022 Review of smallholder palm oil sustainability reveals limited positive impacts and identifies key implementation and knowledge gaps *Land Use Policy* **120** 106258

Qaim M, Sibhatu K T, Siregar H and Grass I 2020 Environmental, economic, and social consequences of the oil palm boom *Annu. Rev. Resour. Econ.* **12** 321–44

Renner S, Ruml A, Lakemann T, Nuryartono N, Tjoa A, D C M and Lay J 2024 Smallholder RSPO certification, economic benefits and agrochemical use *Environ. Res. Lett.* **19** 114093

Richartz C and Abdulai A 2025 Impact of organic and RSPO certifications on smallholder palm oil farmers' welfare and the environment in Ghana *J. Clean. Prod.* **529** 146726

Rietberg P I and Slingerland M A 2016 Barriers to smallholder RSPO certification: a science-for-policy-paper for the RSPO (Wageningen University) (available at: https://scholar.google.com/scholar_lookup?title=Barriers+to+smallholder+RSPO+certification+%3A+A+science-for-policy-paper+for+the+RSPO&author=Rietberg%2C+P.I.&publication_year=2016)

Rizal A R A, Nordin S M, Hussin S H and Hussin S R 2021 Beyond rational choice theory: multifaceted determinants of participation in palm oil sustainable certification amongst smallholders in Malaysia *Front. Sustain. Food Syst.* **5** 638296

Rodthong W, Kuwornu J K M, Datta A, Anal A K and Tsusaka T W 2020 Factors influencing the intensity of adoption of the roundtable on sustainable palm oil practices by smallholder farmers in Thailand *Environ. Manage* **66** 377–94

Rosdin R, Cheah W Y and Moslim R 2023 Systematic literature review on the social and economic impacts of palm oil certification on smallholders *Malays. J. Soc. Sci. Humanit. MJSSH* **8** e002148 (available at: https://msocialsciences.com/index.php/mjssh/article/view/2148)

Roy Rosenzweig Center for History and New Media 2016 Zotero [computer software] (Zotero Forums) (available at: https://forums.zotero.org)

RSPO 2011 Round table on sustainable palm oil (RSPO)—fact sheet (available at: https://rspo.org/wp-content/uploads/RSPOFACTSHEETFINALRT91.pdf)

RSPO 2017 RSPO smallholder strategy: objectives, outputs and implement (RSPO) (available at: https://rspo.org/wp-content/uploads/rspo-smallholder-strategy-english.pdf)

RSPO 2023 Impact update 2023 (available at: https://rspo.org/resources?category=impact-reports&id=41922)

RSPO 2025a Impact update 2025 (roundtable on sustainable palm oil) (available at: https://rspo.org/resources?category=impact-reports&id=66772)

RSPO 2025b RSPO certification *(Roundtable Sustain. Palm Oil RSPO)* (available at: https://rspo.org/as-an-organisation/certification/)

Ruben R and Fort R 2012 The impact of fair trade certification for coffee farmers in Peru *World Dev.* **40** 570–82

Ruml A, Chrisendo D, Iddrisu A M, Karakara A A, Nuryartono N, Osabuohien E and Lay J 2022 Smallholders in agro-industrial production: lessons for rural development

from a comparative analysis of Ghana's and Indonesia's oil palm sectors *Land Use Policy.* **119** 106196
Ruysschaert D and Salles D 2014 Towards global voluntary standards: questioning the effectiveness in attaining conservation goals *Ecol. Econ.* **107** 438–46
Santika T, Wilson K A, Law E A, St John F A V, Carlson K M, Gibbs H, Morgans C L, Ancrenaz M, Meijaard E and Struebig M J 2021 Impact of palm oil sustainability certification on village well-being and poverty in Indonesia *Nat. Sustain.* **4** 109–19
Saswattecha K, Kroeze C, Jawjit W and Hein L 2015 Assessing the environmental impact of palm oil produced in Thailand *J. Clean. Prod.* **100** 150–69
Schmidt J and De Rosa M 2020 Certified palm oil reduces greenhouse gas emissions compared to non-certified *J. Clean. Prod.* **277** 124045
Schmidt J and Weidema I H 2026 A comparative life cycle assessment of palm oil—differentiated by RSPO certified and non-certified, regionally, temporally, and by grower type *Sustain. Prod. Consum.* **64** 124–36 (available at: https://linkinghub.elsevier.com/retrieve/pii/S2352550926000175)
Scriven S A, Carlson K M, Hodgson J A, McClean C J, Heilmayr R, Lucey J M and Hill J K 2019 Testing the benefits of conservation set-asides for improved habitat connectivity in tropical agricultural landscapes *J. Appl. Ecol.* **56** 2274–85
Sibhatu K T 2023 Oil palm boom: its socioeconomic use and abuse *Front. Sustain. Food Syst.* **7** 1083022
Sorrell S 2009 Jevons' Paradox revisited: the evidence for backfire from improved energy efficiency *Energy Policy* **37** 1456–69
Tabe-Ojong M P Jr, Alamsyah Z and Sibhatu K T 2023 Oil palm expansion, food security and diets: comparative evidence from Cameroon and Indonesia *J. Clean. Prod.* **418** 138085
Tey Y S and Brindal M 2021 Sustainability stewardship: does roundtable on sustainable palm oil certification create shareholder value? *Corp. Soc. Responsib. Environ. Manag.* **28** 786–95
Tey Y S, Brindal M, Djama M, Hadi A H I A and Darham S 2021 A review of the financial costs and benefits of the roundtable on sustainable palm oil certification: implications for future research *Sustain. Prod. Consum.* **26** 824–37 (available at: www.sciencedirect.com/science/article/pii/S2352550920314391)
Tey Y S, Brindal M, Hadi A H I A and Darham S 2022 Financial costs and benefits of the roundtable on sustainable palm oil certification among independent smallholders: a probabilistic view of the Monte Carlo approach *Sustain. Prod. Consum.* **30** 377–86 (available at: www.sciencedirect.com/science/article/pii/S2352550921003675)
Tscharntke T *et al* 2012 Landscape moderation of biodiversity patterns and processes—eight hypotheses *Biol. Rev.* **87** 661–85
van der Ven H, Rothacker C and Cashore B 2018 Do eco-labels prevent deforestation? Lessons from non-state market driven governance in the soy, palm oil, and cocoa sectors *Glob. Environ. Change* **52** 141–51
Veriasa T O, Nurrunisa M and Fadhli N 2024 Revisiting the implications of RSPO smallholder certification relative to farm productivity in Riau, Indonesia *For. Soc.* **8** 123–39 (available at: https://journal.unhas.ac.id/index.php/fs/article/view/26964)
Vijay V, Pimm S L, Jenkins C N, Smith S J and Anand M 2016 The Impacts of Oil Palm on Recent Deforestation and Biodiversity Loss *PLoS ONE* **11** e0159668
Xin Y, Sun L and Hansen M C 2022 Oil palm reconciliation in Indonesia: balancing rising demand and environmental conservation towards 2050 *J. Clean. Prod.* **380** 135087
Xu Y, Yu L, Ciais P, Li W, Santoro M, Yang H and Gong P 2022 Recent expansion of oil palm plantations into carbon-rich forests *Nat. Sustain.* **5** 574–7
Zachlod N, Hudecheck M, Sirén C and George G 2025 Sustainable palm oil certification inadvertently affects production efficiency in Malaysia *Commun. Earth Environ.* **6** 200