frontiers | Frontiers in Sustainable Food Systems

TYPE Perspective
PUBLISHED 10 June 2024
DOI 10.3389/fsufs.2024.1398877

Seeing the forest through the palms: developments in environmentally sustainable palm oil production and zero-deforestation efforts

Rosemary Ostfeld[1]* and David M. Reiner[2]

[1]Bailey College of the Environment, Wesleyan University, Middletown, CT, United States, [2]Judge Business School, University of Cambridge, Cambridge, United Kingdom

OPEN ACCESS

EDITED BY
Sui Kiat Chang,
Universiti Tunku Abdul Rahman, Malaysia

REVIEWED BY
Johar Mohamed,
Putra Malaysia University, Malaysia

*CORRESPONDENCE
Rosemary Ostfeld
✉ rosemaryostfeld@gmail.com

RECEIVED 15 March 2024
ACCEPTED 20 May 2024
PUBLISHED 10 June 2024

CITATION
Ostfeld R and Reiner DM (2024) Seeing the forest through the palms: developments in environmentally sustainable palm oil production and zero-deforestation efforts. *Front. Sustain. Food Syst.* 8:1398877. doi: 10.3389/fsufs.2024.1398877

Palm oil is produced on plantations primarily in Indonesia and Malaysia, which, historically, have been responsible for significant tropical deforestation and ecosystem loss. Driven by a shift away from hydrogenated vegetable oils and its high productivity, palm oil is now part of more than half of all packaged consumer products. Given its centrality across many supply chains, certification schemes have sought to improve environmental sustainability in the palm oil industry. Increasingly, there is an intersection between certification schemes and regulatory drivers. The recent 2023 European Union regulation on deforestation-free products has implications for palm oil and many other forest products. Environmental certification schemes, such as the one developed by the Roundtable on Sustainable Palm Oil, have the potential to play a critical role in the implementation of this recent policy for palm oil and can serve as model for many other commodities subject to the new Directive.

KEYWORDS

palm oil, sustainability, supply chains, environmental certification, sustainable agriculture, zero-deforestation, roundtable on sustainable palm oil, biodiversity

1 Introduction

Oil palm, *Elaeis guineensis*, is native to Africa but was introduced to Southeast Asia by the Dutch in 1848 on the island of Java (Hartley, 1967). Dutch colonization in Indonesia and British colonization in Malaysia contributed to the establishment of the palm oil industry. However, it would be many decades before oil palm cultivation in Southeast Asia would become a leading industry. A gradual shift in commodity focus from rubber and eventually to oil palm occurred. The introduction of new cash crops generally came with periods of increased timber production so land could be cleared for subsequent agricultural development (Jomo et al., 2004).

Indonesia and Malaysia are currently the world's two leading producers of palm oil, derived from the oil palm. Palm oil has the largest production and consumption of any vegetable oil in the world. The production of palm oil and palm kernel accounts for 39% of the world's vegetable oil production. In comparison, 28% of the vegetable oil comes from soybeans, the second most widely produced vegetable oil by volume [US Department of Agriculture (USDA), 2024a]. In the 2022 to 2023 marketing year, total global palm oil production was 77.56 mt. Indonesia produced 46.50 mt of palm oil and Malaysia produced 18.39 mt, representing 59 and 24% of the total global market, respectively. The next largest global producer was Thailand with 3.4 mt or approximately 4% of the total global market share [US Department of Agriculture (USDA), 2024b]. Meanwhile, the largest producer in North and South America is Colombia which produces approximately 1.9 mt or 2% of the global total, making it the 4th largest producer globally (US Department of Agriculture (USDA), 2024b). In Brazil, the largest production is located in Para in the Amazonian region. This state is responsible for 82% of the palm oil produced in Brazil (US Department of Agriculture (USDA), 2022). Several of the world's largest palm oil companies based on reported landbank include Sime Darby (headquartered in Malaysia), Golden Agri Resources (headquartered in Singapore), and Wilmar (headquartered in Singapore) (SPOTT, 2024).

Oil palm cultivation in Southeast Asia has colonial roots and has been largely driven by European demand, although in recent years more domestic consumption has occurred, particularly in Indonesia. From the 1960s through the early 2000s, Western Europe was the leading consumer of palm oil produced in Southeast Asia (Kipple and Ornelas, 2000) although markets are now more diverse. During the 2022 to 2023 marketing year, India was the largest importer of palm oil (10.04 mt), followed by China (6.19 mt), and the European Union (4.65 mt). Indonesia consumed approximately 19.09 mt domestically [US Department of Agriculture (USDA), 2024c].

Palm oil's high yields and versatility have led to its prevalence. Palm oil has become ubiquitous and is found in approximately 50% of household products including processed food, beverages, body products, candles, soaps, and detergents [World Wildlife Fund (WWF), 2021a]. Body products and soaps commonly contain palm oil derivatives, such as oleochemicals, which are fatty acids and fatty alcohols. Body product ingredients often derived from palm oil include, but are not limited to sodium lauryl sulfate, sodium laureth sulfoacetate, sodium laureth sulfate, glyceryl stearate, and stearic acid (Rainforest Action Network, 2011). Despite palm oil's pervasive presence in everyday products, consumer awareness of palm oil and its impact on the environment is relatively low (Ostfeld et al., 2019).

Several policies contributed to an increase in palm oil for biofuel use including the EU Renewable Energy Directive (RED) passed in 2001, and amended in 2003 and 2009, which called for 10% of transport fuels to be comprised of biofuels (European Union, 2003, 2009). Controversy regarding the EU RED and national biofuel policies arose after studies highlighted potential negative effects of biofuel production including increased food prices, and greenhouse gas (GHG) emissions caused by direct and indirect land use change. A 2008 World Bank study found that increased food prices were correlated with increased biomass cultivation for biofuels (Mitchell, 2008).

Biodiesel production from palm oil has its largest energy input in industrial phase (De Souza et al., 2010). The sensitivity analysis by De Souza et al. (2010) showed that nitrogen causes a large influence on the NER ratio and GHG and its application is significantly reduced by the use of Pueraria phaseloides. Despite manual harvesting applied in Malaysia, the diesel consumption during the transportation of bunches to the processing unit was responsible for 14% the total LCA emission (De Souza et al., 2010). The industrial phase and agricultural phase contributed with 21 and 64%, respectively of the total LCA emissions. In the industrial phase, the most significant contribution is attributed to methanol production, which is derived from fossil fuel. This input is responsible for up to 16% of the life cycle emissions of palm oil biodiesel. In the agricultural phase, the highest emission comes from nitrogen, which is responsible for 47% of the total life cycle emission. Instead, although it is possible to use both fruit's oil and kernel's oil to produce biodiesel, the biodiesel production in Brazil is based on fatty acid extracted from palm oil fruit through the refining process, adopted by the Agropalma Group in Tailandia, Para State.

Meijide et al. (2020) conducted lifecycle analyses in young and mature Indonesian oil palm plantations and found that emissions were higher in all scenarios except in second rotation-cycle plantations or on plantations established on degraded land. For example, emissions associated with palm oil could be as much as 98% higher than fossil fuel emissions. Most palm oil and other first-generation biofuels would not be in compliance with the EU RED standards.

Nonetheless, compared to other vegetable oils, oil palm has high yields per hectare (Barcelos et al., 2015). Short rotation crops may also result in higher levels of pesticide use and land degradation over time compared to oil palm. A special report produced by the IUCN (Meijaard et al., 2018) highlighted that nine times as much land may be required with other vegetable oil producing crops. Intercropping can also be completed to reduce environmental impacts of oil palm production and improve biodiversity (Namanji et al., 2021). Transitioning to other vegetable oils rather than palm oil could have unintended negative consequences. As in the industrial phase, the most significant contribution is attributed to methanol production, which is derived from fossil fuel.

In Malaysia, future expansion of the palm-oil industry is required to meet the 5% biodiesel target for transportation while preserving the supply of palm oil used as food. The main motivations for these decisions are to decrease dependence on petroleum (energy security), strengthen the price of CPO, and improve environmental performance. In 2011, Malaysia's transportation sector accounts for 41% of the country's total energy use. To encourage renewable energy development and relieve the country's emerging oil dependence, in 2006 the government mandated blending 5% palm-oil biodiesel in petroleum diesel. This can be achieved with careful expansion of the oil-palm industry using suitable land type, i.e., those with low GHG emission factors of with the potential to provide a net capture GHGs.

To this end, there are three policy issues that could aid in attaining such a goal. First, the government could mandate the requirement to reduce GHG emissions from the use of palm-biodiesel by adding a provision in the Biofuel Industry Act 2007 (Act 666) that spells out the requirement that "the life cycle GHG emissions from producing the biodiesel and displacing the petroleum diesel is less than the life cycle of GHG emissions of the petroleum diesel being displaced."

The second policy issue is to assure the mitigation impacts of oil-palm expansion. Jeswani et al. (2020) carried out a meta-analysis of past studies and found that there was wide variation across biofuels and even for a single feedstock such as palm oil (which has a global warming potential (GWP) of 10–50 without land-use change and 50–150 with land-use change). Since the reference for fossil fuels is a GWP of roughly 100 one can see that the climate impact of biofuels such as palm oil is not even necessarily an improvement on fossil fuels. The planting oil-palm trees on peat, primary, and secondary forests results in higher GHG emissions compared with diesel use. It was found that the conversion of tropical forest into palm plantation has resulted in relatively higher GHG emissions (four times higher) compared to converted land use for oil palm development.

Nonetheless, forest replacement mitigates this impact to some extent but is more applicable for secondary forests because it could result in lower GHG emissions compared with diesel fuel and thus should be encouraged. The conversion from previously rubber into oil palm plantation has increased the plantation carbon stocks by about 20%. Additionally, the N and P-related emissions were found greater for the logged-over forest compared to the converted land use. Thus, options exist for obtaining lower overall emissions, including the use of secondary forests (as well as degraded lands and shrub lands) accompanied by reforestation on alternative lands. The government should prohibit the expansion of oil palm plantations into the peat and primary forests as well as displacing other economic crops which cause market mediated indirect land-use change and severely impacts the overall GHG emissions associated with oil palm production. This strategy can be accomplished by amending the Malaysian Palm Oil Board (MPOB), a statutory body, the task to regulate the industry and by strict enforcement of Section 11 of the National Forestry Act 1984 making it mandatory for oil-palm plantation companies to replace the forest with other appropriate land. Section 11 of the Act could also be amended to include secondary forest as a type of forest that needs to be replaced by an approximately equal area of land if it is converted of other economic activities.

The third policy is reducing GHG emissions in the PME production process. Particular attention could be given to PME feedstock production where the largest emissions result from inorganic fertilizer uses and methane production from POME treatment. Regulations under MPOB Act could be modified to require oil palm plantations to increase organic fertilizer use and reduce methane emissions by requiring new and current POME-treatment facilities to use a closer digester tank. At a minimum, the capture gas should be flared but preferably be used to generate process heat or electricity (Hassan et al., 2011).

2 Environmental impact reduction and zero-deforestation efforts

Palm oil production has been associated with a myriad of environmental impacts including deforestation, habitat fragmentation, the drainage and destruction of carbon and methane-rich peatlands, biodiversity loss, soil erosion, degradation of water resources, greenhouse gas (GHG) emissions, forest fires and pollution from synthetic pesticides and fertilizers (Koh and Wilcove, 2008; Koh and Sodhi, 2010; Murdiyarso et al., 2010; Hoekstra and Mekonnen, 2012; Hansen et al., 2013; Carlson and Curran, 2014).

Of course, many of these issues are not unique to palm oil – rapid expansion of agricultural production globally is placing a strain on natural resources and critical ecosystems. Climate change is also increasing the frequency of forest fires (IPCC, 2014; Pausus and Keeley, 2021). However, beef, soy, timber, rubber, cacao, and coffee are other leading commodities responsible for vast environmental impacts. Agriculture and associated land use change contribute to approximately 31% of total greenhouse gas emissions, 78% of eutrophication globally, and 70% of global freshwater withdrawals (Poore and Nemecek, 2018; Ritchie, 2021). Along with soy, beef, and timber production, palm oil is one of the four leading drivers of these environmental issues (Kissinger and Herold, 2012; Pendrill et al., 2022).

Consider just one of these dimensions – deforestation. Several global efforts have been made to address deforestation, but little progress has been made. The New York Declaration on Forests (NYDF), a voluntary and non-binding agreement among world leaders and businesses, pledged to halve deforestation by 2020 and end it by 2030 (United Nations, 2014). Despite the NYDF, deforestation continued at a rate of approximately 10 million hectares per year from 2015 to 2020 [United Nations Food and Agriculture Organization (FAO), 2020, 2021]. In 2021 at COP26 in Glasgow, Scotland, world leaders once again pledged to end deforestation (United Nations, 2021). A recent assessment indicated that global deforestation still occurred at a rate of approximately 6.6 million hectares in 2022 (Forest Declaration Assessment, 2023).

One challenge in interpreting progress is that differences exist in the definitions of "forest" and "zero-deforestation." The World Resources Institute (WRI) highlights that there are over 600 ways "forests" are defined (Lake and Baer, 2015). The United Nations Food and Agriculture Organization (FAO), which provides one of the generally accepted definitions, defines forests as, "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*" [United Nations Food and Agriculture Organization (FAO), 2020]. However, any country can use whatever thresholds or definitions they choose. Zero deforestation can either be categorized as "zero net deforestation" or "zero gross deforestation." "Zero net deforestation" can allow deforestation to occur if new trees are planted, while "zero gross deforestation" does not allow forest to be cleared at all (Brown and Zarin, 2013). Garrett et al. (2019) also clarify that corporate zero deforestation commitments should apply their entire supply chain.

Furthermore, other strategies such as the High Conservation Value (HCV) approach involves identifying land that is deemed to have high conservation value and working with local stakeholders to conserve and monitor it whereas the High Carbon Stock Approach (HCSA) incorporates aspects of the HCV approach but also classifies land as either high carbon stock forest or degraded land that is more suitable for development (Rosoman et al., 2017; HCV Network, 2024). Scientists emphasize that zero deforestation efforts can give rise to concerns over international equity, particularly for developing countries (Lyons-White et al., 2020).

Most recently, the European Union (EU) passed a new regulation on deforestation-free products in May of 2023, also known as the EU Deforestation Regulation (EUDR). The regulation directly relates to agricultural commodities including beef, soy, timber, rubber, coffee, cocoa, and palm oil. It aims to "avoid the listed products Europeans buy," establish tools that aim to "protect and restore forests" and create "deforestation-free value chains." The EU regulation defines deforestation as "conversion of forest to agricultural use" (European Union, 2023). To be in compliance with the regulation, products cannot be derived from land deforested after December 31, 2020.

3 Environmental certification

The Roundtable on Sustainable Palm Oil (RSPO) created the first environmental certification scheme for palm oil. The RSPO is a multi-stakeholder initiative created to make sustainable palm oil the industry norm. The World Wildlife Fund (WWF), an international environmental NGO, developed the concept of the RSPO in 2001, and brought together key stakeholders in the palm oil industry, including Aarhus United UK Ltd., Unilever, Migros, and the Malaysian Palm Oil Association (MPOA) to discuss the concept in greater depth in September of 2002. These key collaborators were involved in the initial discussions surrounding formation of the RSPO. The RSPO is an example of pre-competitive collaboration, a recent trend in the business world to improve environmental sustainability (Kiron et al., 2015).

On 22 August 2003, Aarhus, Unilever, MPOA, Sainsbury's, Migros, and Golden Hope Plantations Berhad and WWF met in Kuala Lumpur to sign a statement of intent to create the RSPO (RSPO, 2003). These members all provided seed funding for the organization's initial meeting. The RSPO Principles and Criteria (P&C) for sustainable palm oil certification were subsequently developed. The first P&C were piloted in 2005, and the official P&C for all members was passed in November 2007 (RSPO, 2007). In August 2008, the RSPO developed the Supply Chain Certification Systems (SCCS), which outlined the various supply chain model options (RSPO, 2011). The P&C are updated every five years and were updated via a group consensus process among members in RSPO (2013, 2018) and there are plans to release revised P&C in 2024. The RSPO currently has over 5,000 members (RSPO, 2023a).

There are two types of RSPO certification: (1) the Principles and Criteria (P&C) by which growers are audited against, and (2) the Supply Chain Certification System (SCCS) that ensures the palm oil moving through the supply chain is indeed certified. These certifications have three integral components: an accreditation body that ensures a certification body is legitimate, a certification body that carries out the audit, and the standard that members are audited against.

Principle 7 of the RSPO – "Protect, conserve and enhance ecosystems and the environment" – pertains directly to forests and is operationalized in the P&C. The 2013 P&C states in principle 7.3 that it is required that, "New plantings since November 2005 have not replaced primary forest or any area required to maintain or enhance one or more High Conservation Values (HCVs)." In 2018, Principle 7.12 expands on this further, "Land clearing does not cause deforestation or damage any area required to protect or enhance High Conservation Values (HCVs) or High Carbon Stock (HCS) forest (Fargione et al., 2008). HCVs and HCS forests in the managed area are identified and protected or enhanced."

The many firms involved in the hundreds of palm oil supply chains need to take account of the different variants of SCCS and decide on the approach best suited to their particular situation. The four SCCS for RSPO certified palm oil include (i) identity preserved, (ii) segregated, (iii) mass balance, and (iv) book and claim. Identity preserved certified sustainable palm oil (CSPO) can be traced from the plantation it was grown on, to the mill, and finally to the product that contains physical certified sustainable palm oil. Segregated CSPO is also physically separated from non-certified palm oil, but its identity is not traced throughout the supply chain. Mass balance CSPO contains a percentage of CSPO, while the rest is non-certified. Finally, RSPO certified palm oil producers can 'book and claim', i.e., sell certificates that represent a volume of certified sustainable palm oil (RSPO, 2020).

Research has found that RSPO certified oil palm plantations have significantly lower levels of deforestation than non-certified oil palm plantations, but that the certified plantations were typically older and did not have much remaining forested area (Carlson et al., 2018). Research has also found that forest fires are significantly lower in certified oil palm plantations than non-certified oil palm plantations when the likelihood of fires is low (Cattau et al., 2016). In some cases, there were conflicting pressures, for example, Heilmayr et al. (2020) found that from 2009 to 2016, spillovers from RSPO certification reduced deforestation within Indonesia's forest estate, but increased deforestation in areas zoned for agricultural use. RSPO have also sought to tighten their P&C, for example, in 2018, the RSPO adopted new P&C which prohibited the clearing of primary forests, but allowed the clearing of secondary forests (RSPO, 2018). From 2018 to 2020, deforestation declined in both Malaysia and Indonesia (Heilmayr and Benedict, 2022; Global Forest Watch, 2024).

Despite global production of over 15.4 mt of RSPO certified sustainable palm oil, consumption was only 9.2 mt in 2022. Additionally, only 56% of processors and traders, consumer goods manufacturers, and retailers achieved their certified sustainable palm oil uptake targets that year (RSPO, 2023a). Europe is the leading consumer of certified sustainable palm oil globally, and consumed 45% of total global certified sustainable palm oil (EPOA, IDH, RSPO, 2022). There is still opportunity for European consumer goods manufacturers and retailers to increase incorporation of physical certified sustainable palm oil into products. A study exploring consumer preferences in Germany found that consumers preferred segregated certified sustainable palm oil over other certified supply chain options (Gassler and Spiller, 2018).

The current CEO of the RSPO, Joseph D'Cruz who previously worked for the UN Development Programme (UNDP), has "welcomed" the new EU regulation (Balch, 2023). In June 2023, RSPO members met to discuss the new EU regulation and "reaffirmed support of the regulation" and stated the need for increased supply chain transparency (RSPO, 2023b).

Certified palm oil plantations are in a strong position to comply with the new EU regulation and the RSPO can assist with ensuring compliance. However, an analysis completed for the RSPO showed that additional high conservation value (HCV) and high carbon stock (HCS) assessment information relevant to certified oil palm plantations may need to be collected and transferred through the supply chain (Brinkman Consultancy and Pasmans Consultancy, 2023). Identity preserved RSPO SCCS require full supply chain transparency and traceability, making compliance relatively straightforward.

Another strategy that has resulted in increased transparency and traceability within the palm oil supply chain is vertical integration. Supply chain vertical integration involves a single company controlling all aspects of the supply chain including growing, processing, and trading the palm oil. De Souza et al. (2010, 2022), Hassan et al. (2011), Kusin et al. (2017), Zamri et al. (2022), have undertaken numerous studies regarding enhancing the transparency and traceability of the palm oil supply chain, advancing bioenergy development, and strategizing for decarbonization in emerging economies. New Britain Palm Oil in Papua New Guinea is an example of a company that is vertically integrated and has a fully traceable RSPO certified supply chain (New Britain Palm Oil, 2024).

Malaysia Sustainable Palm Oil (MSPO) and Indonesia Sustainable Palm Oil (ISPO), government-run sustainable palm oil programs, were developed following the creation of the RSPO and aim to provide another certification option for growers. According to a recent gap analysis commissioned by the Malaysian Palm Oil Council (MPOC) released on May 2, 2024, the author who is also an RSPO auditor concludes that Malaysian Sustainable Palm Oil (MSPO) meets the EUDR deforestation requirements (Bois d'Enghien, 2024).

4 Supporting and sustaining smallholder growers

Concerns arise over not just environmental impacts but also the interaction between increasingly burdensome certification requirements and smaller local producers. The 2009 EU Directive only required some documentation in the form of biennial reports but later certification schemes added requirements on social measures yet these concerns over the societal implications remain. The Solidaridad Network, a non-profit founded in 1969 to "facilitate the development of socially responsible, ecologically sound and profitable supply chains" published a briefing paper highlighting some of the potential impacts the new EU regulation could have on smallholder producers responsible for 30–45% of total global palm oil production. In Malaysia, stallholders produce 27% of palm oil and in Indonesia smallholders produce 41% of palm oil and may face challenges in proving land ownership and providing geolocation (Solidaridad Network, 2023). As a result, implementation of the new EU zero-deforestation regulation should focus on working effectively with smallholder growers.

Jurisdictional RSPO certification poses a unique opportunity for regions to help more smallholders produce palm oil sustainably. In 2015, Sabah, Malaysia pledged to achieve 100% RSPO certified palm oil by 2025 and is currently piloting jurisdictional RSPO certification. Since then, it has been working to certify smallholders and help them create grower cooperatives that have the capacity to comply with any externally imposed mandates [World Wildlife Fund (WWF), 2021b].

5 Discussion

The last few decades have seen increased scrutiny of the impacts of palm oil production. Regulation such as EU's 2003 Biofuel Directive originally drove interest in palm-derived fuels but without sufficient environmental protections or attention to the impacts in the countries of origin. At the time, critics expressed concern that although nominally obligated to balance environmental, social and economic objectives, in reality, the EU often neglected the implications for developing countries (Adelle and Jordan, 2009, p. 114).

Industries play a key role in applying best management practices: for example, it is acknowledged that nature conservation areas within estates are vital for the development of a biodiverse and properly functioning oil palm landscape in oil palm plantation (Zemp et al., 2023). Therefore, in support of sustainable biofuel production from such a developing country, future development may need to incorporate the type of land use changes prior to plantation development.

Although new certification systems have been introduced, outcomes in the sector overall remain mixed. Whereas palm oil production from Malaysian Borneo has remained largely stable overall since the 1970 and 1980s, half of which was coming from shift away from intact forest, by the late 1990s and early 2000s most Malaysian production now comes from logged forest. By contrast, production from the Indonesian side of Borneo increased dramatically since 1990 from less than 500,000 hectares to over 1.5 M hectares and a significant fraction (250,000 hectares) is still derived from new intact forest (Gaveau et al., 2016). As a result, jurisdictions like the European Union, which has long taken the lead in regulating this sector have begun to adopte a more aggressive stance as seen in its recent 2023 Directive.

RSPO has developed an extensive certification system over the past decade that has been in widespread use globally and so is now well poised to contribute to the credible implementation of the 2023 EU directive. There are areas for improvement, however, so RSPO must continue to expand traceable, transparent supply chains and certified sustainable palm oil offerings that include smallholder farmers. Nevertheless, many of the strategies that RSPO has implemented for palm oil could serve as a model for other agricultural commodities as Europe aims to achieve zero-deforestation supply chains.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

RO: Writing – original draft, Writing – review & editing. DR: Writing – review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. The Bailey College of the Environment at Wesleyan University will pay the publication fees.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Adelle, C., and Jordan, A. (2009). "The European Union and the 'external' dimension of sustainable development: ambitious promises but disappointing outcomes?" in *International organizations in global environmental governance* (New York: Routledge).

Balch, O. (2023). Joseph D'Cruz: forging a more sustainable path for palm oil. Reuters, 21 August. Available at: https://www.reuters.com/sustainability/land-use-biodiversity/joseph-dcruz-forging-more-sustainable-path-palm-oil-2023-08-21/

Barcelos, E., Rios, S. A., Cunha, R. N. V., Lopes, R., Motoike, S. Y., Babiychuk, E., et al. (2015). Oil palm natural diversity and the potential for yield improvement. *Front. Plant Sci.* 6:190. doi: 10.3389/fpls.2015.00190

Bois d'Enghien, P. (2024). Assessment of MSPO certification against the requirements of the European Union deforestation regulation. Commissioned by the Malaysian Palm Oil Council.

Brinkman Consultancy and Pasmans Consultancy. (2023). *The RSPO system as a tool to help companies comply with requirements of the EU deforestation regulation*. Available at: https://rspo.org/wp-content/uploads/RSPO-Report-Gap-Analysis-EU-Deforestation-Regulation-05.04.2023-1.pdf

Brown, S., and Zarin, D. (2013). What does zero deforestation mean? *Science.* 342, 805–807. doi: 10.1126/science.1241277

Carlson, K. M., and Curran, L. M. (2014). Influence of watershed-climate interactions on stream temperature, sediment yield, and metabolism along a land use intensity gradient in Indonesian Borneo. *J. Geophys. Res. Biogeo.* 119, 1110–1128. doi: 10.1002/2013JG002516

Carlson, K. M., Heilmayr, R., Gibbs, H. K., and Kreman, C. (2018). Effect of oil palm sustainability certification on deforestation and fire in Indonesia. *Proc. Natl. Acad. Sci.* 115, 121–126. doi: 10.1073/pnas.1704728114

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. doi: 10.1088/1748-9326/11/10/105007

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. doi: 10.1016/j.jclepro.2022.132565

De Souza, S. P., Pacca, S., De Ávila, M. T., and Borges, J. L. B. (2010). Greenhouse gas emissions and energy balance of palm oil biofuel. *Renew. Energy* 35, 2552–2561. doi: 10.1016/j.renene.2010.03.028

EPOA, IDH, RSPO (2022). Sustainable Palm Oil: Europe's Business.

European Union (2003). Directive 2003/30/EC of the European Parliament and of the Council on Biofuels for Transport

European Union. (2009). Directive 2009/28/EC of the European Parliament and of the council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing directives 2001/77/EC and 2003/30/EC

European Union. (2023). Regulation (EU) 2023/1115 of the European Parliament and of the council of 31 may 2023 on the making available on the Union market and the export from the Union of certain commodities and products associated with deforestation and forest degradation and repealing regulation (EU) no 995/2010

Fargione, J., Hill, J., Tilman, D., Polasky, S., and Hawthorne, P. (2008). Land clearing and the biofuel carbon debt. *Science* 319, 1235–1238. doi: 10.1126/science.1152747

Forest Declaration Assessment. (2023). Forest declaration assessment: off track and falling behind.

Garrett, R. D., Levy, S., Carlson, K. M., Gardner, T. A., Godar, J., Clapp, J., et al. (2019). Criteria for effective zero-deforestation commitments. *Glob. Environ. Chang.* 54, 135–147. doi: 10.1016/j.gloenvcha.2018.11.003

Gassler, B., and Spiller, A. (2018). Is it all in the MIX? Consumer preferences for segregated and mass balance certified sustainable palm oil. *J. Clean. Prod.* 195, 21–31. doi: 10.1016/j.jclepro.2018.05.039

Gaveau, D. L., Sheil, D., Salim, M. A., Arjasakusuma, S., Ancrenaz, M., Pacheco, P., et al. (2016). Rapid conversions and avoided deforestation: examining four decades of industrial plantation expansion in Borneo. *Sci. Rep.* 6, 1–13. doi: 10.1038/srep32017

Global Forest Watch. (2024). Available at: https://www.globalforestwatch.org/

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., et al. (2013). High-resolution global maps of 21st-century forest cover change. *Science* 342, 850–853. doi: 10.1126/science.1244693

Hartley, C. (1967). *The oil palm*. London: Longmans, Green and Co. Ltd.

Hassan, M. N. A., Jaramillo, P., and Griffin, W. M. (2011). Life cycle GHG emissions from Malaysian oil palm bioenergy development: the impact on transportation sector's energy security. *Energy Policy* 39, 2615–2625. doi: 10.1016/j.enpol.2011.02.030

HCV Network. (2024). *Principles of the HCV approach*. Available at: https://assets-global.website-files.com/624493bb51507d22cf218d50/65e09e3ed469e8b3ae44bf51_Principles%20of%20the%20HCV%20Approach_v1.pdf

Heilmayr, R., and Benedict, J. J. (2022). Indonesia makes progress towards zero palm oil deforestation, Trase, 14 September. Available at: https://trase.earth/insights/indonesia-makes-progress-towards-zero-palm-oil-deforestation

Heilmayr, R., Carlson, K. M., and Benedict, J. J. (2020). Deforestation spillovers from oil palm sustainability certification. *Environ. Res. Lett.* 15:075002. doi: 10.1088/1748-9326/ab7f0c

Hoekstra, A. Y., and Mekonnen, M. M. (2012). The water footprint of humanity. *Proc. Natl. Acad. Sci.* 109, 3232–3237. doi: 10.1073/pnas.1109936109

IPCC (2014). "Climate Change 2014: Mitigation of Climate Change," in *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. eds. O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, et al. (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press).

Jeswani, H. K., Chilvers, A., and Azapagic, A. (2020). Environmental sustainability of biofuels: a review. *Proc. R. Soc. A* 476:20200351. doi: 10.1098/rspa.2020.0351

Jomo, K. S., Chang, Y. T., and Khoo, K. J. (2004). *Deforesting Malaysia: The political economy and social ecology of agricultural expansion and commercial logging*. London, United Kingdom: Zed Books.

Kipple, K., and Ornelas, K. (2000). *The Cambridge world history of food*. Cambridge, United Kingdom: Cambridge University Press.

Kiron, D., Kruschwitz, N., Haanaes, K., Reeves, M., Fuisz-Kehrbach, S.-K., and Kell, G. (2015). Joining forces: collaboration and leadership for sustainability. *MIT Sloan Manag. Rev.* 56, 1–32,

Kissinger, G., and Herold, M. (2012). *Drivers of deforestation and forest degradation: A synthesis report for REDD+ policymakers*. Lexeme Consulting. Available at: https://www.cifor-icraf.org/knowledge/publication/5167/

Koh, L. P., and Sodhi, N. S. (2010). Conserving Southeast Asia's imperiled biodiversity: scientific, management, and policy challenges. *Biodivers. Conserv.* 19, 913–917. doi: 10.1007/s10531-010-9818-9

Koh, L. P., and Wilcove, D. S. (2008). Is oil palm agriculture really destroying tropical biodiversity? *Conserv. Lett.* 1, 60–64. doi: 10.1111/j.1755-263X.2008.00011.x

Kusin, F. M., Akhir, N. I. M., Mohamat-Yusuff, F., and Awang, M. (2017). Greenhouse gas emissions during plantation stage of palm oil-based biofuel production addressing different land conversion scenarios in Malaysia. *Environ. Sci. Pollut. Res.* 24, 5293–5304. doi: 10.1007/s11356-016-8270-0

Lake, S., and Baer, E. (2015). What does it really mean when a company commits to "zero deforestation." World Resources Institute.

Lyons-White, J., Pollard, E. H. B., Catalano, A. S., and Knight, A. T. (2020). Rethinking zero deforestation beyond 2020 to more equitably and effectively conserve tropical forests. *One Earth* 3, 714–726. doi: 10.1016/j.oneear.2020.11.007

Meijaard, E., Garcia-Ulloa, J., Sheil, D., Wich, S. A., Carlson, K. M., Juffe-Bignoli, D., et al. (2018). *Oil palm and biodiversity. A situation analysis by the IUCN Oil Palm Task Force*. Switzerland: IUCN: IUCN Oil Palm Task Force Gland.

Meijide, A., de la Rua, C., Guillaume, T., Röll, A., Hassler, E., Stiegler, C., et al. (2020). Measured greenhouse gas budgets challenge emission savings from palm-oil biodiesel. *Nat. Commun.* 11:1089. doi: 10.1038/s41467-020-14852-6

Mitchell, D. (2008). A note on rising food prices. World Bank Policy Research Working Paper Series.

Murdiyarso, D., Donato, D., Kauffman, J. B., and Kurnianto, S. (2010). *Carbon storage in mangrove and peatland ecosystems: a preliminary account from plots in Indonesia*. Center for International Forestry Research. Available at: https://www.cifor-icraf.org/knowledge/publication/3233/

Namanji, S, Ssekyewa, C., and Slingerland, M.. (2021). Intercropping food crops into oil palm plantations – Experiences in Uganda and why it makes sense. Policy brief. Ecological Trends Alliance, Kampala, Uganda, and Tropenbos International, Ede, the Netherlands.

New Britain Palm Oil. (2024). Available at: https://www.nbpol.com.pg/

Ostfeld, R., Howarth, D., Reiner, D. M., and Krasny, P. (2019). Peeling back the label—exploring sustainable palm oil ecolabelling and consumption in the United Kingdom. *Environ. Res. Lett.* 14:014001. doi: 10.1088/1748-9326/aaf0e4

Pausus, J., and Keeley, J. (2021). Wildfires and global change. *Front. Ecol. Environ.* 19, 387–395. doi: 10.1002/fee.2359

Pendrill, F., Gardner, T. A., Meyfroidt, P., Persson, U. M., Adams, J., Azevedo, T., et al. (2022). Disentangling the numbers behind agriculture-driven tropical deforestation. *Science* 377:eabm9267. doi: 10.1126/science.abm9267

Poore, J., and Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers. *Science* 360, 987–992. doi: 10.1126/science.aaq0216

Rainforest Action Network. (2011). Palm oil's dirty secret: the many ingredient names for palm oil. Available at: https://www.ran.org/the-understory/palm_oil_s_dirty_secret_the_many_ingredient_names_for_palm_oil/

Ritchie, H (2021). Our World in Data: Palm Oil. Available at: https://ourworldindata.org/palm-oil

Rosoman, G., Sheun, S. S., Opal, C., Anderson, P., and Trapshah, R. (2017). *The HCS approach toolkit*. Singapore: HCS Approach Steering Group.

RSPO. (2003). *RSPO statement of intent*.

RSPO. (2007). *RSPO principles and criteria*. Available at: https://www.rspo.org/wp-content/uploads/e4-rspo-principles-criteria-document-english.pdf

RSPO. (2011). *RSPO supply chain certification systems*. Available at: https://rspo.org/wp-content/uploads/announce_RSPO%20Supply%20Chain%20system.pdf

RSPO. (2013). *RSPO principles and criteria*. Available at: https://png-data.sprep.org/system/files/RSPO%20P%26C%20for%20the%20Production%20of%20Sustainable%20Palm%20Oil%20%282013%29%20-%20including%20Major%20and%20Minor%20Indicators-English.pdf

RSPO. (2018). *RSPO principles and criteria*. Available at: https://rspo.org/wp-content/uploads/rspo-principles-criteria-for-production-of-sustainable-palm-oil-2018revised-01-february-2020-with-updated-supply-chain-requirements-for-mills.pdf

RSPO. (2020). *RSPO supply chain certification systems*. Available at: https://rspo.org/wp-content/uploads/RSPO-Supply-Chain-Certification-Systems-2020-English.pdf

RSPO. (2023a). *RSPO Impact Update*. Available at: https://rspo.org/wp-content/uploads/Impact-Update-2023.pdf

RSPO. (2023b). Sustainable palm oil players discuss implementation of EU deforestation regulation. Press Release. Available at: https://rspo.org/sustainable-palm-oil-players-discuss-implementation-of-eu-deforestation-regulation/

Solidaridad Network. (2023). *Briefing paper: Implications of the EU deforestation regulation (EUDR) for oil palm smallholders*. Available at: https://www.solidaridadnetwork.org/wp-content/uploads/2023/04/Briefing-paper-EUDR-and-palm-oil-smallholders.pdf

SPOTT. (2024). Available at: https://www.spott.org/

United Nations (2014). *New York Declaration on Forests*. Available at: https://unfccc.int/media/514893/new-york-declaration-on-forests_26-nov-2015.pdf

United Nations. (2021). *COP26 Glasgow leaders declaration on forests and land use*. Available at: https://webarchive.nationalarchives.gov.uk/ukgwa/20230418175226/https://ukcop26.org/glasgow-leaders-declaration-on-forests-and-land-use/

United Nations Food and Agriculture Organization (FAO) (2020). The State of the World's Forests.

United Nations Food and Agriculture Organization (FAO) (2021). Emissions due to agriculture: global, regional and country trends 2000–2018. Available at: https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1382716/

US Department of Agriculture (USDA). (2022). *Brazil Palm Oil: Potential and Pitfalls*. Available at: https://ipad.fas.usda.gov/highlights/2022/10/Brazil/index.pdf

US Department of Agriculture (USDA). (2024a). Oilseeds: world market and trade. Available at: https://apps.fas.usda.gov/psdonline/circulars/oilseeds.pdf

US Department of Agriculture (USDA). (2024b). Palm oil: production. Available at: https://fas.usda.gov/data/production/commodity/4243000

US Department of Agriculture (USDA). (2024c). Palm oil: world supply and distribution. Available at: https://apps.fas.usda.gov/psdonline/app/index.html#/app/downloads

World Wildlife Fund (WWF). (2021a). Palm Oil Scorecard.

World Wildlife Fund (WWF). (2021b). Sabah: A Global leader in sustainable palm oil. Available at: https://www.wwf.org.my/?28486/Sabah-A-Global-Leader-in-Sustainable-Palm-Oil

Zamri, M. F., Milano, J., Shamsuddin, A. H., Roslan, M. E., Salleh, S. F., Rahman, A., et al. (2022). An overview of palm oil biomass for power generation sector decarbonization in Malaysia: progress, challenges, and prospects. *Wiley Interdisc. Rev. Ener. Environ.* 11:e437. doi: 10.1002/wene.437

Zemp, D. C., Guerrero-Ramirez, N., Brambach, F., Darras, K., Grass, I., Potapov, A., et al. (2023). Tree islands enhance biodiversity and functioning in oil palm landscapes. *Nature* 618, 316–321. doi: 10.1038/s41586-023-06086-5