



Environmental and Social Impacts of Deforestation from Palm Oil Cultivation, Mining, and Logging in Indonesia (2010–2025): A Systematic Literature Review

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Abstract

Deforestation in Indonesia is a major environmental and social challenge that is rapidly increasing, driven by palm oil plantations, mining, and logging. However, the existing literature remains fragmented and focuses on single drivers or regions. There are limited systematic literature reviews that have integrated both environmental and social impacts across all three drivers for the 2010–2025 period. This study analyzes and synthesizes that literature, aligned with Indonesia's major forest governance reforms. The systematic literature review followed PRISMA 2020 guidelines. A search of the Scopus database identified 3,131 records, from which 191 studies met the eligibility and methodological quality criteria for analysis. The results indicate that Indonesia has lost an estimated 9.75 million ha of primary forest between 2010 and 2022. The other environmental impacts include carbon emissions from the forestry and agriculture sectors, which contribute about 73–75% of total national greenhouse gas emissions. Social impacts include land conflicts in nearly 20,000 villages, the displacement of up to 100,000 indigenous Papuans, and a 37–57% household income decline following land transfer. This study suggests the implementation of sustainable forest management and an inclusive decision-making process for indigenous people to address the root causes of deforestation and balance economic development and environmental conservation.

Keywords: deforestation in Indonesia, palm oil expansion, mining and logging activities, environmental and social impacts

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Introduction

Deforestation in tropical regions continues to become one of the most significant environmental challenges globally, driving biodiversity loss, ecosystem degradation, and climate change. Tropical forests are a source of major ecosystem services that are essential for both the environment and human well-being. These include timber and non-timber forest products, air quality regulation and prevention of soil erosion, hydrological regulation, climate regulation, biodiversity and habitat provision, cultural and spiritual identity for indigenous communities, and source of income. However, they remain highly vulnerable to land-use change driven by human activities such as agricultural expansion, logging, mining, and infrastructure development. Forests host a significant amount of biodiversity, including lots of endemic and threatened species (Lee et al., 2016; Elmhirst et al., 2017; Zahroh & Najicha, 2022).

Indonesia hosts the third-largest area of tropical rainforest worldwide and is one of the most biodiverse countries globally, sustaining a wide diversity of endemic flora and fauna. However, the ratio of forest destruction in Indonesia is the largest among other countries (replacing Brazil) and continues to expand at an average of 47,600 ha year⁻¹ (Arko et al., 2021). Deforestation in Indonesia is not

only an ecological crisis but also a significant social and governance challenge. In the past decade, Indonesia has lost approximately 9.75 million ha of primary forest between 2010 and 2022 (Global Forest Watch, 2023). This loss was primarily driven by land-use change caused by palm oil plantations, mining expansion, and logging activities in Sumatra, Kalimantan, and Papua (Austin et al., 2019; Gaveau et al., 2022; World Resources Institute, 2023).

Between 2010 and 2025 the deforestation in Indonesia was primarily caused by palm oil plantations, mining operations, and logging activities driven by policy frameworks, market demand, and governance gaps. This large-scale land conversion was approved through forest permit systems, including *Hak Pengusahaan Hutan* (HPH, forest concession rights), *Hutan Tanaman Industri* (HTI, industrial plantation forest), and *Hak Guna Usaha* (HGU, right to cultivate state land for agriculture, fishery, or livestock), which accelerated the transformation of primary and secondary forests into monoculture plantations, largely oil palm (Halomoan et al., 2025; Maskun et al., 2025). Palm oil cultivation rapidly expanded across Sumatra, Kalimantan, and Papua, which increased the plantation area by more than 30% between 2016 and 2020 alone (Jaya et al., 2023). In addition, mining-related deforestation, primarily

open-pit coal, gold, and nickel mining has resulted in substantial conversion of natural vegetation, especially in East Kalimantan, Bangka Belitung, and Sulawesi, where thousands of hectares of forest and secondary vegetation have been lost or degraded (Adhi et al., 2022; Winata et al., 2025).

The environmental impacts of deforestation in Indonesia are severe for biodiversity. Forest conversion to oil palm plantations and mining has caused losses in species diversity, habitat fragmentation, and the loss of endemic and threatened species. According to Arko (2021), Ramlah (2021), and Herdiansyah (2023), wildlife populations have experienced declines in bird diversity, macrofungal species biodiversity, and orangutan populations following forest conversion. Mining activities cause biodiversity loss by removing vegetation cover, increasing soil instability, and contaminating surrounding habitats with heavy metals that result in degraded ecosystems that are often unsuitable for natural restoration (Takarina et al., 2021; Adidharma et al., 2023). These impacts are collectively damaging the ecological sustainability of the forest landscapes of Indonesia. Deforestation has also significantly impacted hydrological systems and ecosystem services across Indonesia. The conversion of forests to monoculture plantations and mining sites reduced soil infiltration and increased surface runoff and flood risks, mostly in lowland and peatland ecosystems (Merten et al., 2020; Jaya et al., 2023). In peatland areas, drainage canals are constructed for oil palm cultivation to lower water tables, leading to peat oxidation, subsidence, and heightened fire risk, which in turn contributes to severe greenhouse gas emissions (Nugroho et al., 2021; Abdurrahim et al., 2025). Mining activities worsen ecosystem services by degrading water quality, increasing sedimentation, and reducing carbon sequestration capacity, while post-mining landscapes often remain ecologically degraded for longer periods (Sunarto et al., 2023; Suswati, 2023). The loss of mangrove forests due to agricultural and industrial expansion has similarly decreased coastal protection, fisheries productivity, and carbon storage, increasing socio-environmental vulnerability in coastal regions (Ilman et al., 2016; Basyuni et al., 2021). Deforestation not only causes environmental impacts but also causes significant social impacts. Land claims have resulted in nearly 25 million ha of designated state forest lands (*kawasan hutan*) being in conflict, which has affected nearly 20,000 villages across Indonesia (Fisher et al., 2017). In addition to the land conflict, industrial development in mining and agricultural plantations has caused the displacement of 60,000 to 100,000 Papuans between December 2018 and March 2022 (Saunders et al., 2024). Furthermore, some household incomes have declined 37–57% when land is transferred to plantation companies (Andrianto et al., 2019).

Several studies have explored the environmental and social impacts of deforestation in Indonesia, but their scope remains scattered and fragmented. Abood et al. (2015) assessed forest loss across four sectors between 2000 and 2010 but focused only on environmental impact without a social impact assessment. Miteva et al. (2015) assessed the environmental and socioeconomic impacts of Forest Stewardship Council (FSC) certification in Kalimantan between 2000 and 2008 but limited it both geographically to

a single driver. Werner et al. (2024) conducted an analysis of coal mining governance failures in East Kalimantan, integrating environmental and social impacts, but addressed mining only within a single province. More recently, Hamdani and Ningsih (2025) and Yi and Kunjuran (2025) conducted systematic literature reviews on the environmental impact of oil palm cultivation, including deforestation, biodiversity loss, and carbon emissions; however, both were limited to palm oil only. Collectively, these studies either focus on a single driver or a province. Therefore, there is limited existing systematic literature review that integrated both environmental and social impacts of all three drivers (palm oil, mining, and logging) in a single framework covering the 2010–2025 period. This study addresses the gap across all three drivers (palm oil cultivation, mining, and logging) for both environmental and social dimensions by providing systematic synthesis. A systematic literature review is needed because systematic literature reviews are a method of making sense of large bodies of information and a means of contributing to the answers to questions about what works and what does not. They are a method of mapping out areas of uncertainty and identifying where little or no relevant research has been done, but where new studies are needed (Petticrew & Roberts, 2006). Thereby providing a comprehensive picture for policymakers and the academic community.

The primary objective of this systematic literature review is to analyze and synthesize existing literature on the environmental and social impacts of deforestation caused by palm oil cultivation, mining, and logging activities in Indonesia between 2010–2025. This systematic literature review will inform data-driven decision-making, sustainable land-use planning, and future research directions.

Methods

Study design and objective of the study This systematic literature review used the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. This study aims to systematically analyze and synthesize existing literature on the environmental and social impacts of deforestation caused by palm oil cultivation, mining, and logging activities in Indonesia between 2010 and 2025.

Population, Intervention, Comparison, Outcome (PICO) framework Systematic literature review (SLR) was chosen as the most appropriate approach because it allows for systematic and unbiased identification, evaluation, and interpretation of all research outcomes that are relevant to the research questions. The research conceptual framework was constructed using the PICO approach adapted for the environmental research context, as presented in Table 1.

The selection of the articles followed the PICO framework. The population included communities, ecosystems, and regions affected by deforestation in Indonesia, while the intervention assessed palm oil cultivation, mining activities, and logging operations. The comparison assessed impacts across the three different industries. The outcomes analyzed environmental impacts such as biodiversity loss, greenhouse gas emissions, soil degradation, water pollution, and habitat destruction, and social impacts such as

community displacement and loss of traditional livelihoods.

Search strategy The systematic search was conducted on August 12, 2025, using the Scopus database. Scopus was selected as it indexes a higher number of journals than Web of Science (Paul & Criado, 2020). Google Scholar was excluded due to the lack of reproducible search protocols that are necessary for systematic review methodology and not having a well-defined background database, because it uses a crawl robot to search sites on the Internet (Pozsgai et al., 2021). The keyword string used for Bahasa Indonesia was Deforestasi AND Indonesia* AND ("kelapa sawit" OR pertambangan OR penebangan), and for English was (Deforestation OR "forest loss") AND Indonesia* AND ("palm oil" OR mining OR logging) AND ("environmental impact*" OR "social impact*") (Table 2). Boolean operators (AND, OR) were applied to refine the search results using the 'all fields' option to ensure comprehensive coverage and minimize the risk of excluding relevant studies that may not have used standardized terminology in titles or abstracts.

Inclusion and exclusion Table 3 below presents the inclusion and exclusion criteria for this systematic literature review. The inclusion criteria consisted of empirical research articles (quantitative, qualitative, and mixed methods) published between 2010 and 2025, written in English or Bahasa Indonesia, that focused on the environmental and social impacts of deforestation related to palm oil cultivation, mining, and logging in Indonesia. The exclusion criteria excluded review articles, editorials, opinion pieces, book chapters, and conference papers to avoid duplication of findings; studies published before 2010; articles that are written in other languages other than English and Bahasa

Indonesia; and research that is not addressing the scope of this study.

Data screening and selection The screening process was conducted using Parsifal (<https://parsif.al/>), a systematic review management platform that provides a comprehensive screening of collected metadata. The screening protocol contains three main phases (planning, conducting, and reporting). In this study, only two phases were used: the planning and conducting phases. The planning phase included objectives, the PICO framework, research questions, keywords and synonyms, search strings, sources, and selection criteria. The conducting phase included import studies and study selection. The platform provides tools that systematically remove duplicates. Titles and abstracts were assessed for relevance, and articles were classified as "Accepted," "Rejected," "Unclassified," or "Duplicated." Only the accepted peer-reviewed articles were included in this systematic literature review. The selection process adhered to PRISMA guidelines, and a flow diagram indicated the number of duplicates identified and articles accepted or rejected.

Quality assessment The quality assessment of this was conducted using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018). The MMAT is an appraisal tool that is designed for systematic reviews such as qualitative, quantitative, and mixed-methods studies. This tool allows for the appraisal of five categories of studies: qualitative research, randomized controlled trials, non-randomized studies, quantitative descriptive studies, and mixed-methods studies. Two independent reviewers conducted the quality appraisal to ensure accuracy and minimize bias in the

Table 1 PICO research framework

Component	Description
Population	Communities, ecosystems, and regions affected by deforestation in Indonesia
Intervention	Palm oil cultivation, mining activities and logging operations
Comparison	Impacts across the three different industries
Outcome	Environmental impacts: biodiversity loss, greenhouse gas emissions, soil degradation and erosion, water pollution, habitat destruction and loss of ecosystem services Social impacts: indigenous displacement, income inequality, health impacts, food insecurity and forest tenure conflicts

Table 2 Combined keywords string used in the database

Language (Scopus)	Keyword string
Bahasa Indonesia	(Deforestasi AND Indonesia* AND ("kelapa sawit" OR "pertambangan" OR "penebangan"))
English	(Deforestation OR "forest loss") AND Indonesia* AND ("palm oil" OR "mining" OR "logging") AND ("environmental impact*" OR "social impact*")

Table 3 Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Empirical research articles (quantitative, qualitative, and mixed methods)	Review articles, editorials, opinions, book chapters, and conference papers
Published in the period 2010–2025 (last 15 years)	Articles published before 2010
Written in English and Indonesian	Articles in languages other than English and Indonesian
Focus on environmental and social impacts of deforestation from palm oil cultivation, mining, and logging in Indonesia	Does not discuss environmental and social impacts of deforestation from palm oil cultivation, mining, and logging in Indonesia

assessment process. Each study was first screened using the two MMAT screening questions to confirm it was an empirical study suitable for appraisal. The accepted study category was then identified based on the research methodology used, and the five methodological quality criteria specific to that category were rated. For each criterion, reviewers assigned one of three responses: 'Yes' (criteria met), 'No' (criteria not met), or 'Can't tell' (insufficient information reported to make a judgement). This research used a 60% cutoff to differentiate between higher- and lower-quality studies; studies needed to meet at least three out of five quality criteria to be considered acceptable methodological quality for inclusion in the review. After screening against inclusion and exclusion criteria, 212 articles were assessed for methodological quality using the MMAT by applying a minimum threshold of 60% (≥ 3 of 5 criteria met) to ensure a minimum level of methodological rigor among included studies. This resulted in 191 studies for data extraction and analysis.

Data extraction This SLR included a total of 191 studies that followed the inclusion and exclusion criteria. From each article, systematic information was extracted that included the author(s), publication year, research title, study type (quantitative, qualitative, or mixed methods), language of publication, and the appropriate responses to the three guiding research questions (Q1, Q2, and Q3). 1) What is the extent and spatial pattern of forest clearance from palm oil cultivation, mining, and logging in Indonesia between 2010 and 2025?; 2) What are the environmental impacts of deforestation on biodiversity, hydrological systems, and ecosystem services in Indonesia?; and 3) What are the social impacts of deforestation on indigenous and local communities, including livelihood changes, displacement, and resource conflicts? The characteristics of the assessment

table show the methodological diversity and indicate differences in research design, data sources, analytical techniques, and sectoral focus. In terms of language distribution, the majority of studies were published in English ($n = 190$), while only one study was published in Indonesian ($n = 1$).

Timespan The study period between 2010 and 2025 was selected because it captures significant forest governance reforms in Indonesia, including the first Presidential Forest Moratorium in 2011, the adoption of the National REDD+ Strategy in 2012, the peat megafire crisis in 2015, the Paris Agreement adoption in 2016, and the Omnibus Law of 2020, which have had an impact on deforestation. This period also contains sufficient peer-reviewed literature for meaningful systematic synthesis.

Study selection The article selection process for this SLR of environmental and social impacts of deforestation from palm oil cultivation, mining, and logging in Indonesia is outlined in the PRISMA flowchart as developed by Page et al. (2021) to ensure transparent and comprehensive reporting. A total of 3,131 records were identified from the Scopus database, which was reduced to 3,053 after removing the duplicates. Following the screening, 2,873 records were excluded, leaving 270 articles. 5 articles were inaccessible, resulting in 265 eligibles articles/studies for full-text screening. After the assessment, 53 records were excluded; 21 articles out of 212 articles in the quality assessment do not meet MMAT criteria. A total of 191 articles were included for data extraction. As presented in Figure 1.

Characteristics of the included studies The 191 academic articles from 2010 to 2025 included this systematic literature review. Palm oil was the dominant driver in 128 studies (67%), followed by mining with 24 studies (12.6%), logging with 10 studies (5.2%), and the remaining 29 studies (15.2%) are mixed drivers. Geographically, 121 of the 191 (63.4%) studies were conducted on the Kalimantan, Sumatra, and Papua islands, followed by the national-level studies, which represented 44 studies (23.0%); 16 studies (8.4%) were conducted in multiple regions/islands in Indonesia, and 10 studies (5.2%) were conducted within ASEAN countries, including Indonesia with Malaysia or the Philippines. This research extends from 2010 to 2025, which includes environmental degradation, biodiversity loss, carbon emissions, and social impacts, including land conflicts, community displacement, and economic dependencies. Table 4 details the characteristics of the included studies. As most studies address specific aspects of forest clearance patterns or environmental/social impacts, only a small number comprehensively address all three research questions regarding the extent and spatial patterns of clearance, environmental consequences, and socio-economic impacts collectively.

Results

Figure 2, the Sankey diagram, shows that the flow of evidence from reported impact categories (left) through four main deforestation drivers, which are oil palm expansion ($n =$

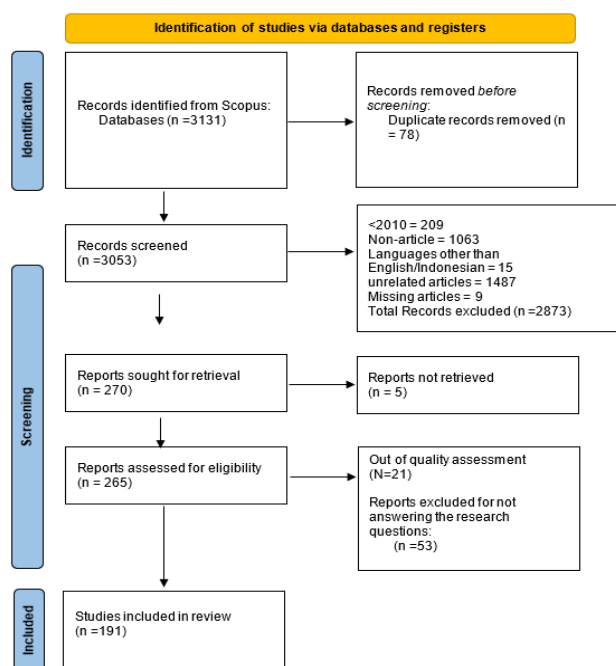


Figure 1 PRISMA flowchart.

Table 4 Forest clearance 2010–2025

Driver	Location	Scale/extent	Period	Key impact	Source
Palm oil expansion	Riau, Sumatra, Kalimantan, Papua	4.2 M ha (2000) → 14.59 M ha (2020); 30.3% increase (2016–2020)	2000–2020	Primary forest clearance; largest single driver nationally	Ramlah et al., 2021; Jaya et al., 2023
Nickel mining	Sulawesi, Maluku	Significant expansion; projected to continue to 2026	2000–2026	Forest loss driven by battery-material demand	Heijlen & Duhayon, 2024
Tin/bauxite mining	Central Bangka District, Bangka Island	+2,117.29 ha mining land (2018–2022); 45% of Bangka Island under active mining licenses	2014–2022	Secondary vegetation decline of 4,187 ha	Winata et al., 2025
Artisanal gold mining (ASGM)	Lebak, Banten	~6,445 ha	Ongoing	Diffuse but intense forest and land clearance	Takarina et al., 2021
Coal mining	National	>17 M ha concession licenses; overlapping 907,500 ha designated forest	Ongoing	Direct encroachment into protected forest zones	Muhdar et al., 2023
Logging (Legal concessions)	National	518,000 ha (2010–2017) vs. 452,000 ha (2000–2010)	2010–2017	Accelerating concession-based forest loss	Humaedi et al., 2024
Illegal logging	Papua	~478,936 ha	2006–2017	Eastward shift as western stocks depleted	Iriyono et al., 2023
Primary Forest Loss (Overall)	Sumatra, Kalimantan, Papua, Sulawesi	9.75 M ha total	2010–2022	Cumulative national primary forest loss	Global Forest Watch, 2023

34), mining expansion ($n = 19$), forest clearance ($n = 19$), and logging ($n = 4$), to affected environmental and socioeconomic systems (right), with band width proportional to the number of articles reporting each relationship; oil palm expansion was shown as the dominant driver, affecting the largest range of receptors, including wildlife habitat, soil systems, and indigenous territories, while mining expansion and forest clearance showed concentrated impacts on water systems and rural communities, respectively, and logging remained notably limited in the literature ($n = 4$), consistent with the identified research gap.

The reviewed literature's word cloud, as shown in Figure 3, strongly emphasizes deforestation in Indonesia, especially concerning palm oil expansion. Figure 4 shows the distribution of corresponding authors' countries. Indonesia and the United States contribute the highest number of publications. The figure also shows a mix of single-country publications (SCP) and multiple-country publications (MCP), indicating that these countries have both strong domestic research output and substantial international collaboration in studies related to deforestation and land-use change.

Forest clearance Indonesia lost an estimated 9.75 million ha of primary forest between 2010 and 2022, driven by palm oil expansion, mining, and logging across Sumatra, Kalimantan, Papua, and Sulawesi (Global Forest Watch, 2023). For instance, the palm oil cultivation expansion is the largest driver of forest clearance in the reviewed research. The area under cultivation grew from approximately 4.2 million ha in 2000 to 8 million ha by 2010, then accelerated to 11.2 million ha by 2016 and 14.59 million ha by 2020, which represents a 30.3% increase in the four-year period alone. Riau Province emerged as the largest production center, which contributes 19.62% of national output (Ramlah et al., 2021; Jaya et al., 2023).

Mining operations such as coal, nickel, bauxite, gold, and tin are secondary but significant drivers of deforestation. For instance, nickel mining expansion in Sulawesi and Maluku accelerated significantly between 2000 and 2020 and is

Environmental impacts collectively surpass social impacts of deforestation (2010–2025)

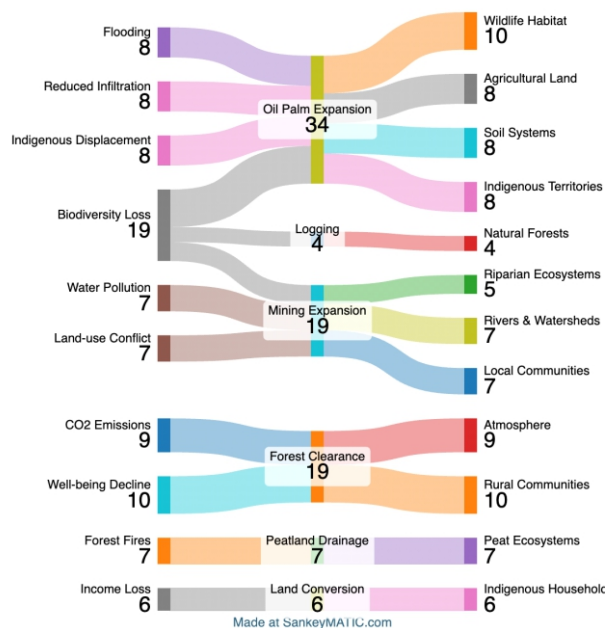


Figure2 Sankey diagram of deforestation across environmental and social impacts in Indonesia (2010–2025).



Figure 3 Word cloud.

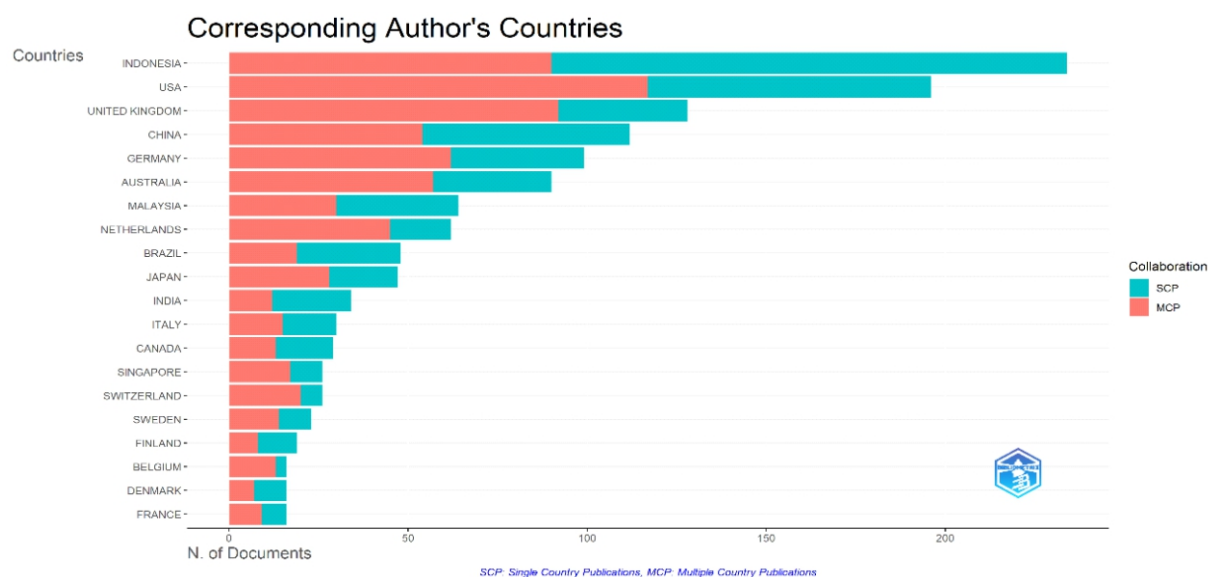


Figure 4 Corresponding authors' countries.

projected to continue until 2026 in response to global demand for battery-grade materials (Heijlen & Duhayon, 2024). In Central Bangka District, the amount of mining land increased by 2,117.29 ha between 2018 and 2022; secondary vegetation declined by 4,187 ha between 2014 and 2022; approximately 45% of the total area of Bangka Island is covered by active mining license concessions (Winata et al., 2025). Artisanal and small-scale gold mining (ASGM) in Lebak, Banten, covers approximately 6,445 ha and is a diffuse but intense pattern of forest and land clearance distinct from the large permit model typical of palm oil and coal operations (Takarina et al., 2021). Coal mining has similarly expanded through large-scale concession licenses. Coal mining licenses in Indonesia cover over 17 million ha, overlapping 907,500 ha of designated forest areas (Muhdar et al., 2023).

In addition to palm oil expansion and mining, logging represents a frequently underestimated driver of forest clearance, operating through both legal concessions and illegal logging methods. Logging activities linked to state-issued concessions between 2010 and 2017 reached 518,000 ha, exceeding the 452,000 ha recorded between 2000 and 2010 (Humaedi et al., 2024). Illegal logging has also shown a progressive shift to the east as timber stocks in Sumatra and Kalimantan declined; deforestation in Papua reached approximately 478,936 ha between 2006 and 2017 (Iriyono et al., 2023). As shown in Table 5, forest clearance in Indonesia (2010–2025) had major environmental impacts and was largely driven by palm oil expansion and mining activities.

Environmental impacts Biodiversity loss from forest clearance is deeply studied in various forms. Forests are the home of more than double the number of species compared to the monoculture plantations. As Prabowo et al. (2016) documented, there were 43–45% fewer species in plantations compared to forests). Frugivorous birds were absent from monoculture oil palm, and bird seed dispersal was severely

decreased in transformed systems. Species of conservation concern were increasingly rare across the land-use conversion gradient and mostly absent in plantations (Prabowo et al., 2016). Sumatran elephants and tigers are critically threatened due to oil palm expansion, while orangutans are facing extinction (Susanti & Maryudi, 2016). Macrofungal loss is worsening as natural forests hold 3.36–6.34 times more species than plantations (Arko et al., 2021). Mining impacts are localized but significant, with only 26.1% of total riparian plant species observed within 1 km of active artisanal mining sites, as well as increased sedimentation and habitat destabilization (Takarina et al., 2021).

The hydrological impacts of forest conversion are indicated across multiple metrics. Soil infiltration capacity has declined significantly after forest conversion to oil palm plantation, from 47 cm hr⁻¹ in forests to 3 cm hr⁻¹ after forest conversion, alongside approximately 30 cm of topsoil loss (Merten et al., 2016). Soil compaction in plantation areas is 1.3 times higher than in surrounding forests, leading to infiltration failure (Merten et al., 2020). As a result, surface runoff has increased 21%, sediment yields rose 16.9%, and water quality deteriorates significantly, with total nitrogen increasing 78% and total phosphorus 144% above baseline levels (Asmara & Randhir, 2024). Flooding frequency increased, and groundwater table fluctuations intensified in proximity to plantations (Merten et al., 2020; Purwanto et al., 2020; Rosyidy & Frimawaty, 2024), causing crop failure among neighboring agricultural smallholders due to flooding (Merten et al., 2020). Peatland drainage for oil palm cultivation also causes hydrological disruption; canalization doubled drought severity, and logging combined with plantation establishment amplified it up to 4.8 times relative to undisturbed forest (Taufik et al., 2020). This drainage has also contributed to repeated large-scale fires causing severe economic and ecological losses across seven provinces in Indonesia (Nugroho et al., 2021).

Forest conversion to industrial concessions has caused a total of 10,922–19,100 Mt of CO₂ between 2000 and 2010;

Table 5 Environmental impact

Impact category	Specific finding	Metric/Scale	Location	Period	Source
Biodiversity loss	43–45% fewer species in oil palm plantations vs. forest; frugivorous birds absent from monoculture	Species richness decline	Sumatra	2016	Prabowo et al., 2016
Biodiversity loss	Sumatran elephants, tigers critically threatened; orangutans facing extinction	Species-level threat	Sumatra	2016	Susanti & Maryudi, 2016
Biodiversity loss	Natural forests hold 3.36–6.34× more macrofungal species than plantations	Fungal diversity ratio	National	2021	Arko et al., 2021
Biodiversity loss	Only 26.1% of riparian plant species observed within 1 km of active mining sites	Species presence near mining	Lebak, Banten	2021	Takarina et al., 2021
Soil & hydrology	Soil infiltration declined from 47 cm/hr (forest) to 3 cm hr ⁻¹ (plantation); ~30 cm topsoil loss	Infiltration rate	National	2016	Merten et al., 2016
Soil & hydrology	Soil compaction 1.3× higher in plantations than forest	Compaction ratio	National	2020	Merten et al., 2020
Soil & Hydrology	Surface runoff +21%; sediment yield +16.9%; total nitrogen +78%; total phosphorus +144% above baseline	Water quality metrics	National	2024	Asmara & Randhir, 2024
Flooding & Drought	Flooding frequency increased near plantations; crop failure among neighbouring smallholders	Flood frequency	National	2020	Purwanto et al., 2020; Merten et al., 2020
Peatland & Fire	Canalization doubled drought severity; logging + plantation establishment amplified drought 4.8× vs. undisturbed forest	Drought severity multiplier	National	2020	Taufik et al., 2020
Peatland & Fire	Repeated large-scale fires across 7 provinces linked to peatland drainage	Provincial fire extent	7 Provinces	2021	Nugroho et al., 2021
CO ₂ Emissions	Forest conversion to industrial concessions released 10,922–19,100 Mt CO ₂ (2000–2010); Kalimantan: 3,045–5,824 Mt; Sumatra: 4,732–8,355 Mt	Mt CO ₂ by island	Kalimantan, Sumatra	2000–2010	Abood et al., 2014
CO ₂ Emissions	Fiber plantations: 1,636–2,963 Mt CO ₂ (35%); oil palm: 1,306–2,345 Mt CO ₂ (28%) of total concession emissions	Concession-type emissions share	National	2000–2010	Abood et al., 2014
CO ₂ Emissions	Total national deforestation released 8,589 MtCO ₂ e from 11,453 kha deforested (2000–2010)	National GHG total	National	2000–2010	Busch et al., 2015
CO ₂ Emissions	Oil palm conversion exceeds 460 Mg CO ₂ e/ha over 25-year plantation; land cover change = 73–87% of total GHG in palm biodiesel lifecycle	Lifecycle emissions per hectare	National	2014	Eddy & Gergel, 2014

Kalimantan and Sumatra contribute the largest amounts of CO₂, 3,045–5,824 Mt CO₂ and 4,732–8,355 Mt, respectively (Abood et al., 2015). Across all concession types, fiber plantations were the largest single source of emissions at 1,636–2,963 Mt of CO₂ (34–35% of total concession emissions), followed by oil palm at 1,306–2,345 Mt of CO₂ (27–28%). Logging, mixed concessions (areas of overlap between concessions), and mining contribute the rest (Abood

et al., 2015). At the national scale, total deforestation across Indonesia released 8,589 MtCO₂e over the same period, based on a deforested area of 11,453 kha between 2000 and 2010 (Busch et al., 2015). Eddy and Gergel (2015) indicated that when prior forest cover is assessed for life-cycle analyses, conversion of forest land to oil palm plantations causes total emissions exceeding 460 Mg CO₂e ha⁻¹ over a 25-year plantation period, and land cover change emissions

represented a substantial share (73–87%) of total GHG emissions during the palm oil biodiesel life cycle.

Social impacts Social conflicts were 22% more prevalent in villages that have industrial oil palm plantation development compared to those without; such conflicts were more common in Kalimantan than in Sumatra and Papua (Santika et al., 2021). Villages that relied on subsistence livelihoods before oil palm development experienced a well-being decline of 16% after 5–11 years compared with no oil palm development across all three islands. This decline was driven by declining access to electricity, sanitation, cooking energy, and secondary schooling, in addition to an increased prevalence of conflicts, low-wage agricultural labor, water pollution, and flooding (Santika et al., 2021). Where subsistence-based villages were subsequently subjected to RSPO certification, a further 11% decline in well-being was recorded relative to non-certified plantations (Santika et al., 2021). Indigenous landowners in Papua who transferred customary lands to companies experienced income losses ranging from 37 to 57% (Andrianto et al., 2019).

Indigenous communities in Indonesia experienced disruption to territorial access and cultural practices due to large-scale logging and plantation expansion. The Orang Rimba, a traditional forest-dwelling people in Jambi Province, faced cumulative development challenges, including logging, oil palm and rubber plantations, transmigration settlements, and road infrastructure expansion. These pressures eroded the viability of hunting, fishing, and gathering, compelling fundamental livelihood adaptation, despite most groups remaining in their original watershed territories (Persoon & Wardani, 2023). Similarly, the Batin Sembilan of Sumatra faced a progressive reduction in nomadic territory driven by oil palm expansion and government resettlement programs. Although they hold no formal land rights in the Harapan concession, an agreement with the project allows access to parcels of land, collection of non-timber forest products, and employment opportunities; however, disputes arising from informal customary land trade agreements have caused conflicts (Enrici & Hubacek, 2018). At the larger territorial scale, the UN Office for the High Commissioner for Human Rights estimated that between December 2018 and March 2022, some 60,000 to 100,000 Papuans had been displaced due to conflict linked to industrial development and armed resistance (Office of the High Commissioner for Human Rights, 2022, as cited in Saunders et al., 2024).

Oil palm expansion in Kalimantan has caused different livelihood and welfare outcomes depending on the baseline conditions of affected communities. As Santika et al. (2019) indicated, in villages where communities traditionally depended on market-oriented livelihoods, oil palm development contributed to improvement in physical and financial well-being; however, in remote villages where communities depended on subsistence-based livelihoods, they faced a substantial decline across all dimensions of well-being that were observed from the early stages of plantation development through 11–14 years after plantation. Regardless of baseline livelihood sector, social and environmental well-being declined faster in villages that have oil palm development than in villages without

plantation development (Santika et al., 2019).

Oil palm expansion in Indonesia has created significant job opportunities. The number of people working in the oil palm sector has reached approximately 5.5 million in 2013, while in 2012 smallholder households managed around 40% of the total oil palm plantation area in Indonesia (Susanti & Maryudi, 2016). However, these employment and smallholder participation figures were actively promoted by government actors and industry as development and poverty alleviation narratives to justify continued forest conversion into oil palm plantations, raising questions about whether the framing of oil palm as a rural development instrument accurately reflects outcomes for the most marginalized communities (Susanti & Maryudi, 2016). Economic benefits from the industry have been concentrated among those with prior capital, land, and market access, while local and indigenous communities in remote forested areas have largely been unable to capture comparable gains, which has contributed to growing socio-economic gaps between and within oil palm-producing regions (Santika et al., 2019).

Coal and nickel mining operations in Indonesia have caused social impacts on surrounding communities through land use conflicts, health risks, and well-being degradation. The coal mining licensing system in Indonesia has caused overlapping claims with other land-based activities (Muhdar et al., 2023). In 2021 alone there were 30 land-use conflicts between mining companies and other land users, which is three times higher than the previous year (Muhdar et al., 2023). In East Kalimantan, approximately 40% of the provincial land area has been allocated to coal mining (Werner et al., 2024). Since 2011, the consequence of these abandoned water-filled coal pits has caused 40 people to drown, predominantly children, while an interview with farmers indicated mining operations cut off upstream water flows and contaminated waterways that significantly reduced rice and crop yields (Werner et al., 2024). In Sulawesi, a large-scale analysis of 7,721 villages between 2011 and 2018 found that nickel mining villages experienced nearly double the rate of deforestation compared to non-mining controls (Lo et al., 2024). As shown in Table 6, oil palm and mining expansion in Indonesia have caused social impacts including land conflicts, indigenous displacement, and declining well-being.

Discussion

The reviewed literature attributed deforestation in Indonesia to three overlapping sectoral drivers that operate at different scales. Oil palm plantations are the dominant deforestation driver. The converted area is from 4.2 million to 14.9 million ha between 2000 and 2020, and it increased 30.3% between 2016 and 2020. The mining sectors (coal, nickel, bauxite, gold, and tin) are another major deforestation driver. In Central Bangka District mining land increased 2,117.29 ha between 2018 and 2022, which caused a vegetation decline of 4,187 ha. Small-scale gold mining covered 6,445 ha in Lebak alone, and coal mining licenses in Indonesia cover over 17 million ha, which overlap 907,500 ha of designated forest areas. Logging contributed through both legal and illegal concessions expanding across 518,000 ha between 2010 and 2017, and illegal extraction progressively shifted toward Papua. These patterns indicate

Table 6 Social impact

Impact category	Specific finding	Metric/Scale	Location	Period	Source
Land-use conflict	Social conflicts 22% more prevalent in oil palm villages than non-oil palm villages	Conflict prevalence rate	Kalimantan, Sumatra, Papua	2020	Santika et al., 2021
Land-use conflict	30 land-use conflicts between mining companies and other land users in 2021 alone — 3× higher than previous year	Annual conflict count	National	2021	Muhdar et al., 2023
Well-being decline	Subsistence-dependent villages experienced 16% well-being decline after 5–11 years of oil palm development	Well-being index decline	Kalimantan, Sumatra, Papua	2020	Santika et al., 2021
Well-being decline	RSPO-certified villages recorded further 11% well-being decline vs. non-certified plantations	Certification-linked decline	National	2020	Santika et al., 2021
Income loss	Indigenous landowners transferring customary lands to companies lost 37–57% of income	Income loss range	Papua	2019	Andrianto et al., 2019
Indigenous displacement	60,000–100,000 Papuans displaced due to industrial development conflict (Dec 2018–Mar 2022)	Displaced persons estimate	Papua	2018–2022	Office of the High Commissioner for Human Rights, 2022 cited in Saunders et al., 2024
Indigenous displacement	Orang Rimba lost hunting, fishing, and gathering viability due to logging, plantation, and road expansion	Livelihood erosion	Jambi, Sumatra	2023	Persoon & Wardani, 2023
Indigenous displacement	Batin Sembilan faced progressive territorial reduction; land disputes from informal customary trade agreements	Territory loss + conflict	Sumatra	2018	Enrici & Hubacek, 2018
Mining — health & safety	40 drowning deaths in abandoned coal pits since 2011, predominantly children	Fatality count	East Kalimantan	2011–2024	Werner et al., 2024
Mining — agriculture	Farmers reported mining operations cut off upstream water flows, reducing rice and crop yields	Agricultural productivity loss	East Kalimantan	2024	Werner et al., 2024
Mining — deforestation	Nickel mining villages experienced nearly double the deforestation rate vs. non-mining controls across 7,721 villages	Deforestation rate ratio	Sulawesi	2011–2018	Lo et al., 2024

that deforestation in Indonesia is not driven by a single sector but by overlapping and geographically different pressures that require driver-specific policy responses instead of unified conservation frameworks.

Deforestation across all three sectors significantly reduced biodiversity. Monoculture oil palm plantations have 43–45% fewer species than natural forests, and frugivorous birds are entirely absent, which affected bird seed dispersal and long-term regeneration. Mining activities accelerated habitat degradation; in one kilometer of active mining sites, there were only 26.1% of riparian plant species. These declines spread across Indonesia, which caused species extinction risk, including Sumatran elephants, tigers, and orangutans.

Forest conversion significantly reduced hydrological function across affected landscapes. Soil infiltration capacity has dropped from 47 cm hr⁻¹ in natural forests to 3 cm hr⁻¹ in oil palm plantations; this increased surface runoff by 21% and sediment loads by 16.9%, while nitrogen

concentrations increased 78% and phosphorus concentrations increased 144%, which negatively affected downstream water quality. Peatland canalization doubled the drought intensity, and the combination of logging and plantation conversion increased this effect 4.8 times, which caused conditions that simultaneously increased flood and drought risk.

Forest conversion across concession areas generated between 10,922 and 19,100 Mt CO₂ between 2000 and 2010. Fiber plantations are the largest single source of emissions at 1,636–2,963 Mt of CO₂ (34–35%), followed by oil palm at 1,306–2,345 Mt of CO₂ (27%–28%). Kalimantan and Sumatra contribute the largest amounts of CO₂, 3,045–5,824 Mt CO₂ and 4,732–8,355 Mt, respectively. At the plantation scale, conversion of forest land to oil palm plantations causes total emissions exceeding 460 Mg CO₂e ha⁻¹ over a 25-year plantation period, with annual net emissions from forest-to-oil-palm conversion estimated at 12.41–25.83 ton C ha⁻¹ yr⁻¹ (Guillaume et al., 2018; Rahman et al., 2018 as cited in

Rahmani et al., 2024), and land cover change emissions represented a substantial share (73–87%) of total GHG emissions during the palm oil biodiesel life cycle. These figures indicate that the carbon impact of land conversion dominates all other emission sources across the production cycle, a pattern corroborated at the provincial scale, where GHG emissions exceeded 400 Mton during the 2015 El Niño in South Sumatra (Hadiwijoyo et al., 2025).

The social impacts of deforestation in Indonesia were not uniformly shared but significantly differed in livelihood baseline, ethnicity, and sector. Social conflicts were 22% more prevalent in oil palm villages, and subsistence-based communities experienced a 16% well-being decline after 5–11 years of plantation development, driven by reduced access to electricity, sanitation, and schooling alongside increased conflict and water pollution, while market-oriented villages showed well-being improvements. RSPO certification was insufficient to protect the most vulnerable, which caused an additional 11% well-being decline in subsistence villages. Although the number of people working in the oil palm sector reached 5.5 million by 2013, with smallholders managing 40% of plantations, economic benefits remained concentrated among those with prior capital, and indigenous people lost income following land transfers. Displacement was most significant among indigenous communities; the displaced number was 60,000–100,000 Papuans between 2018 and 2022, and forest-dwelling groups, including the Orang Rimba and Batin Sembilan, lost access to nomadic territory, despite most groups remaining in their original watershed territories. Mining added to these harms through distinct methods; coal mining produced 30 land conflicts in 2021 alone, three times the previous year, with 40% of East Kalimantan allocated to coal concessions, and abandoned mining pits have caused 40 drownings since 2011, predominantly children, while nickel mining villages experienced nearly double the deforestation rate compared to non-mining areas. These findings indicate that the consequences of resource extraction are shared by the most economically and politically marginalized communities, while economic gains remain concentrated among those with prior capital and institutional access.

The primary advantage of this study is in its temporal and geographical coverage, including 191 articles from a 15-year period that allows identification of long-term trends and spatial differences. The multi-dimensional approach that includes environmental and social aspects delivers holistic literacy that is rarely found in single studies. However, there are several methodological limitations. First, the heterogeneity of definitions and methods of measuring deforestation across studies may affect data comparison. Second, publication bias, whereby studies tend to focus on areas that have significant deforestation, may lead to an overestimation of impacts at the national level. Third, the absence of longitudinal studies that track the same communities over time limits our knowledge of long-term impacts and adaptation mechanisms. Fourth, geographical coverage is different, with regions such as Sumatra and Kalimantan being highly covered while Papua remains underdocumented while experiencing accelerated deforestation. Fifth, the literature, or articles, that are published after August 12, 2025, is entirely absent from this systematic

literature review.

This study has identified a number of knowledge gaps that need further research. First, longitudinal studies are needed that track the same communities over decades to understand the trajectories of long-term socio-economic transformation and resilience capacity. Second, the heterogeneity of smallholder oil palm farmers needs to be mapped in greater detail, differentiating between in-dependent farmers, plasma farmers, and scheme farmers in order to design targeted measures. Third, the gender dimension of deforestation is still largely unexplored, even though women face the additional problem of time and loss of access to specific resources. Fourth, the long-term health impacts of mining pollution and forest fires require more rigorous epidemiological studies. Fifth, evaluating the effectiveness of policy interventions such as forest moratoriums, RSPO certification, and social forestry schemes needs a quasi-experimental approach to isolate causal effects.

The theoretical implication of this research is to expand our knowledge of the political ecology of tropical deforestation by showing that landscape transformation is not just an economic-ecological process but is deep-rooted in power relations, tenure structures, and value disputes between conservation, production, and livelihood. The findings support the land system science theory of telecoupling, in which global commodity demand (palm oil, coal) transmits pressure to local ecosystems through complex value chains. Furthermore, the Environmental Kuznets Curve (EKC) hypothesis predicts that environmental degradation will eventually decline as economies grow beyond an income threshold. It provides a theoretical starting point but is insufficient for addressing tropical deforestation factors (Dinda, 2004). This study confirms that the environmental *Kuznets curve* hypothesis does not apply to tropical deforestation because economic growth is positively correlated with forest loss, which indicates the structural trade-off between conventional development and ecological sustainability.

From a practical perspective, the findings indicate the need for a transition from a command-and-control approach to conservation towards a model that values the rights of indigenous and local communities over land and resources. Ecosystem service payment schemes need to be designed to be inclusive to make sure that smallholders and marginalized communities receive fair compensation. Sustainability certifications such as the RSPO need to be expanded to include smallholders. Peatland restoration faces structural challenges as plantations operate without full permits and require complex negotiations between legality, subsistence, and conservation.

Policy implications include the need to reform the tenure system to strengthen the acknowledgement of customary rights and customary land ownership, even though partially acknowledged under existing law. The implementation of Free Prior and Informed Consent (FPIC) needs to be strengthened from normative processes to meaningful participation check and balance mechanisms. The forest moratorium needs to be expanded to include the Papua region with stricter enforcement due to the acceleration of deforestation in this region. The decentralization of forest governance needs to be revised to prevent a race to the

bottom in which regions battle to lower environmental standards.

The contribution of this research is multi-dimensional. It contributes: 1) empirically, this study provides a comprehensive and up-to-date synthesis on deforestation in Indonesia by integrating data from nearly two decades of research; 2) methodologically, the systematic review approach with the three-dimensional assessment framework (extent-environmental-social) presents a template for similar studies in other geographical contexts; 3) theoretically, the study indicates environmental justice and the political ecology of tropical landscape transformation; and 4) practically, the findings provide an evidence base for more effective and fair policy reform and intervention.

Conclusion

This systematic literature review of 191 articles indicated that deforestation in Indonesia during 2010–2025 was driven primarily by palm oil expansion and mining, along with logging as a secondary factor. Environmental impacts include a 43–45% reduction in species diversity in oil palm monocultures; a complete absence of frugivorous birds; critical extinction risk for Sumatran elephants, tigers, and orangutans; significant hydrological degradation, including a drop in soil infiltration capacity from 47 cm hr⁻¹ in natural forests to 3 cm hr⁻¹ in plantations; and increased runoff, flood, and drought risk. Carbon emissions from forest conversion across concession areas reached between 10,922 and 19,100 Mt CO₂ between 2000 and 2010, with land cover change representing 73–87% of total life cycle emissions. Social impacts include land conflicts 22% more common in oil palm villages, the displacement of 60,000–100,000 Papuans, loss of access to traditional resources for indigenous communities, and income decline in households following land transfers. However, the palm oil industry employs 5.5 million people; the literature indicates an unequal distribution of benefits, with economic gains concentrated among elites, corporations, and the government, while local communities are left to socio-ecological impacts.

Recommendation

For future researchers, it would be better to include 1) longitudinal studies that track the long-term socio-economic transformation of affected communities, mapping the diversity of small-scale palm oil farmers, and 2) it is also necessary to have a policy reform that includes acknowledging customary rights and communal land ownership, strengthening the implementation of FPIC as meaningful participation, and extending the forest moratorium to Papua with stricter enforcement.

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