

Global Research Trends on Oil Palm Plantation and Deforestation: A Bibliometric Analysis

Edwin Mahatir Muhammad Ramadhan^{1,2*}, Suprehatin³

¹Public Administration and Policy Group, Wageningen University & Research, Wageningen, 6706KN, the Netherlands

²Coordinating Ministry for Economic Affairs, Jakarta, 10710, Indonesia

³Department of Agribusiness, IPB University, Bogor, 16680, Indonesia

ABSTRACT

Palm oil is one of the most efficient and widely consumed vegetable oils globally, but its expansion has been linked to tropical deforestation, biodiversity loss, and land use change. As global environmental concerns intensify, scholarly interest in the palm oil-deforestation nexus has grown rapidly. This study offers an updated science mapping analysis of global research on this topic until 10 July 2025. Drawing on 1,622 peer-reviewed articles retrieved from Scopus and Web of Science, we applied bibliometric analysis and science mapping to examine publication trends, thematic structures, collaboration networks, and the intellectual foundations of the field. Findings reveal a sharp increase in research output since the early 2000s, with Environmental Research Letters, Land Use Policy, and PLoS One emerging as the most relevant sources. The most prolific authors and institutions are primarily based in Europe, North America, and Southeast Asia, with the University of Göttingen and Bogor Agricultural University (IPB University) playing central roles. Indonesia now leads in single-country publications, reflecting its growing research capacity and strategic importance in the global palm oil landscape. The existing literature is predominantly framed through ecological and technical lenses, focusing on biodiversity, emissions, and sustainability certification. Keyword and co-citation analyses show emerging themes such as 'spatial analysis', 'machine learning', and expanding regional focus beyond Southeast Asia. However, critical gaps remain, particularly around social justice, land rights, and indigenous knowledge. This study highlights the need for more inclusive and interdisciplinary research approaches that foreground power dynamics, local voices, and alternative knowledge systems. Additionally, as a major producer and increasingly active research contributor, Indonesia holds strong potential to be a focus in future research agendas. The study provides a strategic foundation for researchers, funders, and policymakers engaged in sustainability and land-use governance.

Keywords: Deforestation, Indonesia, international collaboration, palm oil, scientific research

INTRODUCTION

Palm oil has emerged as one of the most contested commodities in the global sustainability landscape because palm oil is the world's most widely consumed vegetable oil (Corley 2009; Hansen *et al.*

2015). However, palm oil is also widely associated with deforestation and land use change in the tropics, particularly in Southeast Asia (Vijay *et al.* 2016; Wicke *et al.* 2011). Palm oil rapid expansion has been strongly linked to forest loss, biodiversity decline, and increased carbon emissions,

Corresponding author:
Public Administration and Policy Group,
Wageningen University & Research, the Netherlands
Email: edwin.mahatir@wur.nl

making it a center of sustainability debates and regulatory interventions (Meijaard *et al.* 2020). The environmental and social complexities of palm oil-driven deforestation have drawn increasing attention from scientists, policymakers, and civil society actors alike (Lyons-White & Knight 2018).

As environmental and governance concerns have intensified, scholarly interest in the palm oil and deforestation nexus has grown substantially (Dauvergne 1993; Teng *et al.* 2020). Over the past two decades, research on this topic has expanded across disciplines ranging from remote sensing and ecology to political science, development studies, and environmental governance (Hansen *et al.* 2015). The literature reflects technical concerns, emissions measurement, land cover mapping, and socio-political issues involving land rights, policy instruments, and corporate accountability (Berenschot *et al.* 2024; Choiruzzad *et al.* 2021; Varkkey *et al.* 2018). Despite this rapid growth, the literature remains fragmented, and there is a lack of systematic synthesis to understand its structure, key themes, and evolving patterns.

Bibliometric analysis offers a robust set of tools to address this gap, allowing for a quantitative overview of the scientific landscape, revealing publication trends, collaborative networks, and emerging research fronts that are not captured through narrative reviews (Donthu *et al.* 2021; Kumar 2025). While foundational bibliometric work has been done by Aleixandre-Benavent *et al.* (2018) on global deforestation research, this lens has not yet analyzed commodity-specific drivers, particularly on palm oil.

Few global studies have systematically mapped the structure of palm oil, but not always linked to deforestation research, using a quantitative method like bibliometric analysis (Fischer *et al.* 2020; Mba *et al.* 2015; Tucker Lima *et al.* 2017). Existing reviews are often qualitative or geographically focused, such as those emphasizing regions like Southeast Asia (Afriyanti *et al.* 2016; Cisneros *et al.* 2021; Mukherjee & Sovacool 2014) and the

Amazon (Kuss *et al.* 2015; Vijay *et al.* 2018), leaving important questions unanswered about broader collaboration patterns, thematic development, and research influence. Moreover, social, political, and economic dimensions, previously flagged as underrepresented by Aleixandre-Benavent *et al.* (2018), may be similarly neglected in the palm oil literature.

This paper aims to map and analyze the global scientific literature on palm oil and deforestation using bibliometric analysis. Specifically, it seeks to answer the following research questions (RQs); What are the key trends and thematic clusters in global research on palm oil and deforestation? How are countries and institutions collaborating in this study area, and which are most influential? What gaps, shifts, or emerging narratives can be observed in the palm oil and deforestation literature?

This paper contributes to ongoing developments in bibliometric scholarship and knowledge mapping by applying a commodity-specific lens to the deforestation research landscape. It also offers timely insights for international policy debates, such as those surrounding the EU Deforestation Regulation (EUDR), by identifying dominant narratives, key actors, and knowledge gaps. It provides a strategic foundation for researchers, funders, and policymakers seeking to engage with and shape the evolving field of palm oil and deforestation research.

MATERIALS AND METHODS

Data Collection and Methods

This paper employed a bibliometric analysis of the global research landscape on palm oil and deforestation. Bibliographic data were retrieved from two widely recognized databases, Scopus and Web of Science (WOS), which are frequently used in bibliometric studies (Berniak-Woźny & Wejsis-Golebiak 2023; Fahimnia *et al.* 2015) due to their extensive coverage of peer-reviewed scientific literature and compatibility with analytical tools. A Boolean search string was developed to identify relevant publications at the intersection of palm oil and deforestation. The search query

used was: ("palm oil" OR "oil palm" OR elais) AND (deforest* OR "forest loss" OR "land use change" OR "forest degradation" OR "forest clearing" OR "forest conversion" OR "tropical deforestation").

This query was applied to the Title, Abstract, and Keywords fields in Scopus and Topic in WOS, to ensure the relevance of retrieved articles while capturing diverse terminologies used in the literature. The search was conducted on 10 July 2025. Only peer-reviewed articles published in journals and marked as final publication stage were included to ensure quality and consistency. All selected records were written in English, with no restriction on the year of publication to allow for a comprehensive temporal analysis.

A total of 1,250 articles were retrieved from Scopus and 1,329 from WOS. 957 duplicated entries across databases were identified and removed using combinations of author, year, article title, and journal metadata, performed in both RStudio and EndNote. A set of 1,622 articles was obtained as final data for further analysis. The bibliographic data from Scopus and WOS were exported in .bib and .ris formats, combined, and processed using two key tools: First is Bibliometrix, an R-tool for comprehensive science mapping analysis (Aria & Cuccurullo 2017).

Second is VOSviewer, a software that visualizing bibliometric networks (Moral-Muñoz *et al.* 2020). A thesaurus method was applied to clean and standardize the keywords, merge synonymous terms, like palm oil and oil palm, land use change vs land-use change, and harmonize author and institutional names to ensure accuracy in collaboration and co-citation mapping.

Data Analysis

The analysis was structured to address three guiding research questions related to trends, collaboration patterns, and thematic evolution in global research on palm oil and deforestation. A combination of quantitative bibliometric analysis and science mapping methods was employed to explore the structure and development of the field. To address RQ1, we conducted a descriptive

bibliometric analysis and keyword co-occurrence analysis. Descriptive indicators included annual publication volume, most prolific journals, authors, and institutions. Keyword analysis was performed using the co-occurrence function in VOSviewer, based on author keywords and keywords plus. The resulting network maps were clustered by modularity, allowing us to identify major research themes and observe the emergence or decline of specific topics over time. Term frequency and temporal overlays were used to detect trending or emerging concepts in recent years.

To answer RQ2, we carried out co-authorship network analysis at the levels of countries, institutions, and individual authors. VOSviewer was used to visualize international collaboration patterns and assess the density and centrality of key actors. Country collaboration networks were analyzed to highlight North–South and South–South research dynamics. We also calculated citation-based indicators such as total citations and average citations per publication to assess influence. For RQ3, we triangulated insights from the keyword evolution analysis, co-citation mapping, and collaboration patterns. Co-citation analysis revealed the intellectual foundations of the field, identifying clusters of frequently co-cited references. This allowed us to assess which bodies of literature are most influential and whether certain perspectives, such as those related to justice, governance, or socio-political dynamics, are underrepresented. Temporal mapping of keywords and co-authorship trends further supported our interpretation of evolving narratives and research gaps.

Limitations

While this study offers a comprehensive bibliometric analysis of global palm oil and deforestation research, several limitations should be acknowledged. First, the analysis was limited to peer-reviewed articles indexed in Scopus and WOS. Although these databases provide broad and reputable coverage, they may exclude relevant publications from other sources such as Google Scholar, regional

databases, or non-English journals. This constraint could lead to the under-representation of Global South scholarship, particularly research published in local languages or national journals from palm oil-producing countries such as Indonesia and Malaysia.

Second, the dataset was restricted to articles published in English and excluded other forms of knowledge production, such as books, policy reports, conference proceedings, and dissertations. These types of documents often contain early-stage insights or practitioner-based knowledge that are not always captured in journal publications. As such, the analysis may lean toward academically established voices and overlook important alternative perspectives.

Third, bibliometric analysis is inherently metadata-driven, relying on titles, abstracts, keywords, and citation relationships. While powerful for identifying patterns and structures, these methods cannot fully capture the nuanced arguments, contextual meanings, or critical perspectives embedded in the full texts of the articles. Consequently, thematic clusters and keyword co-occurrence patterns should be interpreted with caution.

Fourth, using tools such as Bibliometrix and VOSviewer involves several technical constraints, particularly related to threshold settings, clustering algorithms, and the disambiguation of author names and institutional affiliations. Although the analysis used standardized bibliographic formats, combining Scopus and Web of Science datasets, which differ in content despite sharing similar file formats, can present challenges. Specifically, VOSviewer is limited in its ability to analyze merged datasets, restricting outputs to co-authorship and keyword co-occurrence networks, while co-citation analysis cannot be performed on combined data. These limitations may affect network visualizations' accuracy and resolution, especially when dealing with large, heterogeneous datasets.

Finally, citation-based indicators are subject to temporal bias. Recently published articles may not have had sufficient time to accumulate citations, potentially limiting the

visibility of emerging research areas or new contributors in the field.

RESULTS AND DISCUSSION

Trends and Thematic Clusters in Palm Oil and Deforestation Research

A total of 1,622 peer-reviewed journal articles were included in this bibliometric analysis. As shown in Figure 1, the annual number of publications has increased significantly over the past two decades, reflecting growing academic attention to the environmental and socio-political implications of palm oil-driven deforestation. The earliest article identified in the dataset was published in 1980, but publication activity remained minimal until the early 2000s. Since then, a marked acceleration has been observed, particularly after 2005, which aligns with rising global concern over tropical forest loss and the expanding footprint of oil palm plantations.

The field reached its highest output in 2019, with 162 articles published. This peak coincides with intensified policy debates, including zero-deforestation commitments and the rising influence of sustainability certification schemes such as the RSPO. While publication numbers declined slightly after 2020, the overall trend, illustrated by the polynomial trendline in Figure 1, demonstrates sustained scholarly engagement and thematic diversification.

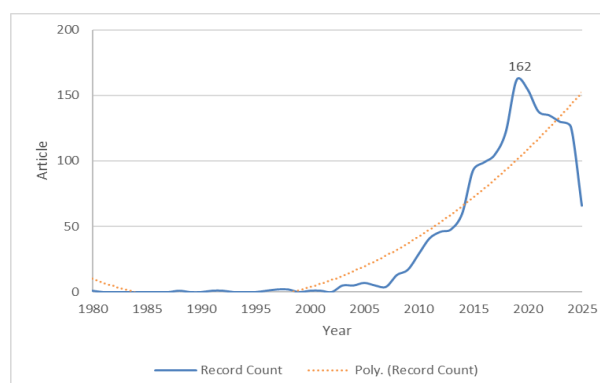


Figure 1 Annual scientific production and publication trends (1980–2025)

The publication landscape on palm oil and deforestation is concentrated in many high-impact, interdisciplinary journal, reflecting environmental, policy, and scientific complexity. The most prolific source was

Environmental Research Letters, based in the United Kingdom, which published 54 articles on this subject, followed closely by Land Use Policy with 46 articles and PLoS One with 42 articles. These journals represent platforms that attract wide-ranging contributions from environmental science, land use studies, and sustainability research.

Table 1 presents the top 10 most relevant journals regarding publication volume. Notably, journals such as Biological Conservation, Conservation Letters, and Forest Policy and Economics show strong disciplinary emphasis on biodiversity, conservation policy, and socio-environmental governance. Despite having fewer articles, some journals demonstrated high influence per publication. For example, Proceedings of the National Academy of Sciences of the United States of America (PNAS) had only 19 relevant articles but recorded a striking 4,523 total citations, resulting in an average of 238.1 citations per article. Similarly, Conservation Letters and Global Change Biology had high citations per article, indicating the enduring impact of select contributions in those journals.

These patterns suggest that while the topic is broadly distributed across environmental journals, a few key outlets serve as intellectual hubs for high-visibility and widely cited research. Open-access platforms (PLoS One) and high-impact, policy-relevant journals, like Global Environmental Change and Journal of Cleaner Production, indicate that palm oil and deforestation research spans technical science and applied policy domains.

Author-level analysis reveals a concentrated group of highly productive researchers who have shaped the development of palm oil and deforestation studies. As shown in Figure 2, the most prolific contributor is Erik Meijaard, with 34 publications, many of which are foundational to the field, particularly in the areas of biodiversity conservation, ecological impacts of oil palm expansion, and sustainable land-use strategies. His work spans empirical ecological research and applied conservation policy, often within Southeast

Asia. Following closely are David Edwards, 32 articles, and Stefan Scheu, 30 articles, which have contributed significantly to ecological studies of deforestation and habitat degradation. Other leading authors include Robert Ewers, Benoit Goossens Azhar, Alexander Knohl, and David Gaveau, whose research often combines remote sensing, land-use modeling, and conservation planning. Scholars like Lian Pin Koh and Marc Ancrenaz are also prominent for their work on sustainable palm oil certification, wildlife monitoring, and socio-ecological dynamics within palm-producing regions.

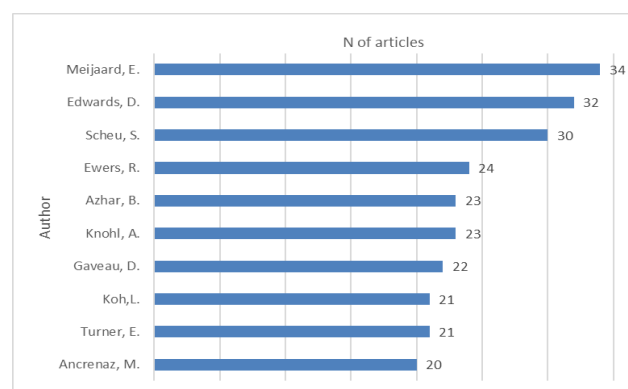


Figure 2 Top 10 most prolific authors

The dominance of these authors underscores the ecological emphasis in the literature, as most of their work is grounded in conservation biology and land system science. While highly cited and influential, this concentration may also reflect the field's reliance on particular institutions and collaborations, raising questions about epistemic diversity and the visibility of Global South researchers.

The keyword analysis offers insights into the conceptual structure and thematic orientation of the oil palm plantation and deforestation research landscape. As shown in Table 2, the most frequently used keywords across the dataset include palm oil (1,056 occurrences), land use change (706), deforestation (644), and oil palm plantation (447). These terms reflect the core environmental issues that underpin much of the literature, emphasizing the role of oil palm plantations as land-intensive agricultural systems that have expanded

rapidly across tropical regions, particularly in Southeast Asia.

The term oil palm plantation refers to the crop and its cultivation system, encompassing the spatial and ecological dimensions of large-scale monoculture that are often associated with deforestation, habitat loss, and carbon emissions. Its prominence as a keyword also signals growing scholarly interest in the land-use dynamics, sustainability challenges, and governance mechanisms linked to oil palm expansion. In contrast, palm oil refers to the processed commodity derived from the crop, representing the economic and trade dimensions of the sector and drawing attention to research on global supply chains, market access, and sustainability certification. Together, these keywords delineate the interconnected production and environmental dimensions that shape the global discourse on oil palm plantations and deforestation.

The prominence of Indonesia (383 occurrences) and Malaysia (186) among the top keywords further underscores the geographical concentration of research in Southeast Asia, where oil palm expansion has been most pronounced. Similarly, keywords such as biodiversity (313), forest (190), agriculture (182), and tropical forest

(154) indicate that the literature is heavily focused on ecological impacts, habitat change, and the spatial footprint of monoculture plantations.

Interestingly, new analytical and thematic directions have emerged in recent years, especially in 2024. Keywords such as spatial analysis and machine learning have appeared more frequently in temporal overlays, suggesting a growing integration of geospatial technologies and advanced computational methods into deforestation monitoring and prediction. The increased mention of India as a keyword also hints at a shift toward new regional case studies beyond the traditional Southeast Asian context. These findings reveal both the maturity and potential expansion of the field. Further examination of the literature's conceptual structure, a keyword co-occurrence, visualized in Figure 3, maps author keywords and Keywords Plus based on co-occurrence frequency, grouping them into thematic clusters through color-coded modularity analysis. The network reveals four dominant clusters, each representing a significant research focus. The red cluster, centrally anchored by keywords such as palm oil, deforestation, and land use change, represents the core environmental and land-use dynamics that define much of the field.

Table 1 Top 10 most relevant journals.

Source	Country	Year start	N of articles	N of citations	Citation per article	H Index 2024 (SJR)	Journal Impact Factor 2024 (Clarivate)
Environmental Research Letters	United Kingdom	2009	54	2,378	44.0	201	5.6
Land Use Policy	United Kingdom	2011	46	1,916	41.7	171	5.9
PLoS One	United States	2011	42	2,505	59.6	467	2.6
Biological Conservation	Netherlands	2008	41	1,545	37.7	244	4.4
Conservation Letters	United States	2008	18	2,024	112.4	115	5.9
Forest Policy and Economics	Netherlands	2014	28	820	29.3	92	3.8
Journal of Cleaner Production	United Kingdom	2010	27	991	36.7	354	10
Proceedings of the National Academy of Sciences of the United States of America	United States	2009	19	4,523	238.1	896	9.1
Global Environmental Change: Human and Policy Dimensions	United Kingdom	2001	20	1,179	59.0	242	9.1
Global Change Biology	United Kingdom	2012	18	1,391	77.3	332	12

Table 2 Top 10 most frequently occurring keywords.

Keyword	Occurrences	Total link strength
Palm oil	1,056	13,981
Land use change	706	10,102
Deforestation	644	7,953
Oil palm plantation	447	7,242
Indonesia	383	5,330
Biodiversity	313	4,520
Forest	190	3,052
Malaysia	186	3,052
Agriculture	182	3,132
Tropical forest	154	2,346

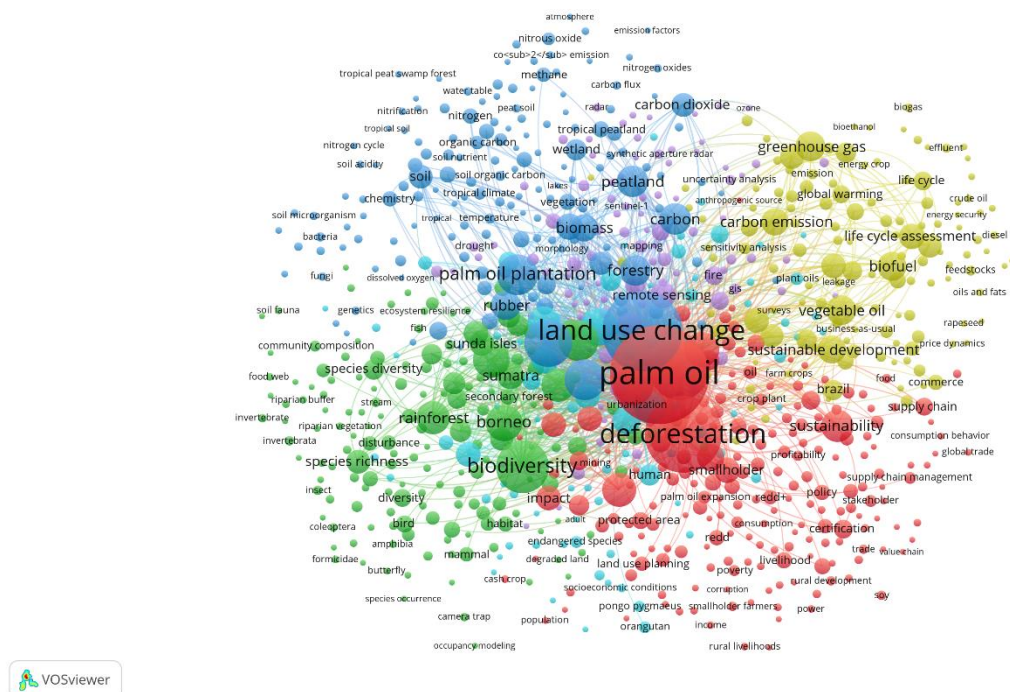


Figure 3 Keyword co-occurrence network

The green cluster focuses on biodiversity, species richness, and rainforest ecology, highlighting research on the ecological consequences of palm oil expansion. The blue cluster groups terms like peatland, carbon emissions, wetland, and biomass, corresponding to emissions accounting studies, peat degradation, and tropical carbon cycles. Meanwhile, the yellow cluster captures a more policy- and economy-oriented body of research, with keywords such as sustainability, life cycle assessment, supply chain, and biofuel, reflecting increasing attention to gover-

nance, global trade, and corporate responsibility.

The size of each node corresponds to the frequency of keyword usage, while the proximity and strength of links indicate co-occurrence intensity. As expected, palm oil, land use change, and deforestation form the densest and most central nodes, reinforcing their position as the conceptual anchors of the literature. Surrounding clusters show the thematic diversity that has developed over time, pointing to areas of convergence between ecological science, carbon accounting, and sustainability governance.

Collaboration Patterns and Influential Actors

Institutional analysis highlights the central role of a select group of universities and research organizations in shaping global research on palm oil and deforestation. As illustrated in Figure 4, the University of Göttingen in Germany is by far the most prolific institution, contributing 277 articles to the field. This reflects its sustained focus on land-use science, tropical ecology, sustainability governance, and long-standing collaborations with partners in Southeast Asia.

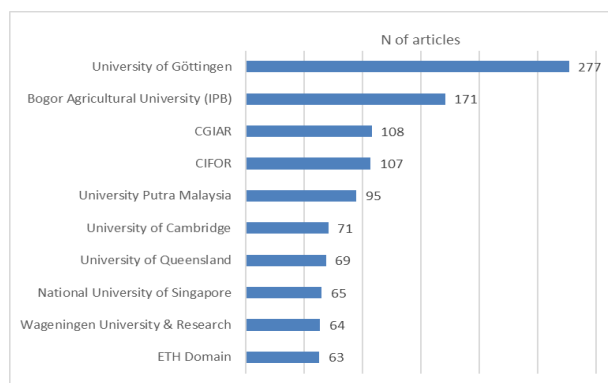


Figure 4 Top 10 most relevant affiliations, based on the number of articles.

Bogor Agricultural University (IPB University) in Indonesia follows as the second most productive affiliation, with 171 articles, underscoring Indonesia's increasing leadership in generating empirical and policy-relevant knowledge from one of the world's most affected regions. International research centers such as CGIAR (Consultative Group on International Agricultural Research) and CIFOR (Center for International Forestry Research) also rank highly, each contributing over 100 articles. These institutions are key in bridging scientific research and development practice across tropical forest landscapes.

Other notable contributors include Universiti Putra Malaysia, University of Cambridge, and University of Queensland, indicating strong engagement from producer and consumer country institutions. The presence of Wageningen University & Research, ETH Domain, and the National University of Singapore further reflects the

international and interdisciplinary nature of the field, combining expertise in agronomy, policy, remote sensing, and environmental governance. The distribution of single-country and multiple-country publications offers important insight into the geopolitical structure of collaboration in palm oil and deforestation research. As illustrated in Figure 5, the United States leads overall international engagement, with 111 multiple-country publications and 88 single-country publications, making it the top country for corresponding authorship (199 articles total). This reflects the U.S.'s broad involvement in global environmental research and its frequent collaborations with both Global North and Southeast Asian partners.

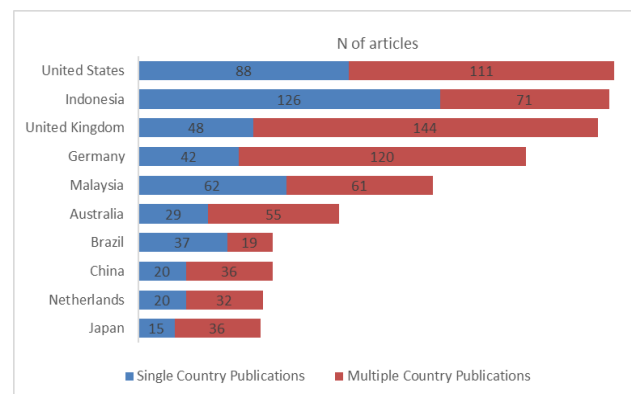


Figure 5 Distribution of single-country and multiple-country publications by author affiliation.

In contrast, Indonesia has the highest number of single-country publications (126), indicating a strong independent national research base. This is particularly notable given Indonesia's central role as the world's largest palm oil producer. The country's growing academic engagement is further underscored by its rising publication volume, which surpassed Malaysia in 2024, placing it second in overall annual output. However, Indonesia's relatively lower number of multiple-country papers (71) suggests room to expand its international collaboration footprint.

The United Kingdom dominates multiple-country publications, with 144 collaborative articles, reinforcing its status as a key node in global environmental

science networks. Germany follows closely with 120 multi-country publications, reflecting its institutional investment in tropical land-use and forest governance research. Countries such as Malaysia, Australia, and Brazil also demonstrate balanced engagement across domestic and international publications, while China, Japan, and the Netherlands are more active through cross-border collaboration than domestic-only contributions.

The global collaboration map in Figure 6 illustrates the spatial distribution and intensity of co-authorship networks in palm oil and deforestation research. The map highlights strong transnational ties between institutions located in Europe (notably the United Kingdom and Germany), North America (particularly the United States), and Southeast Asia (especially Indonesia and Malaysia). These regions form the structural backbone of global scientific cooperation in this field. European institutions emerge as major hubs, with the United Kingdom acting as a central node that connects extensively with both Global South and Global North partners. Germany, too, demonstrates broad international collaboration, especially through land-use research and sustainability governance. The United States maintains dense linkages with both Asia and Europe, reflecting its position as a key contributor to cross-regional research projects and environmental science networks. On the

producer side, Indonesia and Malaysia play vital roles within the collaboration landscape, engaging in both North–South and intra-Asian partnerships. While Indonesia leads in single-country publication volume, its collaborative reach is increasingly evident in partnerships with institutions in Europe and Australia. However, the map also reveals noticeably fewer connections among Global South countries themselves, suggesting that South–South collaboration remains under-developed.

The co-authorship network, visualized in Figure 7, provides insight into the collaborative structure of palm oil and deforestation research. Generated through VOSviewer, the map reveals several distinct author clusters, each representing closely linked research communities with frequent co-publications. At the center of the network is Erik Meijaard (purple cluster), who serves as a prominent bridge across multiple clusters, connecting authors focused on biodiversity, conservation science, and policy. His collaborations with researchers such as Ancrenaz M, Gaveau D, and Laurance W highlight a strong Southeast Asia-focused conservation community. Similarly, David Edwards and Lian Pin Koh anchor another influential group that connects tropical ecology with land use change, reflecting interdisciplinary research that links ecological modeling with remote sensing and policy applications.

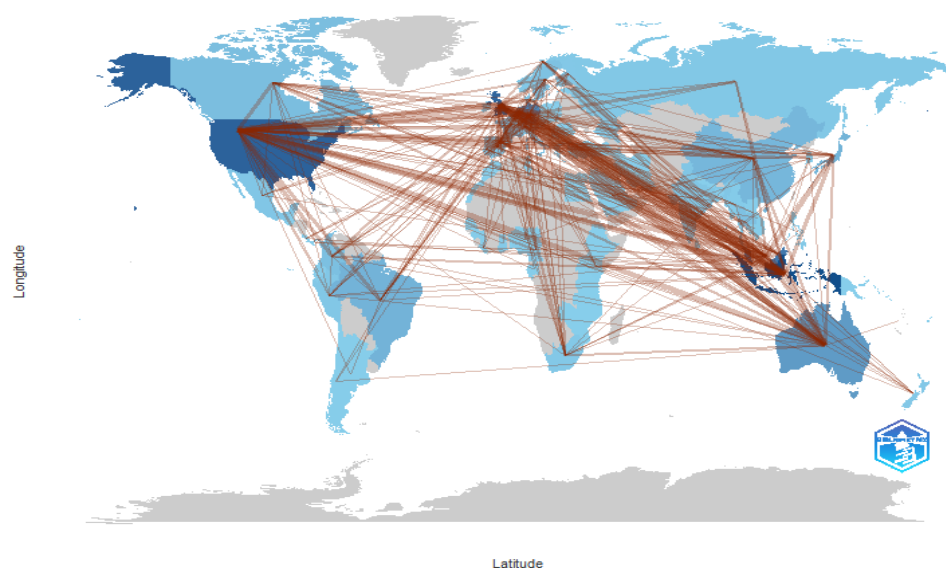


Figure 6 Collaboration world map

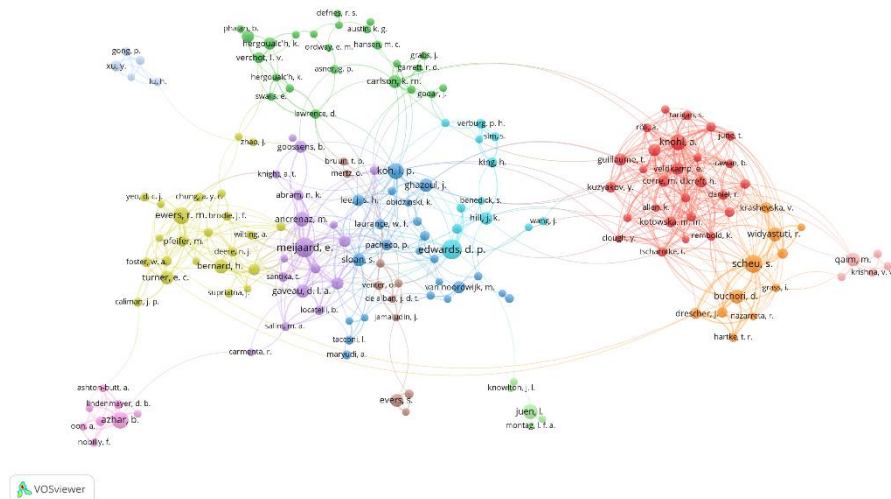


Figure 7 Co-authorship network

The red cluster, dominated by Knohl, A. and Scheu, S., represents a dense European collaboration network focused on carbon cycling, land use systems, and agroecological transitions. This group is notable for its internal connectivity and high publication volume, reflecting a cohesive research agenda rooted in landscape ecology and ecosystem processes. Another distinct cluster (purple) features Azhar, B., and collaborators, primarily focused on biodiversity outcomes in Malaysian plantation landscapes.

Several smaller but important clusters exist on the periphery, such as those involving Qaim, M., who integrates agricultural economics with deforestation and sustainability studies, and researchers like Turner, E., active in landscape ecology and species distribution modeling. The relatively limited number of South–South linkages in the network suggests that while international collaboration is robust, Global South institutions tend to collaborate more often with Global North partners than with each other.

Research Gaps, Shifts, and Emerging Narratives

The temporal distribution of keywords presented in Figure 8 provides valuable insight into the thematic evolution of palm oil and deforestation research over time. Early

work (pre-2010) focused heavily on environmental and atmospheric science, with terms such as greenhouse gas, emission control, logging, and tropical deforestation dominating the landscape. These foundational topics reflect the initial focus on carbon emissions, climate impacts, and forest degradation associated with palm oil expansion.

From 2012 to 2018, the field began diversifying, as shown by the appearance and intensification of terms such as biodiversity, land use change, Southeast Asia, and deforestation. This period marks the emergence of ecological and geographic specificity, with Malaysia, Borneo, and peatlands becoming central case studies. The frequency and prominence of sustainable palm oil, expansion, and poverty around 2018–2020 point to a growing concern with socio-economic dimensions and sustainability governance.

More recently, trend topics have shifted toward technical innovation and methodological sophistication. From 2021 onward, keywords like spatial analysis, machine learning, land cover, smallholder, and passive acoustic monitoring have become increasingly prominent. These indicate a broader integration of remote sensing, AI tools, and participatory field methods into the analysis of deforestation dynamics. The emergence of India as a

research hotspot also suggests a gradual geographical broadening of palm oil-related studies beyond traditional Southeast Asian contexts. To explore the temporal dynamics and emerging focus areas in the field, an overlay visualization of keyword co-occurrence was generated using VOSviewer. This map, shown in Figure 9, displays the average publication year of keywords, with colors ranging from dark blue (older topics) to yellow (newer topics), based on articles published between 2015 and 2020. As expected, the core thematic structure of the field continues to center around foundational keywords such as palm oil, land use change, and deforestation,

which appear in green, indicating sustained relevance across multiple years. These terms form the backbone of the literature and are tightly linked to topics like biodiversity, rainforest, and Malaysia, reflecting early and ongoing ecological concerns related to tropical forest conversion.

Surrounding these central concepts, clusters of older research (dark blue nodes) emphasize carbon dynamics, including terms such as carbon dioxide, greenhouse gas, peatland, biomass, and carbon emission. These topics were heavily studied in earlier phases of the literature, particularly in the context of emissions accounting and land-based climate mitigation.

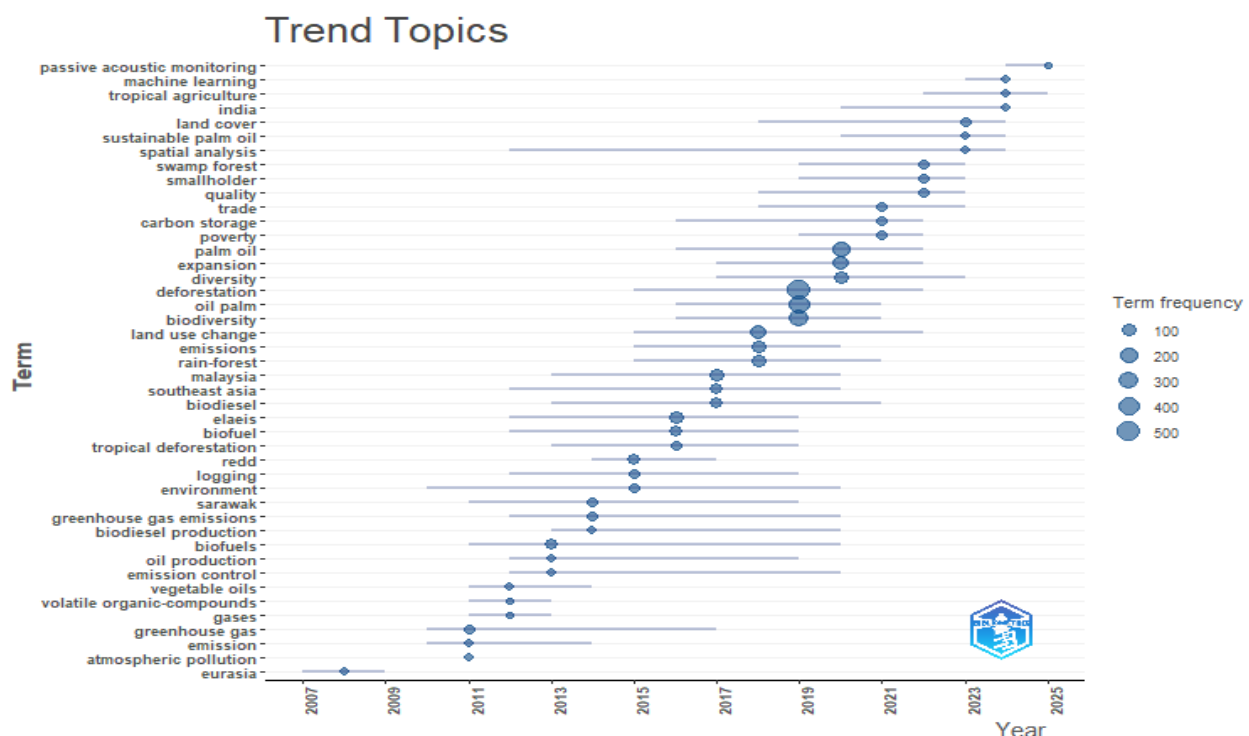


Figure 8 Overlay visualization of palm oil and deforestation research

In contrast, the yellow and light green nodes signal more recently emerging topics. These include sustainable development, life cycle assessment, certification, commerce, smallholder, and supply chain management, indicating a shift toward sustainability governance, socio-economic equity, and responsible sourcing frameworks. The growing visibility of keywords such as socio-economic conditions, human rights, and biofuel policies suggests broadening the research agenda to incorporate justice-

oriented and policy-relevant themes. This visual and temporal evolution highlights the gradual diversification of the field moving from a strong ecological and carbon centric core toward more integrated approaches that include supply chain transparency, sustainability metrics, and socio-political dimensions, also suggests that palm oil research increasingly intersects with global governance and market-based interventions to mitigate tropical deforestation.

Future Research Agenda

There are several promising directions for research on palm oil and deforestation, especially if the goal is to build a more inclusive, interdisciplinary, and grounded body of knowledge.

To begin with, it is hard to ignore how much the current literature leans toward ecological and technical framings. That's not bad, after all, biodiversity loss and land use change are at the heart of this issue, but there's still a noticeable absence of work that foregrounds justice, local experiences, or power dynamics. Terms like land rights, customary tenure, or indigenous knowledge barely appear in the keyword networks. Future studies would engage more with political ecology, critical agrarian studies, and decolonial perspectives to ask what is happening on the ground, but for whom, by whom, and with what consequences.

Another important agenda item is changing who gets to do the research or who leads it. While it is encouraging to see Indonesia's productivity rise and overtake Malaysia in 2024, most influential papers still come from institutions in Europe and North America. Strengthening South-South collaborations and supporting Southern-led initiatives is crucial, not just for equity, but for producing context-sensitive, locally-informed insights that might otherwise be missed.

On the methods side, there's a clear shift happening. Topics like spatial analysis, machine learning, and even India are emerging strongly in recent years. This approach suggests the field is branching out, technologically and geographically. Integrating remote sensing, AI, and big data can deepen our understanding of where and how forest conversion occurs, but it also raises questions about access to data, digital capacity, and interpretive authority. Pairing high-tech tools with grounded fieldwork and participatory approaches could help bridge this gap.

The global policy landscape is also shifting, with instruments like the implementation of EUDR, there's a lot to unpack: How are producing countries

responding? What does compliance look like on the ground? Are smallholders being heard, or sidelined? We need more research that not only evaluates policy effectiveness, but also looks at questions of legitimacy, ownership, and procedural fairness, especially from the perspective of those most directly affected.

And finally, there's a more philosophical, but no less urgent, question to consider: whose knowledge counts in this debate? Much of the literature still reflects a top-down, global framing of deforestation, while local voices and alternative worldviews remain under-represented. Future work should make space for different ways of knowing, whether through oral histories, community mapping, or collaborative ethnography.

In short, the next generation of palm oil and deforestation research should aim to be broader, faster, and more equitable, reflexive, and responsive to context. It requires methodological diversity, ethical awareness, and critical engagement with scientific and political dimensions of land use change.

Finally, this bibliometric analysis, while global in scope, also reinforces the strategic importance of Indonesia. As a research hub and a policy battleground, Indonesia is uniquely positioned to lead future work integrating scientific evidence, grassroots insights, and governance innovation. Supporting Indonesia's role in shaping the global research agenda will be crucial for advancing knowledge and action in the palm oil-deforestation nexus.

CONCLUSION

This study provides the first comprehensive bibliometric and science mapping analysis of global palm oil and deforestation research. Drawing from 1,622 peer-reviewed journal articles indexed in Scopus and Web of Science, and using Bibliometrix and VOSviewer for analytical tools, the study maps the structure, evolution, and collaborative patterns that define the knowledge landscapes of this increasingly critical field.

The results show a significant and sustained growth in research output over the past two decades, with a peak in 2019. Most of this literature is published in high-impact, interdisciplinary journals and led by scholars and institutions based in Europe, North America, and Southeast Asia. As a research subject and publishing actor, Indonesia has risen in visibility, recently surpassing Malaysia in annual output. However, Global North institutions continue to dominate in terms of co-authorship networks and citation impact.

Thematically, the literature has been primarily framed through ecological and technical lenses, strongly focusing on biodiversity loss, land use change, emissions, and sustainable certification. Keyword and co-citation analyses reveal a mature core around land systems and conservation, but also point to a growing body of work on machine learning, spatial analysis, and new regional contexts like India. However, justice-oriented topics, such as land rights, indigenous knowledge, and community governance, remain underrepresented, signaling a persistent gap in the field.

Looking forward, the study highlights the need for a more inclusive and reflexive research agenda that strengthens Southern-led scholarship, encourages South–South collaborations, and incorporates methodological pluralism, including qualitative and participatory approaches. As policies like the EUDR reshape governance landscapes, research must also grapple with equity, legitimacy, and local agency questions.

The study advances bibliometric scholarship by identifying the key contributors, thematic trajectories, and collaboration structures within this literature. It offers a strategic foundation for researchers, policymakers, and funders seeking to build more just and sustainable pathways in the palm oil-deforestation nexus.

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