Palm Oil and Biodiversity: Mapping the Research Landscape using Bibliometric Methods

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ABSTRACT

The rapid expansion of palm oil production has triggered widespread concerns over its impact on global biodiversity, particularly in tropical regions rich in endemic species. This study employs a bibliometric analysis using data exclusively from the Scopus database and visualization through VOSviewer to map the scientific research landscape on palm oil and biodiversity between 2004 and 2024. A total of 980 documents were analyzed to identify key publication trends, influential authors, institutions, countries, and thematic clusters. The findings reveal a significant increase in research output over the past two decades, with a peak in 2019, reflecting growing academic and policy interest in environmental sustainability. Indonesia, Malaysia, and the United Kingdom emerged as the most productive and collaborative countries, while institutions such as IPB University and Universiti Putra Malaysia were identified as central contributors. Keyword co-occurrence and overlay visualizations indicate a thematic shift from ecological impact studies—such as species richness and deforestation—to broader sustainability concerns, including climate change, land use, and conservation policy. The study also highlights research gaps in geographic representation, underexplored taxa, and socio-political dimensions. These insights offer a foundation for guiding future interdisciplinary research and promoting more effective biodiversity conservation strategies in the context of palm oil production.

Keywords: Palm Oil, Biodiversity, Bibliometric Analysis, VOSviewer, Scopus

1. INTRODUCTION

The global expansion of palm oil production has become one of the most pressing environmental concerns of the 21st century. Originating primarily in Southeast Asia, particularly Indonesia and Malaysia, palm oil plantations have proliferated due to the crop's high yield and diverse industrial applications, ranging from food products to biofuels and cosmetics [1]. While palm oil offers significant economic benefits, its rapid development has raised widespread concern regarding deforestation, habitat loss, and the decline of native biodiversity. These environmental repercussions have sparked debates among policymakers, environmentalists, and researchers about the sustainability of palm oil cultivation.

Biodiversity, the variety of life in all its forms, is considered essential for ecosystem functioning, resilience, and human well-being [2]. Tropical regions, which house the majority of palm oil plantations, are among the most biodiverse ecosystems on Earth. However, the transformation of tropical forests into monoculture palm oil plantations often results in the fragmentation or complete removal of native habitats. Numerous studies have documented the negative impacts of palm oil expansion on species richness, particularly for mammals, birds, and insects [3]. The complexity and scale of these effects have led to a growing body of interdisciplinary research attempting to quantify and mitigate biodiversity loss related to palm oil.

Over the past two decades, research on palm oil and biodiversity has evolved significantly, with scholars addressing various aspects including land-use change, conservation strategies, policy frameworks, and sustainable certification systems such as the Roundtable on Sustainable Palm Oil (RSPO) [4]. While some studies focus on direct ecological impacts, others examine governance

mechanisms and socio-economic trade-offs. This diversity of topics has resulted in a fragmented research landscape, where insights are dispersed across disciplines and geographies. Synthesizing this growing volume of literature is crucial for identifying knowledge gaps and guiding evidence-based policy and management strategies.

Bibliometric analysis offers a powerful methodological approach to map and assess scientific research trends across large volumes of academic publications. By employing quantitative tools to analyze publication metadata such as keywords, authorship, citations, and affiliations, bibliometric methods can reveal patterns in research development, thematic clustering, and influential contributors [5]. In the context of palm oil and biodiversity, bibliometric analysis can provide a comprehensive overview of how scholarly attention has shifted over time, which topics have gained prominence, and where research collaborations are taking place. This is particularly valuable in addressing interdisciplinary challenges that require coordinated global responses.

Despite the critical need for integrated understanding, few studies have applied bibliometric methods to systematically analyze the relationship between palm oil and biodiversity. Existing reviews often focus on narrow themes or specific geographies, without capturing the full breadth of the academic discourse. Given the urgency of the biodiversity crisis and the central role of palm oil in tropical land-use dynamics, a comprehensive mapping of the research landscape is both timely and necessary. This study seeks to fill that gap by employing bibliometric techniques to analyze the global research output on palm oil and biodiversity.

While the academic literature on palm oil and biodiversity has grown significantly over the past two decades, it remains scattered across various domains, with limited efforts to synthesize overarching trends, thematic developments, and knowledge gaps. This fragmentation hinders the ability of scholars, practitioners, and policymakers to derive holistic insights and coordinate effective interventions. Without a structured mapping of the research landscape, it is difficult to assess the maturity of the field, identify under-researched areas, and facilitate interdisciplinary collaboration. Thus, there is a pressing need for a systematic bibliometric analysis that can consolidate existing knowledge, highlight influential works, and provide direction for future research efforts. The objective of this study is to map the research landscape of palm oil and biodiversity using bibliometric methods.

2. LITERATURE REVIEW

2.1 Palm Oil Expansion and Land-Use Change

Palm oil, derived from the fruit of Elaeis guineensis, has become the most widely consumed vegetable oil globally due to its high yield, versatility, and relatively low production cost [6]. The rapid expansion of oil palm plantations—particularly in tropical regions like Indonesia, Malaysia, and increasingly in parts of Africa and Latin America—has had significant implications for land use. Studies have shown that the majority of new oil palm plantations have replaced tropical forests, peatlands, and other high-carbon ecosystems [7]. This conversion has led to widespread deforestation, contributing to greenhouse gas emissions, soil degradation, and disruption of water cycles [8]. Land-use change driven by palm oil development often results in habitat loss and fragmentation, which are among the leading causes of biodiversity decline. For instance, [9] found that conversion of Southeast Asian forests to oil palm plantations

has drastically reduced habitat availability for a range of endemic and endangered species, including orangutans, tigers, and various bird species. As forests are replaced by monocultures, the complexity and heterogeneity that support diverse biological communities are lost, leading to homogenization of landscapes.

2.2 *Biodiversity Impacts of Palm Oil Plantations*

A growing body of empirical research has documented the negative consequences of oil palm expansion on biodiversity. Meta-analyses, such as those by [10] and [11], confirm that oil palm plantations support significantly fewer species than natural forests. Although some adaptable species may survive in plantation landscapes, overall species richness, abundance, and ecosystem function are severely diminished. The simplification of structure in oil palm plantations—such as the lack of canopy layers, understory vegetation, and deadwood—translates into less ecological niche space and fewer resources for wildlife [12]. However, not all studies present a uniformly negative picture. Some research suggests that certain biodiversity-friendly management practices within plantations—such as maintaining riparian buffers, preserving forest fragments, and establishing wildlife corridors—can mitigate biodiversity loss to some extent [13]. Additionally, the concept of "land sparing" versus "land sharing" has been debated in the context of oil palm development, where scholars argue whether biodiversity is better protected by intensifying production on existing land or integrating conservation within plantation landscapes [14]. Nonetheless, even under best-case scenarios, plantations rarely match the conservation value of intact forests.

2.3 *Governance, Certification, and Sustainable Practices*

The environmental and social impacts of palm oil production have spurred the development of sustainability standards and certification schemes. The most prominent among these is the Roundtable on Sustainable Palm Oil (RSPO), established in 2004 to promote environmentally and socially responsible palm oil production. The RSPO sets criteria related to forest protection, labor rights, community engagement, and transparency. While certification has gained traction, its effectiveness remains contested. Some studies find that RSPO-certified plantations have reduced deforestation rates and better management practices [15], whereas others criticize the scheme for weak enforcement and greenwashing [16]. Beyond RSPO, national and regional efforts such as Indonesia's ISPO (Indonesian Sustainable Palm Oil) and Malaysia's MSPO (Malaysian Sustainable Palm Oil) aim to align production with sustainability goals. Nevertheless, enforcement gaps, land tenure conflicts, and political interests continue to pose significant challenges. In addition, the global demand for palm oil remains strong, driven by consumer markets in Asia, Europe, and North America. Therefore, scholars argue for stronger supply chain transparency, consumer awareness, and integrated policy frameworks that balance economic, ecological, and social considerations [17].

3. METHODS

This study utilized a bibliometric approach to analyze the scientific literature on palm oil and biodiversity by extracting data exclusively from the Scopus database, due to its comprehensive

indexing of peer-reviewed journals across multiple disciplines. A structured search was conducted using the keywords "palm oil" AND "biodiversity" within article titles, abstracts, and keywords, focusing on publications from the year 2004 to 2024 to capture recent scholarly developments. The search was limited to English-language journal articles, reviews, and conference papers to maintain quality and relevance. After refining the results, the metadata were exported in RIS format and imported into VOSviewer software for analysis. VOSviewer was employed to perform co-authorship analysis, citation analysis, and keyword co-occurrence mapping, enabling the identification of influential authors, leading journals, and major thematic trends in the research field.

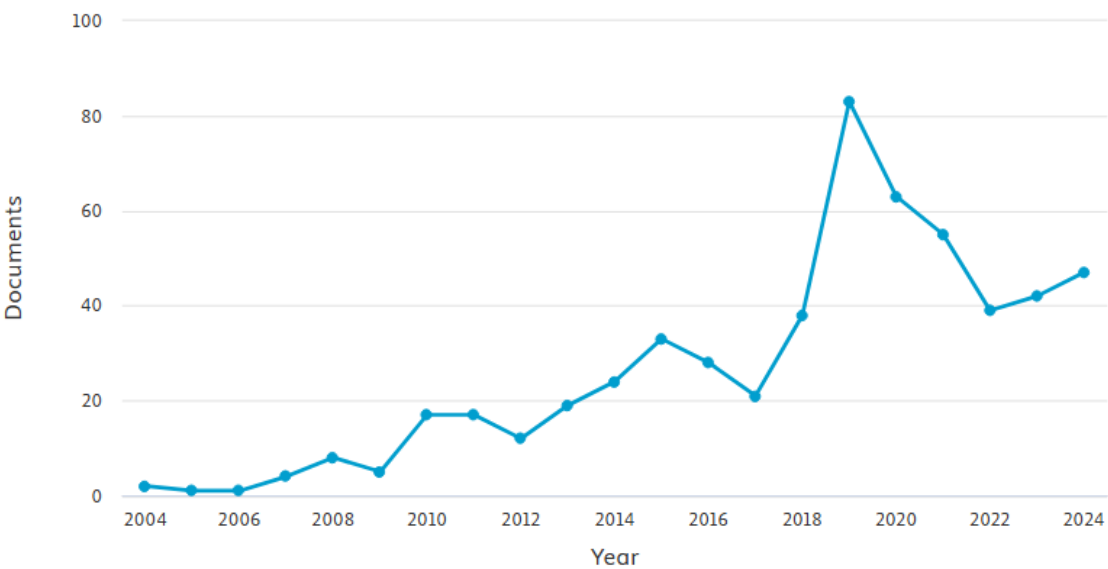## 4. RESULTS AND DISCUSSION

4.1 Yearly Publication

Figure 1. Documents by Year
Source: Scopus Database, 2025

The chart illustrates the annual publication trend of documents related to palm oil and biodiversity from 2004 to 2024. The data show a gradual increase in scholarly attention over time, beginning with minimal publications between 2004 and 2008. A notable rise begins in 2010, with steady growth through the mid-2010s. The most significant spike occurs in 2019, where the number of publications sharply peaks at over 80 documents, indicating heightened academic interest, possibly driven by global environmental policy debates and intensified public concern over deforestation and biodiversity loss. After 2019, a decline is observed, with publication numbers dropping each year until 2022. However, from 2023 to 2024, the trend begins to rise again, suggesting a potential resurgence in research activity in this field.
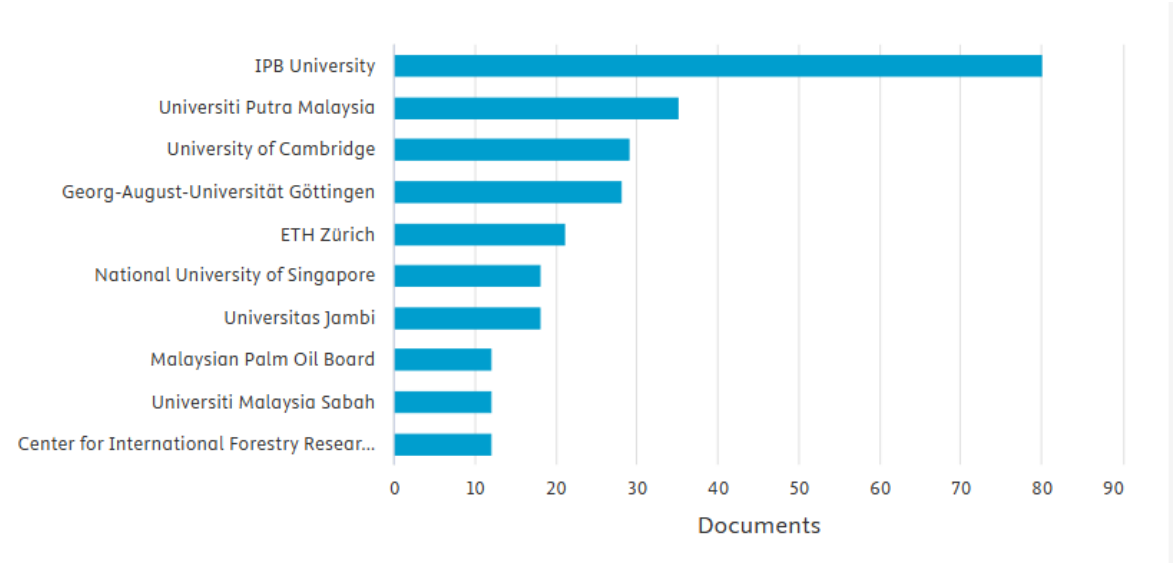
4.2 Documents by Affiliations

Figure 2. Documents by Affiliation
Source: Scopus Database, 2025

The bar presents the top contributing institutions in the field of palm oil and biodiversity research based on the number of documents published. IPB University (Bogor Agricultural University) leads significantly with nearly 85 documents, indicating its dominant role and research focus in this area, likely due to its geographic and academic proximity to palm oil production in Indonesia. Universiti Putra Malaysia follows with just over 30 documents, reflecting Malaysia's central involvement in palm oil issues. Other prominent institutions include the University of Cambridge and Georg-August-Universität Göttingen, showing strong international academic interest, particularly from Europe. ETH Zürich, National University of Singapore, and Universitas Jambi contribute moderately, with around 15–20 documents each. Additional contributors like the Malaysian Palm Oil Board, Universiti Malaysia Sabah, and the Center for International Forestry Research (CIFOR) underscore the collaboration between academic, governmental, and research organizations in addressing the environmental impacts of palm oil.
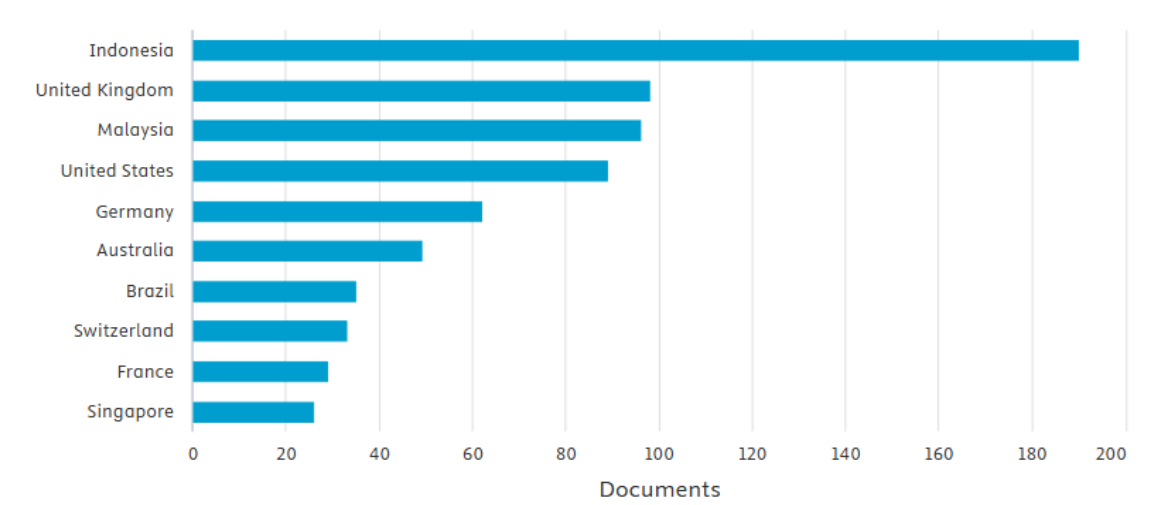
4.3 Documents by Country

Figure 3. Documents by Country
Source: Scopus Database, 2025

The bar displays the top contributing countries in research on palm oil and biodiversity based on the number of documents published. Indonesia stands out as the leading contributor with close to 200 documents, which is consistent with its status as the world's largest palm oil producer and a hotspot for biodiversity. Following at a distance are the United Kingdom, Malaysia, and the United States, each with approximately 90 to 100 documents, reflecting strong academic interest and international collaboration on environmental issues tied to palm oil. Germany and Australia also show moderate research output, while Brazil, Switzerland, France, and Singapore contribute between 25 and 40 documents each. This distribution indicates that while the research is globally dispersed, it is especially concentrated in countries directly involved in palm oil production or those with strong environmental research institutions. The chart also highlights the critical role of both producing and non-producing countries in advancing scientific understanding and solutions for biodiversity conservation in the context of palm oil expansion.
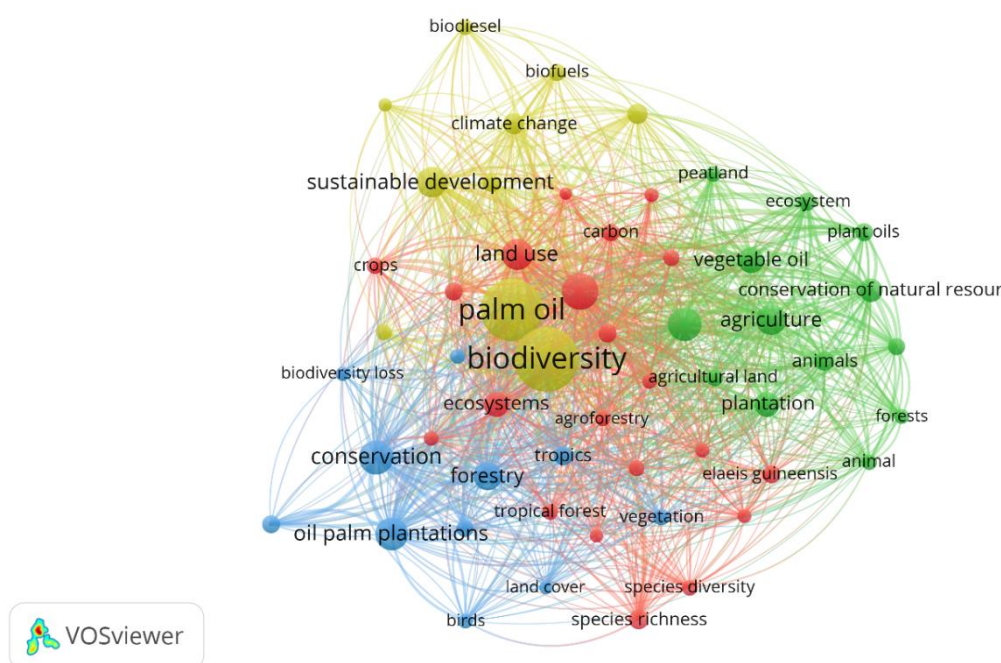
4.4 Keyword Co-Occurrence Network

Figure 4. Network Visualization
Source: Data Analysis, 2025

The keyword co-occurrence network map presents a visual representation of the major themes and relationships within the scholarly literature on palm oil and biodiversity. Each node in the network represents a keyword, with node size indicating the frequency of occurrence, while the colors represent different thematic clusters based on co-occurrence patterns. Thicker lines between nodes denote stronger connections or higher co-occurrence rates. At the center of the map, the terms "palm oil" and "biodiversity" emerge as the most dominant and frequently co-occurring keywords, serving as central hubs from which other related topics branch out. This confirms their foundational role in framing the research landscape. The red cluster, centered around keywords such as "land use," "agroforestry," "carbon," "tropics," and "species richness," represents a strong focus on the ecological and land transformation impacts of palm oil cultivation. This cluster highlights how researchers have investigated the conversion of natural landscapes into palm oil plantations, and the subsequent effects on carbon storage, habitat complexity, and species diversity. It reflects a multidisciplinary concern with balancing agricultural expansion and environmental sustainability.

The green cluster features keywords like "agriculture," "plantation," "vegetable oil," "ecosystem," "forests," and "animals," suggesting an emphasis on agricultural systems and ecosystem interactions. This thematic group delves into the relationships between cultivated landscapes and natural ecosystems, examining how agricultural intensification affects wildlife, vegetation, and ecological processes. This cluster also touches on system-level conservation strategies and the need for integrating ecological knowledge into plantation management. The blue cluster is primarily concerned with conservation, forestry, and species protection, including terms such as "conservation," "forestry," "biodiversity loss," "birds," and "oil palm plantations." This suggests a strong research focus on the consequences of plantation expansion on forest biodiversity, especially with regard to species-specific impacts and conservation priorities. The presence of taxonomic and habitat-specific keywords indicates that many studies have taken a granular approach, investigating how oil palm affects particular groups or ecosystems.

Lastly, the yellow cluster is characterized by keywords like "sustainable development," "climate change," "biofuels," "biodiesel," and "crops," indicating a thematic concern with sustainability and global environmental change. This area of research reflects a broader discourse that situates palm oil within international policy contexts, such as the Sustainable Development Goals (SDGs) and climate change mitigation strategies. The discussion includes biofuel policies and debates over whether palm oil is a viable component of sustainable energy systems, especially given its links to deforestation and carbon emissions. The keyword network reveals an interconnected yet multi-dimensional research field, with strong thematic clusters representing ecological, agricultural, conservation, and policy-driven approaches. The overlap and interlinkages among clusters suggest a growing interdisciplinary engagement, as scholars increasingly address the complexities of palm oil's environmental and social implications. This map also helps identify gaps and potential areas for future exploration, such as underrepresented regions, underexplored taxa, or integrated socio-ecological frameworks.
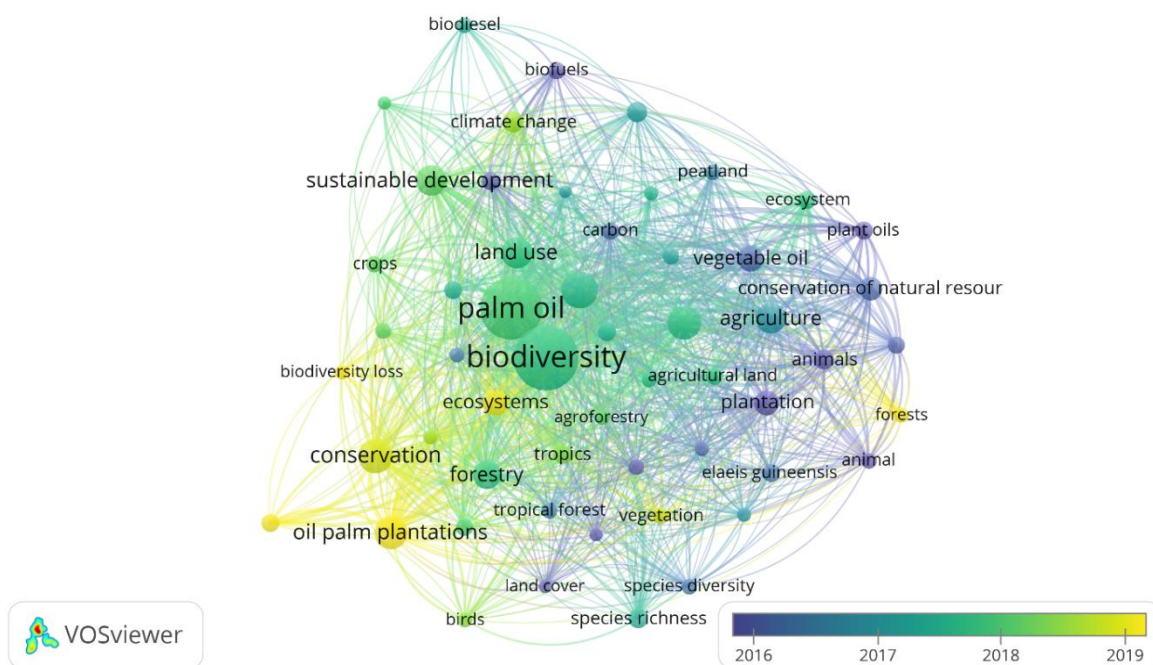

Figure 5. Overlay Visualization
Source: Data Analysis, 2025

The overlay visualization presents a temporal analysis of keyword co-occurrence in the field of palm oil and biodiversity, where colors indicate the average publication year associated with each

keyword. The color gradient ranges from dark blue (older terms, around 2016) to yellow (more recent terms, around 2019). Core terms such as "palm oil" and "biodiversity" appear in green, suggesting consistent usage and relevance across the study period. These central terms have remained the focal point of the discourse and are well-integrated with multiple thematic areas, highlighting their foundational role in shaping the research landscape.

Keywords shown in yellow, such as "oil palm plantations," "conservation," "sustainable development," and "biodiversity loss", indicate areas of increasing scholarly interest in the more recent years (2018–2019). These terms suggest a growing concern with sustainability practices and conservation frameworks in response to the ecological impacts of palm oil expansion. The emergence of "sustainable development" and "biodiesel" also reflects a shift in research focus towards broader policy and global environmental agendas, including climate change mitigation and the Sustainable Development Goals (SDGs). On the other hand, keywords shown in blue and purple hues, including "species richness," "land cover," "forests," "eleaeis guineensis," and "agricultural land," are associated with earlier research trends around 2016. These topics largely represent foundational ecological assessments of habitat conversion and species-specific studies that characterized the early phase of research in this field. Over time, the focus appears to have expanded from biological assessments toward integrated themes that include governance, sustainability, and socio-environmental strategies.
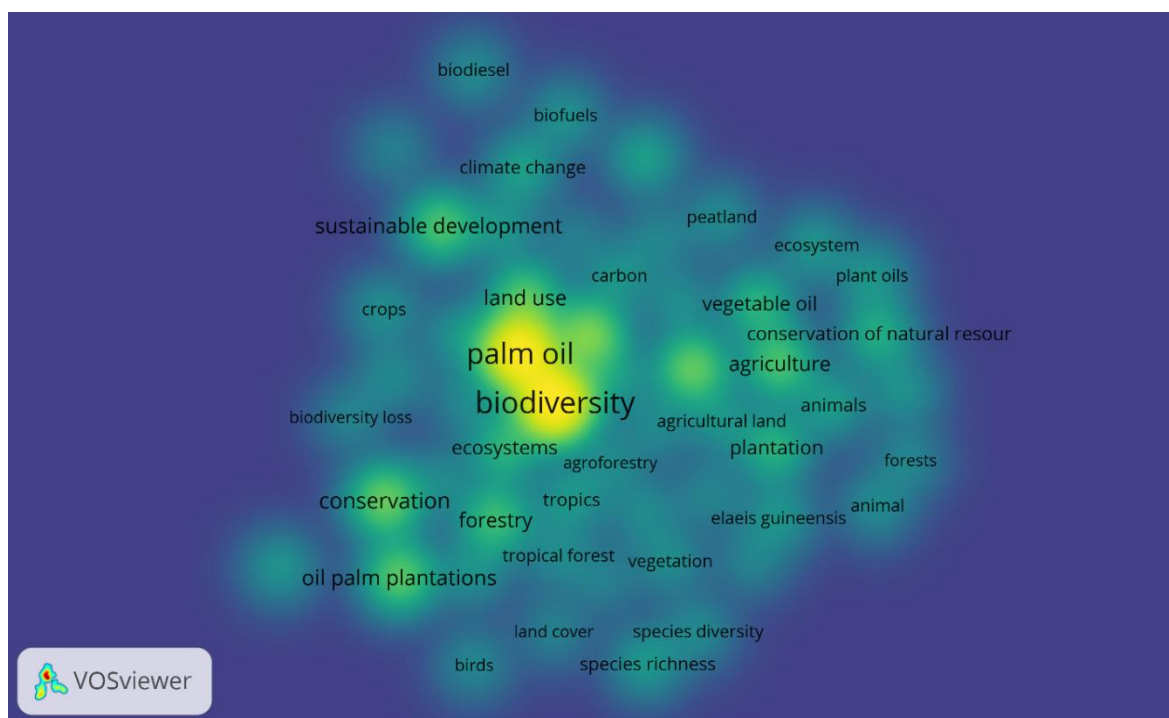

Figure 6. Density Visualization
Source: Data Analysis, 2025

The heatmap visualization illustrates the density of keyword co-occurrences in the literature on palm oil and biodiversity. Keywords displayed in bright yellow to green represent areas of high frequency and centrality, while those in darker green to blue hues reflect lower levels of occurrence. The terms "palm oil" and "biodiversity" occupy the brightest and most concentrated zone in the center of the map, indicating that these are the most frequently used and most interconnected keywords across the dataset. This reinforces their role as core concepts around which the rest of the research themes are organized. Surrounding this core, moderately dense keywords such as "land use," "agriculture," "ecosystems," "conservation," "sustainable development," and "forestry" show

that the research strongly engages with environmental, agricultural, and sustainability-related issues. Less dense but still relevant terms like "biodiesel," "biofuels," "tropical forest," and "species richness" appear more peripherally, suggesting these are secondary or more specialized topics within the field.
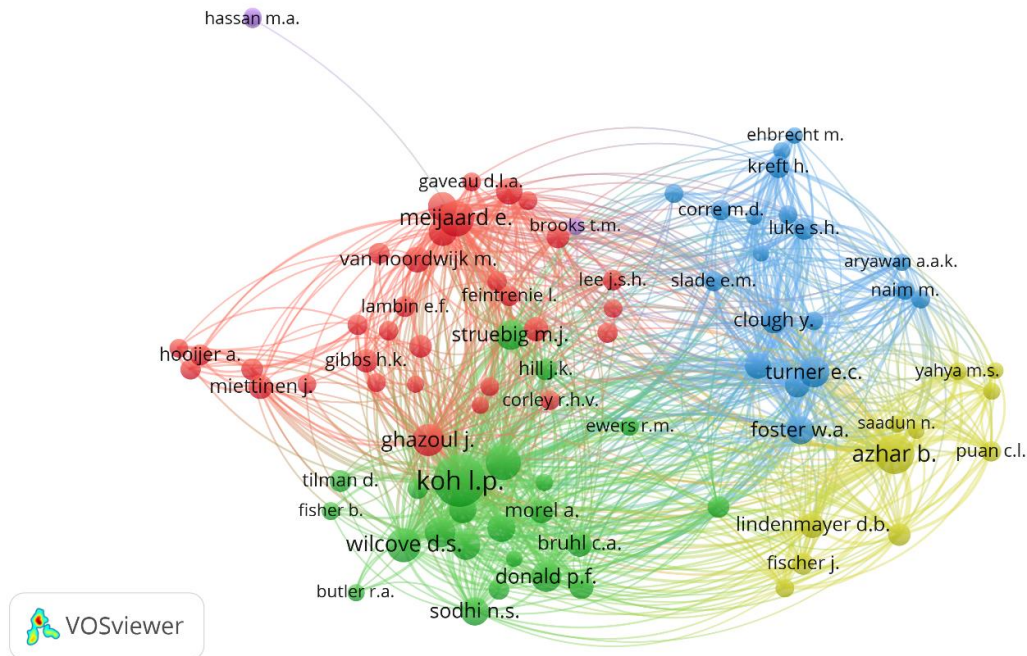
4.5 Co-Authorship Network

Figure 7. Author Visualization
Source: Data Analysis, 2025

The co-authorship network visualization reveals clusters of researchers who have collaborated on publications related to palm oil and biodiversity. Each node represents an author, and the size of the node corresponds to the number of publications or collaborative strength. The colored clusters indicate distinct research groups or communities. At the center of the map, Koh L.P., Meijaard E., Ghazoul J., and Wilcove D.S. emerge as key influencers with dense collaborative ties, suggesting they are central figures in the field. The red cluster, led by Meijaard and Gaveau, reflects a network focused on landscape and conservation strategies, while the green cluster centers around Koh and Ghazoul, likely emphasizing ecological and biodiversity impact studies. The blue cluster, featuring Turner E.C. and Clough Y., indicates another prominent group involved in conservation and agroecological research. The yellow cluster, with authors like Azhar B. and Lindenmayer D.B., suggests a focus on biodiversity-friendly agriculture or socio-ecological approaches. Notably, Hassan M.A. appears isolated in a small purple cluster, showing minimal integration with the main collaborative networks.
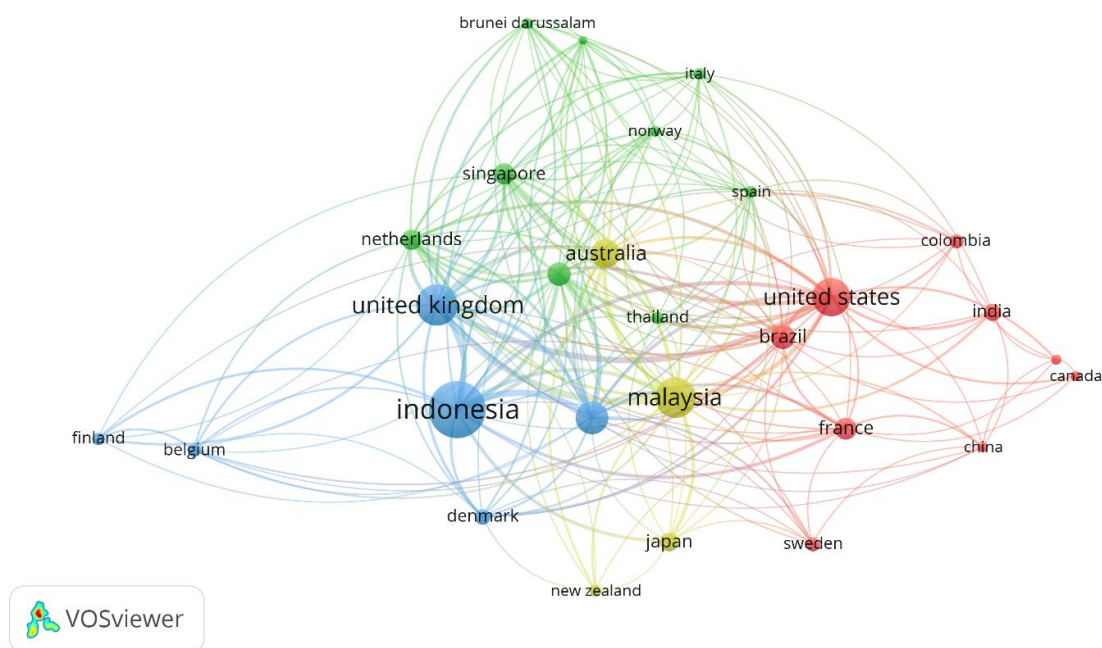
Figure 8. Country Visualization
Source: Data Analysis, 2025

The co-authorship network by country illustrates international collaboration in palm oil and biodiversity research. The most prominent nodes (Indonesia, Malaysia, United Kingdom, and United States) are larger in size, indicating high publication output and central roles in the global research network. Indonesia and Malaysia, as major palm oil-producing nations, are deeply integrated into the network, collaborating extensively with Western countries such as the UK, Netherlands, and Australia, as well as with regional partners like Singapore and Thailand. The United States leads a separate cluster characterized by collaborations with Brazil, France, India, and Canada, reflecting its influence on global environmental policy and scientific outreach. The presence of multiple clusters with dense interconnections suggests a strong global engagement, though some countries, like China, Sweden, and Colombia, appear more peripheral.

Discussion

The bibliometric analysis of research related to palm oil and biodiversity reveals a dynamic and evolving scholarly landscape shaped by global environmental challenges, regional production realities, and interdisciplinary collaboration. The increasing number of publications over the last two decades, especially the surge observed between 2017 and 2019, indicates a rising academic and policy-level concern regarding the ecological consequences of palm oil expansion. This heightened interest aligns with growing public awareness and international debates about deforestation, climate change, and sustainable agriculture, particularly in biodiversity-rich regions such as Southeast Asia. The temporal analysis confirms that the topic of palm oil and biodiversity has moved from being a relatively niche area in the early 2000s to becoming a central focus within environmental and agricultural research. The significant peak in 2019 suggests a convergence of scholarly, media, and policy attention around that time—possibly triggered by global climate summits, biodiversity assessments (e.g., IPBES reports), and criticisms of unsustainable palm oil practices. The decline in publications post-2020 could be partially attributed to the COVID-19 pandemic's disruption of research and fieldwork. However, the slight recovery in 2023–2024 may reflect renewed momentum and adaptation to hybrid research methodologies.

Institutional and national-level analyses further emphasize the strong geographic link between palm oil production and academic research output. IPB University (Indonesia) and Universiti Putra Malaysia emerge as the most prolific institutions, underscoring the role of local academic actors in investigating and addressing sustainability challenges in their respective countries. The prominence of institutions from the United Kingdom, Germany, and Switzerland, such as the University of Cambridge and ETH Zürich, highlights robust international collaboration and the influence of Western research funding and expertise in shaping narratives around conservation and development in the Global South.

On the country level, Indonesia leads in terms of research output, followed by the United Kingdom, Malaysia, and the United States. This finding reflects the dual dynamic of producer and consumer country engagement. While Indonesia and Malaysia dominate the global palm oil market and face the most direct environmental consequences, Western countries contribute significantly to the academic debate, often with a focus on conservation, sustainable development, and policy frameworks. This collaboration between Global North and South indicates increasing recognition of the need for globally coordinated but locally grounded research efforts. The involvement of countries like Brazil, Australia, and Germany also points to comparative and transregional interest in land-use change and biodiversity management.

The co-authorship network analysis identifies key scholars such as Koh L.P., Meijaard E., Ghazoul J., and Wilcove D.S. as influential figures who have shaped the scientific discourse through frequent collaboration and high-impact contributions. These scholars are often central nodes within dense collaborative networks, signaling their leadership roles and interdisciplinary engagement. The presence of distinct clusters in the author network also reflects thematic specialization—for instance, conservation ecology, sustainable agriculture, and socio-environmental governance. The isolation of some researchers, such as Hassan M.A., highlights opportunities for deeper integration of underrepresented perspectives or geographic areas.

Keyword analysis reveals the conceptual structure of the field, with "palm oil" and "biodiversity" as dominant terms interlinked with clusters such as "land use," "conservation," "forestry," "climate change," and "sustainable development." These interconnected themes point to the inherently multidisciplinary nature of the topic, spanning ecology, agriculture, environmental policy, and socioeconomics. The presence of terms like "ecosystems," "species richness," "deforestation," and "carbon" reflects traditional ecological concerns, while newer terms such as "sustainable development" and "biofuels" suggest a shift toward policy-oriented and solution-driven research. The overlay visualization supports this thematic evolution by showing a temporal shift in keyword emphasis. Early research (pre-2017) focused heavily on ecological impacts, such as species richness, tropical forests, and habitat loss. In contrast, more recent literature integrates broader sustainability concerns, evidenced by the increasing prominence of keywords like "sustainable development," "climate change," and "biodiversity loss." This transition illustrates a maturing research agenda that moves beyond documenting environmental degradation to exploring mechanisms for mitigation, resilience, and policy alignment.

The heatmap visualization complements this understanding by highlighting the density of research interest around the central themes. High-intensity zones around "palm oil," "biodiversity," "land use," and "agriculture" reflect the core focus of most studies. Moderately dense areas like "forestry," "ecosystems," "oil palm plantations," and "conservation" indicate secondary but substantial engagement. In contrast, lower-density zones such as "species diversity," "birds," and "biofuels" suggest specialized or emerging niches within the broader research landscape. These areas could serve as entry points for future investigations, especially given the increasing relevance of ecosystem services, wildlife protection, and renewable energy. International collaboration is a defining feature of palm oil and biodiversity research, as demonstrated by the country co-authorship network. Indonesia, Malaysia, and the United Kingdom form a highly integrated hub, reflecting strong bilateral academic ties and joint research programs. The United States forms another cluster

with countries like Brazil, France, and Canada, suggesting a North-South collaboration pattern focusing on global environmental governance. Countries such as Singapore, Netherlands, and Australia play bridging roles, linking different clusters and enhancing knowledge exchange across continents. These findings underscore the importance of fostering transnational research partnerships that combine local ecological knowledge with global policy perspectives.

Despite these strengths, the analysis also reveals some critical gaps and limitations in the current research landscape. First, there is still an uneven geographical distribution of research output, with underrepresentation of African and Latin American producer countries like Nigeria, Colombia, or Peru. These regions are witnessing growing palm oil expansion but lack comparable research coverage. Second, while many studies focus on flagship species and forest ecosystems, there is limited attention to invertebrates, soil biota, fungi, and other less-visible taxa that play crucial roles in ecosystem functioning. Third, the social dimensions of biodiversity loss—such as impacts on indigenous communities, land tenure conflicts, and gendered experiences—remain underexplored and warrant greater interdisciplinary attention. Furthermore, while certification schemes such as the RSPO appear frequently in the literature, critical assessments of their effectiveness are still fragmented. There is a need for more longitudinal studies that evaluate the real-world impact of sustainability standards on biodiversity outcomes. Similarly, the literature would benefit from more comparative case studies across different governance contexts, plantation types, and landscape configurations. Methodologically, future research could integrate bibliometric insights with qualitative evidence, remote sensing, and participatory approaches to produce more holistic analyses.

CONCLUSION

The bibliometric findings demonstrate that palm oil and biodiversity research is a vibrant and increasingly interconnected field. It has transitioned from documenting environmental impacts to engaging with sustainability narratives, multi-stakeholder governance, and solution-based frameworks. While there is clear progress in terms of volume, collaboration, and thematic richness, ongoing efforts are needed to address remaining gaps, diversify research perspectives, and strengthen the policy-science interface. By identifying influential actors, emerging trends, and underexplored areas, this study contributes to a more strategic and informed approach to future research in the intersection of biodiversity conservation and palm oil production.

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