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Bibliometric Analysis on Oil Palm, Food Security, and Bioenergy

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ABSTRACT

This study presents a bibliometric analysis of global research on oil palm, food security, and bioenergy, aiming to map the intellectual structure, thematic evolution, and collaboration networks in this multidisciplinary domain. Using data from the Scopus database (2000–2024) and analyzed through VOSviewer, the study identifies key trends, influential authors, and emerging research themes. The results reveal that early research predominantly focused on the role of palm oil in biodiesel and biofuel production, while recent studies increasingly emphasize environmental sustainability, waste-to-energy technologies, and circular economy principles. Core keywords such as *palm oil*, *bioenergy*, and *biodiesel* remain central, with newer themes like *anaerobic digestion* and *greenhouse gas* gaining momentum. Malaysia leads in publication output and collaboration intensity, followed by the United States and the Netherlands. Despite robust growth in bioenergy-related research, the food security dimension remains underexplored. The study highlights the need for more integrated, socially inclusive, and geographically diverse research to support sustainable palm oil systems in the context of global food–energy–land challenges.

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1. INTRODUCTION

The rapid expansion of oil palm (Elaeis guineensis) cultivation has become a significant feature of agricultural development in tropical regions, particularly in Southeast Asia, Latin America, and parts of Sub-Saharan Africa. This crop, valued for its high yield and efficiency in producing vegetable oil, has spurred economic growth in many developing countries, especially Indonesia and Malaysia, which together account for over 80% of global palm oil production [1]. Palm oil is a versatile commodity used in food, cosmetics, industrial lubricants, and increasingly as a feedstock for biodiesel. Its growing demand is tied to the global push for renewable energy and sustainable alternatives to fossil fuels [2]. Consequently, the literature on oil palm has expanded rapidly, encompassing diverse fields such as agronomy, socioeconomics, food systems, energy studies, and environmental sciences [3].

Parallel to this development, concerns have emerged regarding the implications of oil palm expansion for food security. On the

one hand, the palm oil industry provides income, employment, and export revenues, which can support rural livelihoods and national food access [4]. On the other hand, land conversion for oil palm often competes with food crop cultivation, potentially undermining local food sovereignty and increasing dependency on imported staples [5]. Land tenure issues and displacement of smallholders have further complicated the narrative, raising questions about the equitable distribution of the benefits of palm oil-based development. Thus, the relationship between oil palm expansion and food security is complex and context-dependent, necessitating an integrated and multidisciplinary approach in assessing its long-term sustainability [6].

Another dimension that has attracted scholarly attention is the role of oil palm in the global bioenergy agenda. As nations strive to meet their renewable energy targets under the Paris Agreement, palm oil-based biodiesel has been promoted as a viable substitute for fossil fuels. Countries like Indonesia have implemented mandatory biodiesel blending policies (e.g., B30 program), positioning oil palm as a strategic asset for energy independence and climate mitigation [7]. However, critics argue that the carbon benefits of biodiesel are often offset by deforestation and peatland degradation associated with plantation expansion [8]. The debates around bioenergy, sustainability standards, and indirect land use change continue to influence global trade and policy frameworks surrounding palm oil.

Given the intersection of oil palm cultivation with critical global issues—climate change, food security, and energy transition—there has been an upsurge in scholarly publications examining these linkages. However, the growing body of literature is fragmented across disciplines, journals, and regions, which hinders the synthesis of knowledge and identification of research gaps. Bibliometric analysis offers a powerful methodological tool to systematically map, quantify, and visualize the evolution of scientific output in this field. Through co-authorship networks, keyword co-occurrence, and citation trends, researchers can gain insights into the dominant themes, influential authors and institutions, and emerging areas of inquiry [9].

While bibliometric studies have been conducted on oil palm in general, there remains a lack of focused analyses on the triadic nexus of oil palm, food security, and bioenergy. This triad reflects the interconnectedness of agricultural policy, environmental sustainability, and socio-economic development. Understanding how these themes co-evolve in academic research is critical for informing policy-making, directing future research investments, and fostering interdisciplinary collaboration. Moreover, such analysis can illuminate regional disparities, institutional collaborations, and the balance between applied and theoretical studies in this domain.

Despite the prolific growth in scholarly output on oil palm, food security, and bioenergy, there is currently no comprehensive bibliometric study that integrates these three interrelated themes. The fragmented nature of the existing literature—often siloed within environmental studies, agricultural economics, or energy policy—limits the capacity of researchers and policymakers to grasp the full spectrum of knowledge and debates surrounding oil palm development. Furthermore, the lack of clarity about intellectual structure, leading contributors, and conceptual hotspots hampers the formulation of holistic and sustainable strategies to manage oil palm's impact on food systems and renewable energy goals. Without a systematic mapping of the literature, the field risks duplicating efforts, overlooking critical perspectives, and failing to address urgent global challenges in a coordinated manner. This study aims to conduct a bibliometric analysis of global research on oil palm, food security, and bioenergy using data retrieved from the Scopus database.

2. METHODS

This study employed a bibliometric analysis approach to systematically evaluate the development, structure, and thematic trends in the scientific literature related to oil palm, food security, and bioenergy. Bibliometric methods are quantitative tools used to analyze large volumes of academic publications, allowing researchers to assess publication patterns, citation dynamics, collaboration networks, and conceptual structures within a given field [9]. The analysis was conducted in accordance with established bibliometric procedures, incorporating performance analysis and science mapping to provide both descriptive and visual representations of the research landscape.

The data were collected from the Scopus database, which is widely recognized for its extensive coverage of peer-reviewed journals and high-quality metadata. A comprehensive search strategy was formulated using Boolean operators and combinations of keywords such as "oil palm" OR "palm oil" AND "food security" AND "bioenergy" OR "biodiesel." The search was limited to the period between 2000 and 2024 to capture the evolution of research over the past two decades, during which global interest in sustainability, food systems, and renewable energy has intensified. Only English-language documents categorized as articles, reviews, or conference papers were included to ensure consistency and relevancy. The retrieved metadata—comprising title, abstract, author, affiliation, source, keywords, and citations—were exported in CSV and BibTeX formats for analysis.

In the analysis phase, VOSviewer is used to construct and visualize various bibliometric networks, including co-authorship networks between authors and institutions, keyword co-occurrence to identify dominant topics, and co-cite analysis to explore conceptual relationships between literatures. Each node in the visualization represents an entity (e.g., a keyword or an author), while the size and color of the node reflect its frequency of occurrence and thematic cluster.

3. RESULTS AND DISCUSSION

3.1 Keyword Co-Occurrence Network

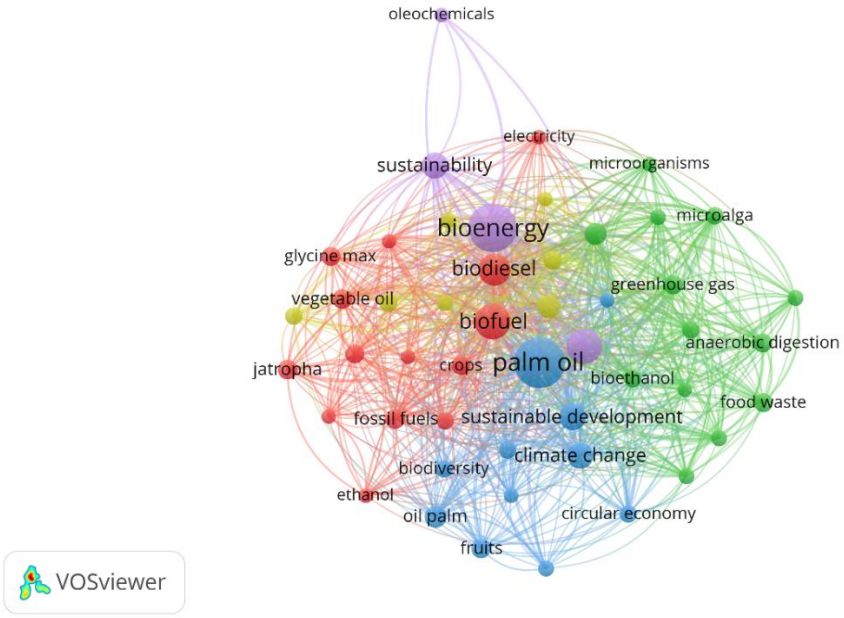

Figure 1. Network Visualization
Source: Data Analysis Result, 2025

Figure 1 illustrates the co-occurrence of keywords in academic publications related to *palm oil*, *food security*, and *bioenergy*. The size of each node represents the frequency with which a keyword appears in the dataset, while the color indicates clusters of related terms that frequently appear together. Central and prominent keywords such as "palm oil," "bioenergy," "biofuel," and "biodiesel" dominate the map, signaling their central role in scholarly discourse. These nodes serve as bridges connecting various subthemes, reflecting the interdisciplinary nature of research in this field.

The red cluster focuses on *biofuel feedstocks* and comparative studies of renewable versus fossil fuels. Keywords like *jatropha*, *vegetable oil*, *glycine max*, *ethanol*, and *fossil fuels* suggest a concentration of research on alternative bioenergy crops and their potential to substitute conventional energy sources. This cluster indicates a technological and agronomic orientation, particularly around optimizing crop types for biodiesel production. The presence of "ethanol" alongside biodiesel also implies a comparative interest in different types of biofuels and their respective environmental and economic implications.

The green cluster represents environmental and biotechnological processes. Terms such as *anaerobic digestion*, *microorganisms*, *microalga*, *greenhouse gas*, and *food waste* suggest a strong research interest in microbial and waste-to-energy technologies. This cluster highlights the biological pathways for converting organic material into bioenergy and the environmental consequences—particularly greenhouse gas emissions—associated with these processes. The inclusion of *food waste* points to growing interest in integrating circular economy principles and resource recovery into bioenergy strategies.

In contrast, the blue cluster connects *palm oil* to broader socio-environmental contexts such as *climate change*, *sustainable development*, *biodiversity*, and *circular economy*. This group of terms reflects the sustainability discourse surrounding palm oil expansion and its implications for ecological systems and long-term development goals. The presence of "oil palm," "fruits," and "biodiversity" suggests attention to both agricultural production and ecological consequences. Furthermore, the inclusion of "circular economy" emphasizes efforts to design regenerative production systems that minimize waste and enhance resource efficiency.

The purple cluster, including keywords like *sustainability*, *oleochemicals*, and *electricity*, indicates research into value-added products and energy conversion from palm oil. "Oleochemicals" represents the downstream processing of palm oil into chemical derivatives used in multiple industries, highlighting industrial innovation within the palm oil value chain. Although smaller and more peripheral, this cluster shows growing interest in diversified palm-based products and their contribution to sustainable energy generation, including electricity. Its link to sustainability reflects both environmental and economic dimensions of bioenergy policy.

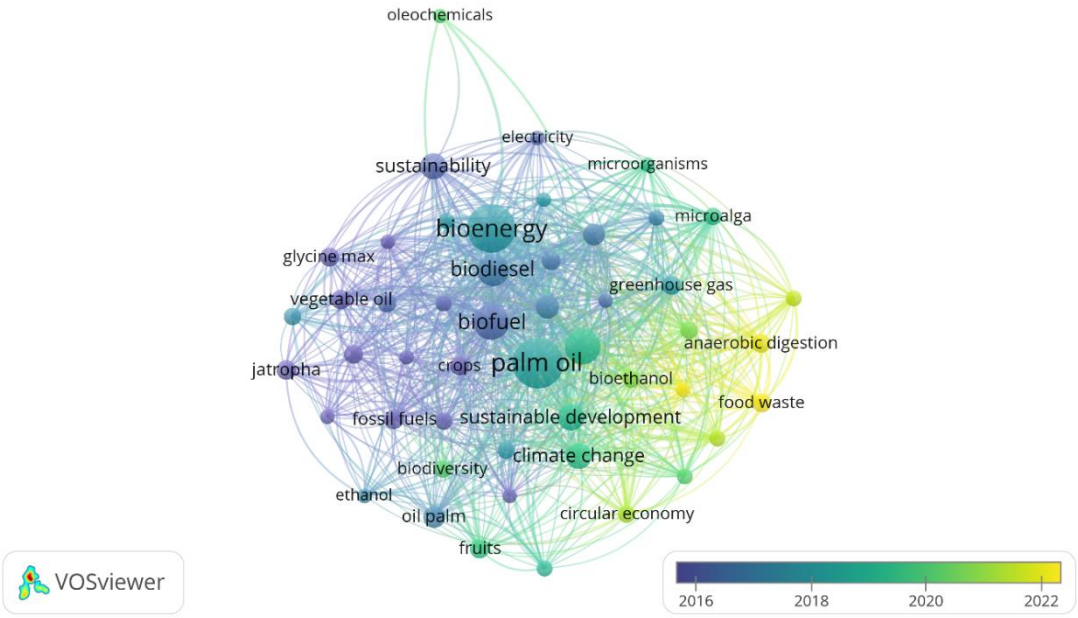

Figure 2. Overlay Visualization

Source: Data Analysis Result, 2025

Figure 2 displays the temporal evolution of research themes within the intersection of palm oil, bioenergy, and food security from 2016 to 2022. The color gradient—ranging from dark blue (older studies) to yellow (more recent studies)—represents the average publication year of each keyword. Core keywords such as "palm oil," "bioenergy," "biofuel," and "biodiesel" are primarily colored in blue to teal, indicating that they have been central themes in earlier phases of research, especially between 2016 and 2019. These foundational terms reflect the initial surge of academic interest in palm oil's role in the bioenergy sector and its implications for sustainability and energy policy.

In contrast, newer and emerging research directions are highlighted in yellow and green hues, which cluster toward the right side of the map. Keywords like "anaerobic digestion," "food waste," "microalga," "microorganisms," and "greenhouse gas" are associated with publications from 2021–2022, signaling a recent shift toward waste-to-energy innovations, microbial technologies, and environmental impact mitigation. This transition suggests that scholars are increasingly focusing on improving the ecological footprint of palm-based bioenergy, emphasizing low-emission technologies and circular economy practices. The rise of these keywords also reflects growing concern over climate change and the sustainability of current biofuel systems.

Additionally, the keyword "circular economy" appearing in greenish-yellow reflects an emerging conceptual pivot in the literature toward integrated, resource-efficient production models. While earlier studies (blue/purple cluster) emphasized biofuel crop types and energy output comparisons, recent works are increasingly oriented toward system-level sustainability, including biodiversity, food waste recovery, and climate-smart practices. This evolution suggests that the field is maturing beyond productivity and energy efficiency, incorporating holistic frameworks that link agricultural sustainability, environmental health, and renewable energy development

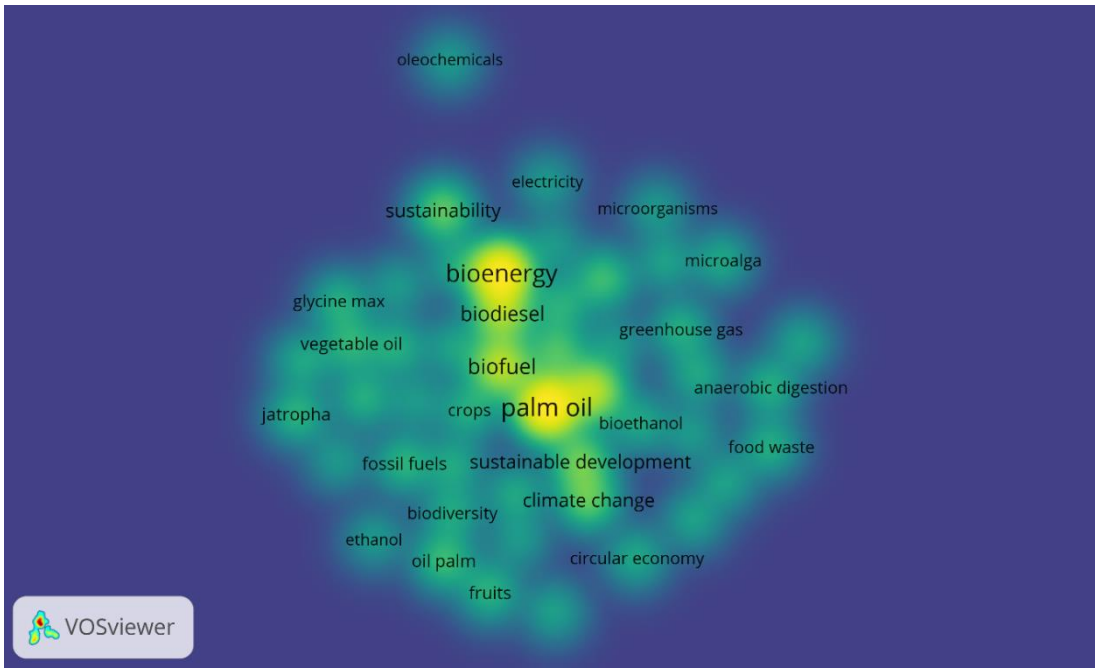

Figure 3. Density Visualization

Source: Data Analysis, 2025

This figure 3 illustrates the **intensity and concentration of research activity** in the field of palm oil, bioenergy, and food security. Keywords shown in **bright yellow** indicate high-frequency usage and central relevance in the literature, while **green to blue** areas represent lower frequency and peripheral topics. The terms **"palm oil," "bioenergy," "biofuel," "biodiesel," and "sustainable development"** appear as the most concentrated and frequently occurring terms, suggesting that these concepts form the **core thematic focus** in this research domain. Their central positioning and high density signify the primary academic attention and knowledge production around these topics, especially in relation to energy transition and sustainable agriculture.

Surrounding the high-density core, there are **moderately active areas**—such as *climate change*, *circular economy*, *greenhouse gas*, and *anaerobic digestion*—which indicate growing but still secondary interests. More peripheral keywords such as *oleochemicals*, *electricity*, and *microalga* show relatively low density, implying **emerging or niche research areas** with limited but potentially increasing scholarly attention.

3.2 Co-Authorship Network

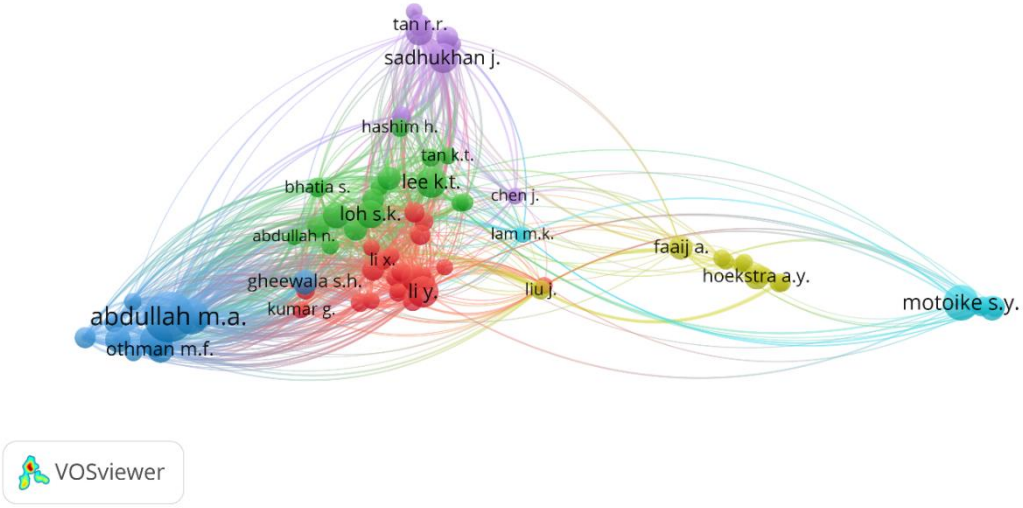

Figure 4. Author Collaboration Visualization
Source: Data Analysis, 2025

Figure 4 above illustrates the structure of scholarly co-authorship within the field of palm oil, food security, and bioenergy. Each node represents an individual author, and links between nodes indicate co-authorship relationships. Prominent clusters—such as those centered around Abdullah M.A., Li Y., Sadhukhan J., and Motoike S.Y.—highlight key research communities. The blue cluster, anchored by Abdullah M.A., appears to be highly collaborative and dense, indicating a strong internal network, likely based in Malaysia. Meanwhile, Li Y. and Liu J. in the red and yellow clusters reflect active Chinese research groups with strong ties to bioenergy systems. Motoike S.Y., although more peripheral, has distinct cross-linkages with international scholars like Hoekstra A.Y. and Faaij A., suggesting cross-regional or interdisciplinary collaboration.

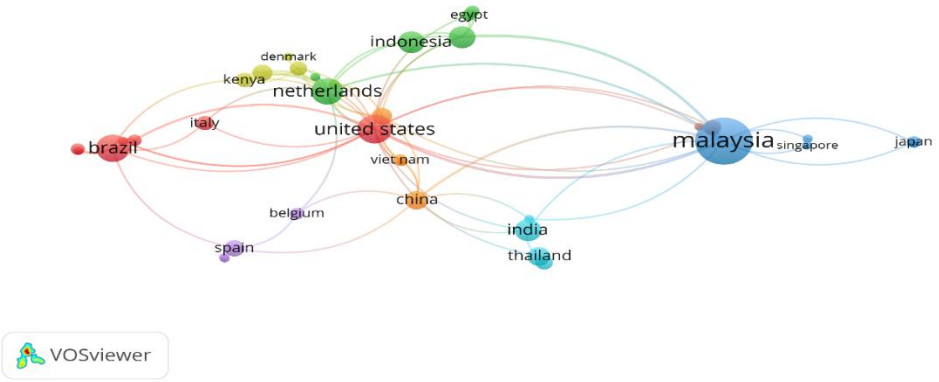

Figure 5. Country Collaboration Visualization
Source: Data Analysis, 2025

The figure 5 visualizes **international research partnerships** in the field of palm oil, bioenergy, and food security. **Malaysia** emerges as the most dominant and centrally connected country, reflecting its leadership and productivity in palm oil-related research. It shows strong bilateral collaborations with **Singapore**, **India**, **Japan**, **Indonesia**, and the **United States**, suggesting that Malaysia serves as a key hub linking both Asian and Western research institutions. The **United States** also plays a central role, forming bridges with various regions including **Brazil**, **China**, and **the Netherlands**—the latter also showing notable multilateral links with European and African countries such as **Denmark**, **Kenya**, and **Egypt**. Meanwhile, **Brazil** and **China** demonstrate regional influence with more localized connections.

3.3 Citation Analysis

Table 1. Top Cited Research

Citations	Authors and year	Title
553	[10]	Indirect land-use changes can overcome carbon savings from biofuels in Brazil
207	[11]	Oil palm economic performance in Malaysia and r&d progress in 2017
206	[12]	Crop Expansion and Conservation Priorities in Tropical Countries
165	[13]	Biofuel scenarios in a water perspective: The global blue and green water footprint of road transport in 2030
155	[14]	A comprehensive review on biomass and solar energy for sustainable energy generation in Nigeria
150	[15]	Role of bioenergy, biorefinery and bioeconomy in sustainable development: Strategic pathways for Malaysia
143	[16]	LCA applied to perennial cropping systems: A review focused on the farm stage
141	[17]	Role of microalgae in achieving sustainable development goals and circular economy
130	[18]	Oil palm economic performance in Malaysia and r&d progress in 2018

Source: Scopus, 2025

Discussion

1) Thematic Core and Research Priorities

The keyword co-occurrence map demonstrates that the core research themes revolve around *palm oil*, *bioenergy*, *biodiesel*, and *biofuel*. These keywords form a tightly interconnected cluster at the center of the visualization, indicating their foundational role in the literature. Early studies in the field largely focused on the technical and economic potential of oil palm as a biofuel feedstock, especially its high oil yield and suitability for biodiesel production [19]. The integration of these themes with "sustainable development" and "climate change" suggests that scholars have been critically evaluating the broader implications of palm oil expansion beyond productivity, addressing trade-offs between economic growth and environmental degradation.

Over time, the research focus has expanded and diversified, as reflected in the overlay visualization. Keywords such as *anaerobic digestion*, *microalga*, *greenhouse gas*, *food waste*, and *circular economy* emerged as more recent themes (appearing in yellow tones, post-2020), indicating a paradigm shift toward environmental sustainability and circular bioeconomy. These developments align with growing global pressure to decarbonize energy systems and minimize the ecological impacts of agricultural commodities. The presence of

"microorganisms" and "bioethanol" also suggests increased attention to biotechnological innovations for converting organic matter—including waste—into usable energy.

2) Intensity and Gaps in Literature

The density visualization further confirms the dominance of the bioenergy-focused cluster. The brightest yellow zones include "bioenergy," "biodiesel," "biofuel," and "palm oil," reflecting high publication frequency and scholarly attention. These hotspots suggest that much of the academic effort has been concentrated on energy-related aspects of oil palm, with sustainability considerations gaining traction more recently. In contrast, peripheral keywords such as *oleochemicals*, *electricity*, and *circular economy* appear in cooler zones, indicating emerging or niche topics. These areas may represent underexplored research frontiers, particularly the development of value-added palm-based products (e.g., oleochemicals for industrial use) or integration with renewable electricity systems.

Interestingly, *food security*—while conceptually central to this study—is less prominent in the keyword networks, suggesting a relative underrepresentation in the bibliometric dataset. This could imply that while many studies focus on energy and sustainability, fewer directly address the interplay between palm oil production and food systems, such as land use trade-offs, household nutrition, or local agricultural displacement. Bridging this gap may be critical to ensuring a more holistic understanding of the food–energy–land nexus in palm-dominated landscapes.

3) Intellectual Structure and Influential Contributors

The author collaboration network highlights the intellectual structure and social dynamics of the field. Prominent contributors include Abdullah M.A., Li Y., Lee K.T., and Sadhukhan J., each representing different research hubs in Malaysia, China, and the UK. These scholars lead tightly knit co-authorship clusters with dense internal links, reflecting strong national or institutional research teams. For instance, the blue cluster led by Abdullah M.A. suggests a Malaysian academic ecosystem with deep expertise in palm oil and bioenergy, while Li Y. and Liu J. anchor a growing Chinese research presence with connections to technological applications and waste management.

While several clusters exhibit regional cohesion, the overall network reveals moderate cross-border collaboration, with only a few scholars (e.g., Motoike S.Y. and Hoekstra A.Y.) acting as bridges between distant clusters. This pattern suggests that while domestic research capacity is strong, there is still room to enhance international cooperation, particularly across continents. Encouraging cross-institutional partnerships could foster innovation by blending diverse disciplinary, climatic, and policy perspectives.

4) Geographical Distribution and Global Collaboration

The country collaboration map adds a geopolitical lens to the analysis, revealing that Malaysia dominates the research landscape in terms of output and centrality. This is unsurprising given Malaysia's status as one of the world's largest palm oil producers and a hub for palm oil-related academic research. Malaysia maintains robust collaborative ties with countries such as Singapore, Indonesia, India, and the United States, positioning itself as a regional and global leader in this domain.

The United States and the Netherlands also emerge as central players in the network, with diverse collaborations across Asia, Europe, and Latin America. The Netherlands' linkages with Kenya, Egypt, and Denmark suggest a European-African research corridor, possibly driven by shared interest in sustainability and agro-industrial transitions. Meanwhile, Brazil, China, and India show strong regional but limited global connectivity, despite their significant roles in agriculture and bioenergy. This hints at an opportunity to strengthen South–South cooperation, especially among countries with

similar developmental challenges and climate risks.

Notably, several countries with high palm oil production or consumption potential—such as Nigeria, Colombia, and the Philippines—are absent or minimally connected in the map. Their limited representation signals potential research blind spots and underscores the need for capacity building and funding mechanisms that bring more diverse voices into global academic dialogue.

5) Strategic Implications and Future Directions

This bibliometric analysis offers several strategic insights for researchers, practitioners, and policymakers. First, while bioenergy remains the dominant lens, future studies should more deeply integrate food security dimensions, especially the impact of land conversion on local food access and rural livelihoods. A stronger emphasis on social justice, gender, and indigenous perspectives could also enrich the field and ground sustainability in lived realities.

Second, emerging themes such as anaerobic digestion, food waste utilization, and microbial energy conversion should be further explored and supported through interdisciplinary collaboration. These areas not only address environmental concerns but also offer scalable technological solutions aligned with circular economy principles. Funding agencies and academic institutions may consider prioritizing these topics to stimulate innovative and policy-relevant research.

Third, fostering inclusive global partnerships is vital. Institutions in Global South countries, especially outside of Southeast Asia, should be more actively integrated into international research networks. This includes enhancing knowledge transfer, joint publications, and south-south cooperation that reflect the global nature of palm oil's challenges and opportunities.

4. CONCLUSION

This bibliometric study provides a comprehensive overview of the scientific landscape at the intersection of **oil palm, food security, and bioenergy**. The analysis reveals that while core research has traditionally centered around biofuel production—particularly biodiesel from palm oil—recent years have seen a shift toward sustainability-focused themes such as anaerobic digestion, food waste utilization, and climate change mitigation. Malaysia emerges as the most prolific contributor, both in authorship and international collaboration, while the United States and the Netherlands play key roles in cross-regional partnerships. However, notable gaps remain, especially in research explicitly addressing food security implications and broader socio-environmental impacts. As global attention intensifies on sustainable land use and renewable energy transitions, future research must adopt a more integrated, interdisciplinary, and geographically inclusive approach to ensure that palm oil development supports both energy resilience and food system sustainability.

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