



## Mapping Global Research on Oil Palm Leaves (2008–2025): A Scientometric Analysis of Trends, Themes, and Collaboration

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### ABSTRACT

Palm oil leaves represent a substantial yet underutilized biomass resource within the palm oil industry, particularly in major producing countries such as Indonesia and Malaysia. Despite growing global interest in sustainable biomass valorization, no comprehensive scientometric review has previously examined the development, structure, and research trajectories of studies focusing on palm oil leaves. This study aims to map global research trends from 2008 to 2025 and to evaluate the thematic evolution, geographic distribution, and collaborative patterns within this emerging field. Using a systematic search strategy in the Scopus database and employing Bibliometrix and VOSviewer for scientometric analysis, the study identifies publication growth, citation structures, institutional contributions, and keyword networks across 88 selected documents. Results demonstrate a significant increase in research output, particularly after 2014, indicating expanding scholarly attention to palm oil leaf utilization. Malaysia dominates publication activity and citation impact, supported by strong university-based research infrastructures, while Pakistan, Indonesia, and New Zealand show growing participation. Thematic analyses reveal concentrated research clusters in chemical characterization, bioactive compound discovery, detection technologies, and preliminary applications in pharmaceuticals and biomaterials. Collaboration patterns indicate increasing international engagement, reflecting shared scientific interests in sustainable bioresource development. Overall, the findings highlight the considerable scientific and industrial potential of palm oil leaves, reinforcing their relevance to circular economy strategies and green innovation. This study provides the first integrated scientometric mapping of the field, offering essential insights for guiding future research, strengthening cross-country collaboration, and advancing high-value applications of palm oil leaf biomass.

### Keywords:

Palm oil; Leaves; Scientometric, Trends, Themes, Collaboration

### INTRODUCTION

Palm oil (*Elaeis guineensis*) has long been recognized as one of the most economically significant plantation crops in Southeast Asia, particularly in Indonesia and Malaysia, which collectively dominate global production (Zulkefli et al., 2020). Over several decades, the expansion of palm oil plantations has positioned both countries as central actors in the international vegetable oil market, with Indonesia becoming the world's largest producer and Malaysia holding a substantial share of global exports. The

crop's high yield efficiency, adaptability to tropical climates, and stable global demand have sustained its strategic importance for national economies, rural livelihoods, and industrial development. Despite ongoing debates related to land-use change and ecological sustainability, palm oil continues to serve as a backbone commodity in the region's agro-industrial sector, driving employment and contributing significantly to GDP (Meijaard et al., 2020). Within this broader context, the biological structure of the palm oil plant offers multiple biomass components; yet historical utilization patterns reveal that commercial interest has been narrowly concentrated on the fruit and its derivatives, while other plant parts remain largely undervalued (Ayompe et al., 2021).

Industrial exploitation of the palm oil plant has been predominantly oriented toward fruit-based extraction processes, particularly the production of crude palm oil (CPO) and palm kernel oil (PKO) (Zamanhuri et al., 2022). These two commodities account for the vast majority of economic returns from the crop, forming the basis for food products, oleochemicals, biofuels, and numerous consumer goods (Adwiyah et al., 2023). The high commercial value of palm fruit components has encouraged enterprises and policymakers to emphasize yield optimization, extraction efficiency, and downstream oil processing technologies. Consequently, research, innovation, and industrial investment have been heavily directed toward enhancing fruit-derived outputs rather than exploring the potential of non-fruit biomass. The predominance of fruit utilization reflects a broader pattern in agricultural industries, where economic priorities often drive selective biomass exploitation. This pattern has resulted in a relatively narrow resource-use paradigm within the palm oil sector, despite the plant's extensive biomass productivity (Ayyildiz et al., 2023).

Among the various underutilized components of the palm oil plant, palm oil leaves represent the largest source of agricultural residue in plantation environments. These leaves, routinely pruned during plantation maintenance, accumulate in substantial quantities and are commonly treated as organic waste (Pulunggono et al., 2019). In most commercial plantations, palm oil leaves remain unprocessed or are simply left to decompose naturally on the plantation floor, used occasionally for mulching but rarely developed for higher-value applications. Their status as a persistent yet undervalued biomass stream highlights a missed opportunity within the circular bioeconomy framework. Although emerging studies have demonstrated the biochemical richness of palm leaves—including the presence of flavonoids, phenolics, and other bioactive constituents—their commercial utilization remains minimal (Onakurhefe et al., 2019). This underutilization reflects a combination of technological gaps, limited scientific exploration, and weak integration of palm leaf biomass into existing industrial value chains.

Given the contemporary shift toward sustainable development and green economic transformation, research on palm oil leaf utilization has gained increasing relevance. The global urgency to reduce waste, valorize agricultural residues, and transition toward renewable biological resources underscores the strategic importance of exploring non-fruit palm biomass (Hechmi et al., 2022). Integrating palm oil leaves into value-added processing streams aligns with global efforts toward green chemistry, sustainable materials development, and eco-friendly production systems. The potential of palm oil leaf biomass to contribute to the circular economy is particularly significant for countries with extensive palm oil industries, where residue management persists as a major environmental challenge. Research attention to this biomass resource is therefore critical not only for waste reduction but also for supporting innovation in sustainable bioproducts, thereby advancing national and global commitments to green economic practices (Goh et al., 2025).

Despite the growing recognition of biomass valorization, a comprehensive literature review focusing specifically on research trends related to palm oil leaves has not yet been conducted. Existing scholarly work tends to address isolated aspects of palm oil leaf utilization—such as chemical extraction, bioactive profiling, or preliminary product development—without systematically mapping the evolution of scientific inquiry, thematic clusters, or geographic patterns of research. Consequently, there remains a lack of consolidated understanding regarding the trajectory of palm oil leaf research, the key contributing countries and institutions, and the emerging application domains. Scientometric evaluations, which combine bibliometric analysis with visualization tools, are well-suited to address this gap by providing empirical insights into publication trends, collaborative networks, and conceptual structures within a specific research field. However, such an evaluation has not been applied to palm oil leaf research, leaving an important gap in scholarly synthesis (López-Pernas et al., 2023).

Furthermore, the empirical findings presented in recent experimental studies suggest substantial promise for palm oil leaves, particularly within pharmaceutical and biomedical domains.

Several investigations have reported noteworthy antioxidant, antimicrobial, (Syarifah-Noratiqah et al., 2019) of such bioactive compounds reinforces the importance of systematic research into this biomass resource, as its valorization could contribute meaningfully to innovation in natural product chemistry and plant-based pharmaceuticals. The emerging evidence base underscores the need for a comprehensive assessment of the scientific landscape surrounding palm oil leaf research, both to consolidate current knowledge and to guide future investigations into pharmaceutical potential and beyond (Indrawati et al., 2023).

This study aims to systematically examine the global research trends, intellectual structure, and collaborative dynamics underlying studies on palm oil leaves. Using a scientometric approach, this article maps the evolution of research from 2008 to 2025, identifies influential authors, institutions, and countries, and highlights the thematic trajectories that define the field. By integrating quantitative bibliometric indicators with qualitative interpretation, the study seeks to provide a holistic understanding of how palm oil leaf research has developed, what scientific gaps remain, and where future opportunities lie. Ultimately, the objective of this review is to generate a consolidated framework that supports researchers, industry stakeholders, and policymakers in harnessing the untapped potential of palm oil leaves as a sustainable and valuable biological resource within the emerging green economy.

## METHODS

The methodological framework for this review was designed to provide a comprehensive and systematic scientometric assessment of global research trends on palm oil leaves. Scientometric review methodologies have been widely adopted in contemporary scholarship for mapping intellectual landscapes, identifying thematic structures, and evaluating the evolution of scientific inquiry across various domains (Liu & He, 2023). Their utility has been demonstrated in fields such as agriculture, sustainability science, green technology, and natural product research, where the expansion of literature necessitates transparent, replicable, and data-driven approaches to synthesis. In alignment with established bibliometric protocols, this study employed a multi-stage process encompassing data collection, document selection, keyword formulation, data extraction, and scientometric analysis using advanced visualization tools (López-Pernas et al., 2023). The methodological steps were guided by principles of systematicity, reproducibility, and analytical rigor to ensure that the resulting interpretations accurately reflect global research patterns. Research on soursop plants and their health benefits (Bonkra et al., 2023). The study will proceed through data gathering and selection. To design the search strategy for completing this work, use the flow chart below in Figure 1



Fig.1 Procedure for Selection of Documents from Scopus Database

## Initial data collection

The initial phase of the methodology involved data collection from Elsevier's Scopus database, selected due to its recognized breadth, multidisciplinary coverage, and established reliability as a source of peer-reviewed scientific literature. Scopus indexes a vast collection of journals, conference proceedings, book series, and academic documents across science, technology, social sciences, and related disciplines, making it well-suited for a comprehensive scientometric analysis (Baas et al., 2020; de Sousa Lopes et al., 2023). More than 3000 academic, governmental, and industrial institutions utilize Scopus as a primary source of research intelligence, highlighting its credibility and relevance. In accordance with best practices in bibliometric research, the study defined the temporal scope of analysis between 2008 and 2025, reflecting both the historical emergence of palm oil leaf research and the increasing scholarly attention observed in recent years. Accessing documents through Scopus also allowed for the integration of metadata required for advanced scientometric mapping, including keywords, authorship details, citations, affiliations, and publication venues (Pachauri & Singh, 2025; Velasquez et al., 2022).

### Significant keyword

The study relied on a structured search strategy using specific keyword combinations To ensure precision in retrieving relevant literature. The formulation of these search terms was informed by terminological variations in the literature related to palm oil leaves and the scientific nomenclature of *Elaeis guineensis*. Therefore, the following search string was employed: “palm oil leaf” OR “palm oil leave” OR “*Elaeis guineensis* leaf.” This approach ensured the capture of documents using both common descriptive terminology and formal species classification. Keyword selection plays a pivotal role in scientometric retrieval, as demonstrated in prior reviews on agricultural biomass and natural products research, where terminological precision significantly influences data inclusiveness. The search was executed within the title, abstract, and keyword fields to maximize coverage and avoid omitting relevant studies that might not explicitly reference palm oil leaves in the title but nevertheless contain substantial content (Pachauri & Singh, 2025)

### Bibliometric Analysis Tools

Since there are numerous bibliometric review tools, each one is distinctive in its own manner. As we all know, plain text is less appealing than visual representation. Understanding the relationships between study components was made easier by using bibliometric analysis with graphical representation or scientific map representation. Even though the research can be conducted with basic social network analysis software, there are different software solutions built expressly for science mapping. Several programmes include the following

#### Bibliometrix

A special programme called Bibliometrix was created in the R statistical computing and graphics language in accordance with a logical bibliometric methodology. Implement bibliometric analysis and create data matrices for co-citation, coupling, scientific collaboration analysis, and co-word analysis, among other activities, using the Bibliometrix software. Bibliographic information may be imported from the Scopus, PubMed, Digital Science Dimensions, Web of Science, and Cochrane databases, among others. Even individuals without coding experience can utilise bibliometrics owing to the shiny web app Biblioshiny. “Bibliometrix for no coders” is Biblioshiny. It makes it simple for academics to utilise Bibliometrix’s key capabilities, including data importation, analytics, and graphs for triple cognitive structures (K-structures): logical structure, cerebral structure, and class fabric, using data files from WoS, Scopus, PubMed, Lens, and dimensions (Ghorbani, 2024; Gupta et al., 2021a)

#### VOSviewer

VOSviewer is a piece of software created especially for creating and displaying bibliometric maps, with a focus on their graphical depiction. Considering the usage of density metaphors, special labelling algorithms, and zoom functionality, huge maps can be represented appropriately. The bibliometric research community can use the software application for free. Leide University’s Center for Science and Technology Studies was responsible for its creation (the Netherlands). The things are organised on the maps using VOSviewer’s VOS mapping technology. The method generates an identical matrix from a co-occurrence matrix using the association strength similarity measure. The tools Biblioshiny and VOSviewer are utilised in the execution of this study to obtain the best outcomes (Mingzhu, 2021; Rana, 2024)

## RESULTS AND DISCUSSION

### Dataset

The dataset provides a quantitative foundation for understanding the structural properties of research output in the domain of palm oil leaves. As summarized in Table 1, the dataset spans a 17-year period from 2008 to 2025 and comprises 88 documents sourced from 69 different journals, books, and conference outlets. This diverse source distribution demonstrates the multidisciplinary nature of palm oil leaf research, intersecting fields such as agriculture, environmental science, biotechnology,

pharmaceutical studies, and material science. The annual growth rate of 9.25% indicates steady progress in scholarly interest, with marked increases in publication frequency over time, particularly after 2014, as later figures further confirm. contributions reflects ongoing exploration and early-stage dissemination of findings, which often precede journal publication in emerging research fields.

**Table 1.** Detailed description of the chosen dataset along with the study's results

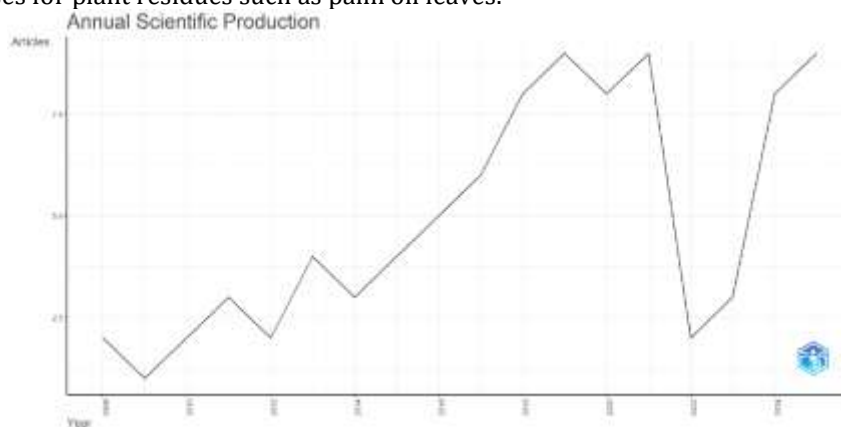
Description	Results
<b>MAIN INFORMATION ABOUT DATA</b>	
Timespan	2008:2025
Sources (Journals, Books, etc)	69
Documents	88
Annual Growth Rate %	9.25
Document Average Age	6.45
Average citations per doc	17.59
References	0
<b>DOCUMENT CONTENTS</b>	
Keywords Plus (ID)	930
Author's Keywords (DE)	316
<b>AUTHORS</b>	
Authors	310
Authors of single-authored docs	1
<b>AUTHORS COLLABORATION</b>	
Single-authored docs	1
Co-Authors per Doc	4.61
International co-authorships %	21.59
<b>DOCUMENT TYPES</b>	
article	64
book chapter	2
conference paper	18
conference review	2
erratum	1
review	1

The average age of the documents is 6.45 years, suggesting that the research field is relatively young, with most contributions emerging within the last decade. The average citation rate of 17.59 citations per document reflects healthy knowledge dissemination and suggests growing academic engagement with palm oil leaf topics. Furthermore, the dataset contains 316 unique author keywords and 930 Keywords Plus, indicating high thematic diversity and exploratory research patterns. This richness in keyword representation aligns with the characterization of palm oil leaf research as an emergent domain without yet fully consolidated conceptual boundaries.

Authorship patterns further illuminate the social structure of the research community (Gupta et al., 2021b). The dataset includes 310 authors, with only one single-authored document, demonstrating that research in this field is predominantly collaborative. The average co-authorship rate of 4.61 per document and an international co-authorship rate of 21.59% highlight the increasing globalization of scientific cooperation. These patterns are consistent with broader trends in biomass, green technology, and agricultural research, where interdisciplinary collaboration and cross-border partnerships are essential to addressing complex challenges. Document types within the dataset further underscore the field's developmental stage. Of the 88 documents, 64 are peer-reviewed journal articles, followed by 18 conference papers, 2 conference reviews, 2 book chapters, 1 erratum, and 1 review paper. The relatively high proportion of conference.

### Publication and Citation Structure

The temporal evolution of palm oil leaf research is illustrated in Figure 2, which documents annual publication output between 2008 and 2025. The graph shows clear evidence of a developing research field, with a slow initial emergence followed by sustained growth after 2014 (Ghorbani, 2024). This upward trend reflects rising awareness of palm oil biomass valorization and increased global attention to sustainable resource management. As palm oil production continues to expand in Southeast Asia, researchers have increasingly recognized the need to address biomass waste and explore alternative uses for plant residues such as palm oil leaves.



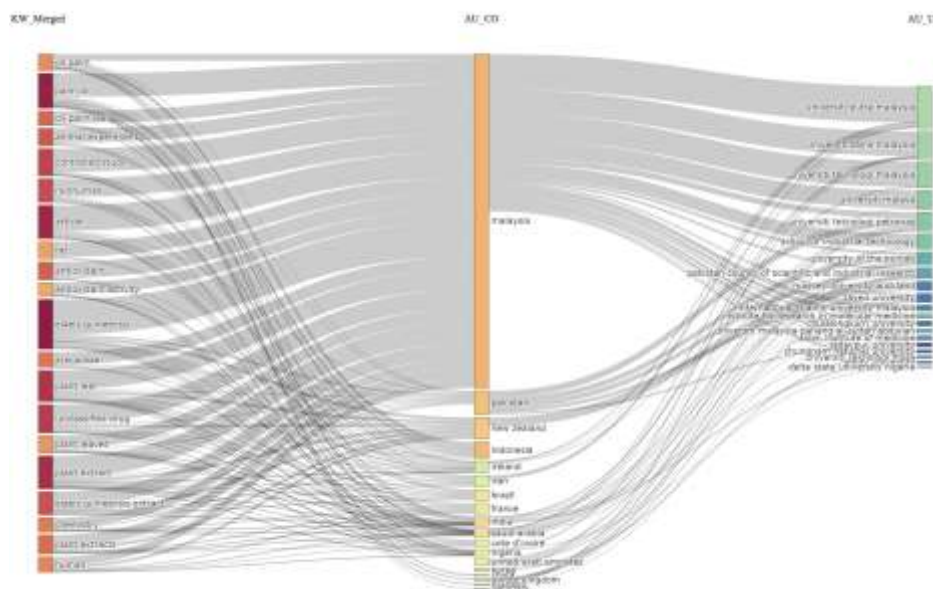
**Figure 2.** Scientific Article Production by Year

Although publication data for 2025 remains incomplete due to the ongoing nature of the year at the time of database querying, visible projections suggest continued growth, indicating that palm oil leaf research is gaining momentum rather than reaching saturation. The citation structure parallels this trend, with highly cited papers generally emerging after 2014, reinforcing the notion that research activity has intensified in recent years. This growth in publications and citations aligns with global policy shifts toward circular economy models and sustainable waste management, as well as increasing interest in natural bioactive compounds, biomaterials, and renewable feedstocks. Literature in the broader field of palm biomass utilization corroborates these patterns, demonstrating that undeveloped plant residues offer promising research opportunities in bioproduct innovation, pharmaceutical development, and biodegradable materials. (Pachauri & Singh, 2025)

### Thematic and Geographic Patterns: Three-Field Plot Analysis

The three-field plot (Figure 3) provides a vivid representation of the interplay between publication countries, author keywords, and institutional affiliations. This Sankey diagram reveals that research activity is geographically concentrated in a small number of countries: Malaysia, Pakistan, New Zealand, and Indonesia emerge as the most prominent contributors. Such dominance by Malaysia is unsurprising given its position as one of the world's leading palm oil producers and the strategic prioritization of palm biomass research within national innovation agendas.

The diagram also highlights that palm oil leaf research is thematically concentrated around applications such as detection, chemical profiling, and utilization technologies. Keywords associated with bioactive compounds, biomass conversion, and material science applications appear frequently, reflecting growing scientific recognition of the potential value embedded in palm oil leaves. These emerging themes align with global trends in phytochemistry and sustainable biomaterials research, where scholars have increasingly explored non-traditional plant residues as sources of functional compounds and renewable resources.



**Fig 3.** Three Field Plot (Sankey Diagram) of Country, Keywords and affiliation of publication for the ten most researched topics.

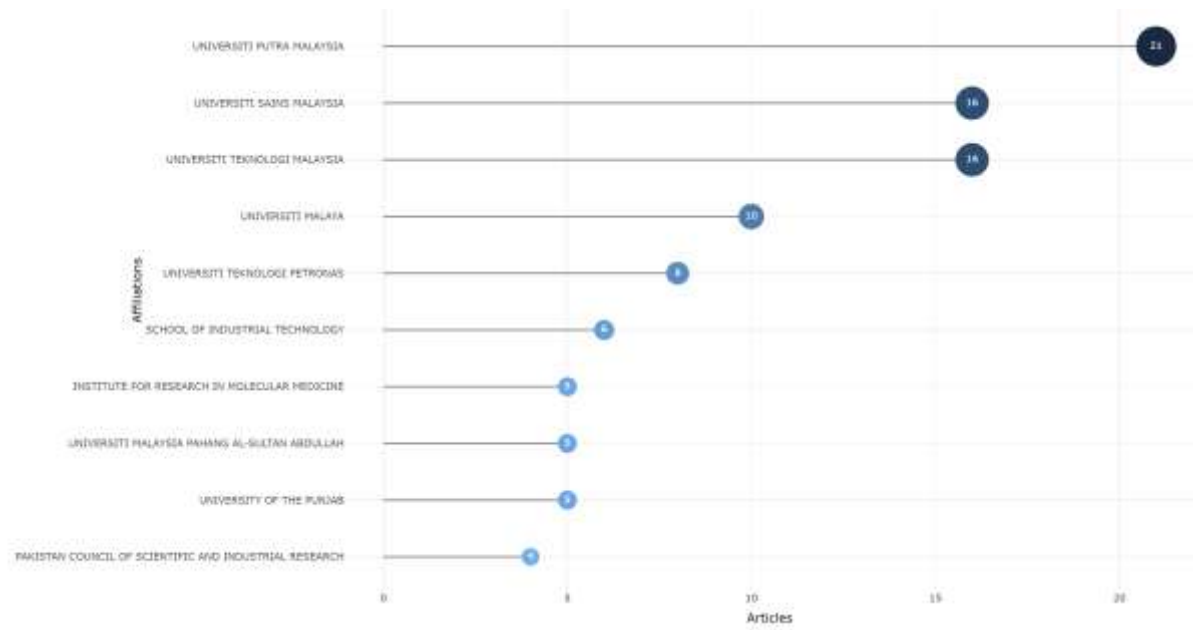
Malaysian universities—particularly Universiti Putra Malaysia (UPM)—dominate the research landscape, supported by strong agricultural and biotechnology research infrastructures. The prominence of Malaysian institutions also reflects governmental efforts to propel the nation toward a knowledge-based economy through strategic investments in the palm oil sector (Singh et al., 2022). Pakistan, New Zealand, and Indonesia also contribute significantly, indicating expanding international interest beyond traditional palm-producing regions.

#### Most Relevant Affiliations

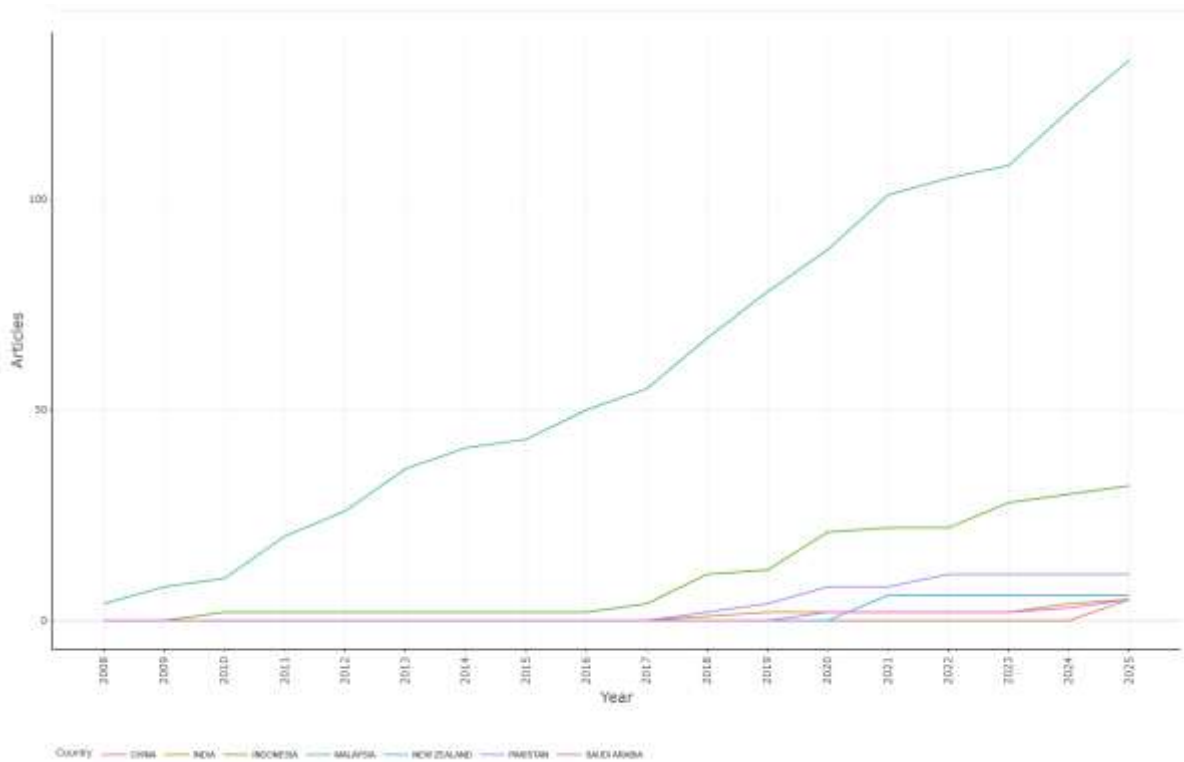
The affiliation analysis presented in Figure 4 examines how different research institutions contribute to palm oil leaf scholarship. UPM stands out as the leading institution both in terms of publication frequency and citation count. Its longstanding research capacity in agricultural science, plant biology, and biomass processing positions it uniquely to drive innovation in this domain. The institution's strong alumni research output further reflects a sustained tradition of excellence in palm-related studies.

#### Country's Production Over Time

The temporal distribution of publications by country, illustrated in Figure 5, sheds light on longitudinal shifts in global research participation. Malaysia demonstrates the highest sustained research activity across the entire 2008–2025 period, confirming its leadership in this field. Pakistan and Indonesia show increasing contributions in the later years, indicating growing engagement with palm oil leaf topics among countries seeking to advance their biomass utilization strategies. These patterns reflect broader regional developments in Southeast Asia and South Asia, where national policies increasingly encourage circular economy models, agro-industrial innovation, and sustainable waste management. Indonesia's growing research activity aligns with its emergence as the world's largest palm oil producer, which carries both economic opportunity and pressure to develop sustainable residue management strategies. Similarly, Pakistan's involvement suggests a broader regional interest in bioresource research and agricultural innovation, even in countries where palm oil is not a dominant industry. New Zealand's participation, though less prolific, highlights the widening global appeal of plant-based natural product research and the cross-disciplinary relevance of palm biomass studies (Kuswa et al., 2025).



**Fig 4.** Affiliation Statistics of Palm oil Leaves research

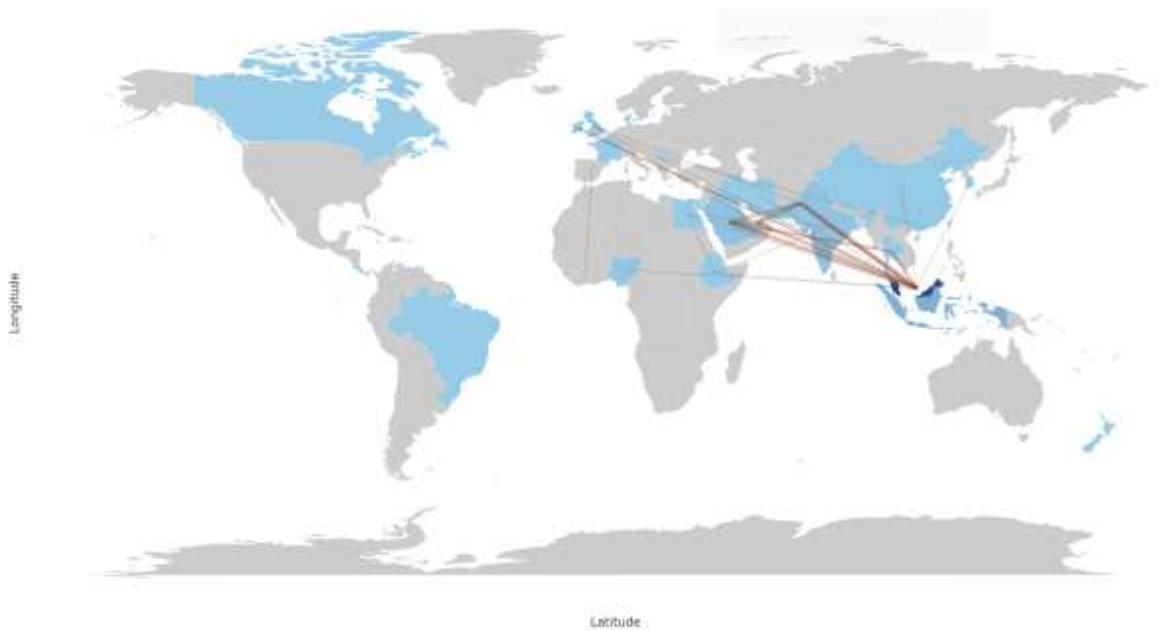


**Fig 5.** Country's Production Overtime of studies of palm oil leaves .

Other institutions, including the Pakistan Council of Scientific and Industrial Research (PCSIR) and universities in New Zealand and Indonesia, contribute to a more diversified global network. However, their output remains comparatively modest. This distribution suggests a potential area for strengthening international academic partnerships, especially between high-output and emerging institutions. The concentration of publications in Malaysian universities underscores not only geographical proximity to palm plantations but also the country's extensive expertise in palm-based industries and its leadership in palm biomass valorization research (Singh et al., 2022). The citation patterns reveal that Malaysian institutions are not only prolific but also influential, with their publications serving as central nodes in the academic discourse.

### Collaboration World Map

The Collaboration World Map shown in Figure 6 illustrates the increasingly global and interconnected nature of palm oil leaf research. International collaboration has become a defining feature of agricultural and environmental science, driven by the need for specialized expertise, advanced analytical technologies, and shared knowledge resources. The visualization indicates that many palm oil leaf studies involve multinational research teams, fostering intellectual exchange and enhancing research quality.



**Fig 6.** Spatial Distribution of Total Publications by Country

Such collaboration is particularly evident between Malaysia and research institutions in Pakistan, Indonesia, and other Asian countries (Singh et al., 2022). This pattern reflects shared environmental challenges and complementary research capacities within the region. Additionally, global crises such as the COVID-19 pandemic have accelerated digital collaboration, allowing researchers to exchange data and ideas across borders despite physical restrictions. The increasing trend in international co-authorship, quantified at 21.59% within this dataset, also suggests growing recognition of palm oil leaves as a research topic of global significance. This aligns with international shifts toward bioeconomy strategies and interest in plant-based raw materials for pharmaceuticals, renewable materials, and functional biomolecules.

## CONCLUSIONS

This scientometric review provides a comprehensive assessment of global research on palm oil leaves from 2008 to 2025, revealing a steadily expanding field characterized by increasing publication output, diverse thematic exploration, and growing international collaboration. The analysis of 88 Scopus-indexed documents demonstrates that scholarly interest in palm oil leaves has accelerated particularly after 2014, reflecting broader global shifts toward biomass valorization, sustainable material development, and green economic transformation. Malaysia emerges as the dominant contributor in terms of publication volume, institutional engagement, and citation impact, while Pakistan, Indonesia, and New Zealand represent emerging contributors that broaden the geographic scope of the research landscape. Thematic patterns identified through keyword mapping show strong emphasis on chemical profiling, bioactive compound discovery, biomass utilization technologies, and preliminary pharmaceutical applications, suggesting that palm oil leaves possess significant scientific and industrial potential beyond their current status as agricultural waste. The findings carry important implications for the advancement of sustainable resource management and innovation in plant-based industries. By highlighting the bioactive and biomaterial potential of palm oil leaves, this study underscores opportunities for developing high-value applications that support circular economy principles and reduce biomass disposal burdens in major palm-producing countries. Scientometrically, the study contributes to the existing body of knowledge by offering the first comprehensive mapping of research trends, intellectual structures, and collaborative networks in this emerging domain. Future research should expand experimental investigations into pharmaceutical and functional material applications, explore advanced extraction and processing technologies, and deepen interdisciplinary collaborations to fully unlock the potential of palm oil leaf biomass. Together, these directions hold promise for transforming an underutilized residue into a valuable scientific and industrial resource.

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