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BIBLIOMETRIC ANALYSIS OF ENVIRONMENTAL AND CLIMATE CHANGE VARIABLES IN PALM OIL PRODUCTION MODELS: TRENDS AND INTELLECTUAL LANDSCAPES

ANALISIS BIBLIOMETRI PEMBOLEH UBAH ALAM SEKITAR DAN PERUBAHAN IKLIM DALAM MODEL PENGELUARAN MINYAK SAWIT: TREND DAN LANDSKAP INTELEKTUAL

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Abstract

Palm oil is one of the most important global commodities, yet its production is often linked to deforestation, greenhouse gas emissions, and climate vulnerability. This raises the need to examine how environmental and climate-related factors are integrated into production efficiency models. Motivated by these sustainability concerns, this study conducts a bibliometric analysis of research published between 1989 and 2024 using the Scopus database. Bibliometric mapping techniques were applied to assess publication trends, citation impacts, co-authorship networks, and thematic shifts in the literature. The results show a consistent growth in research output, with a marked increase after 2017, reflecting heightened global attention to sustainability and climate resilience. While Malaysia and Indonesia dominate in publication volume, European and Australian institutions achieve higher citation impacts, often focusing on regulatory policies and mitigation strategies. Interdisciplinary collaboration remains limited, and systematic modelling of variables such as drought resilience and carbon sequestration is often absent. Thematic evolution highlights a transition from waste and pollution management (2006–2010) to sustainability and climate adaptation strategies (2018–2024). This study highlights key research gaps and emphasizes the need for stronger interdisciplinary collaboration, climate-resilient models, and policy-driven innovations to advance sustainable palm oil production.

Keywords: Bibliometric analysis, palm oil production, environmental variables, efficiency models

Abstrak

Minyak sawit merupakan salah satu komoditi global yang paling penting, namun pengeluarannya sering dikaitkan dengan masalah penebangan hutan, pelepasan gas rumah hijau, dan kerentanan terhadap perubahan iklim. Hal ini menimbulkan keperluan untuk meneliti bagaimana faktor alam sekitar dan iklim diintegrasikan ke dalam model kecekapan pengeluaran. Didorong oleh kebimbangan terhadap kelestarian ini, kajian ini menjalankan analisis bibliometrik terhadap penyelidikan yang diterbitkan antara tahun 1989 hingga 2024 menggunakan pangkalan data Scopus. Teknik pemetaan bibliometrik digunakan untuk menilai tren penerbitan, impak sitasi, rangkaian kerjasama pengarang, dan peralihan tema dalam literatur. Hasil kajian menunjukkan pertumbuhan berterusan dalam output penyelidikan, dengan peningkatan ketara selepas tahun 2017, mencerminkan tumpuan global yang semakin *meningkat terhadap kelestarian dan daya tahan iklim. Walaupun Malaysia dan Indonesia mendominasi dari segi jumlah penerbitan, institusi dari Eropah dan Australia mencatatkan impak sitasi yang lebih tinggi, dengan penekanan kepada dasar peraturan dan strategi mitigasi. Kerjasama antara disiplin masih terhad, dan pemodelan sistematik bagi pemboleh ubah seperti daya tahan terhadap kemarau dan penyerapan karbon sering diabaikan. Evolusi tema menunjukkan peralihan daripada pengurusan sisa dan pencemaran (2006–2010) kepada strategi kelestarian dan penyesuaian iklim (2018–2024). Kajian ini menekankan jurang penyelidikan utama dan menegaskan keperluan untuk memperkukuh kerjasama antara disiplin, membangunkan model yang berdaya tahan iklim, serta mendorong inovasi berasaskan dasar bagi memajukan pengeluaran minyak sawit yang mampan.*

Kata Kunci: *Analisis bibliometrik, pengeluaran kelapa sawit, pemboleh ubah alam sekitar, model kecekapan*

INTRODUCTION

Palm oil production efficiency and productivity are increasingly scrutinized due to their interaction with climate change. Climate change affects palm oil productivity by altering weather patterns, increasing temperatures, and intensifying extreme weather events, directly impacting crop yields and growth conditions. For instance, disruptions in rainfall and temperature variations reduce productivity, while rising pest and disease prevalence further exacerbate challenges (CABI Agriculture and Bioscience 2021). Malaysia, a major producer, is particularly vulnerable, with even slight climate deviations posing substantial economic and social risks, necessitating urgent mitigation strategies (United Nations University 2021).

Conversely, the palm oil industry significantly contributes to climate change. The expansion of plantations often leads to large-scale deforestation, especially in tropical regions like Indonesia and Malaysia. Peatland drainage and deforestation release substantial carbon emissions, with over 3.7 million hectares of forests cleared for plantations, contributing to approximately 20% of global emissions (Yale Center for Business and the Environment 2023). Despite this, 93% of palm oil producers have not conducted comprehensive climate risk assessments, highlighting critical gaps in environmental responsibility (Zoological Society of London 2023).

To address these challenges, strategies such as regenerative agriculture—incorporating mixed cropping, agroforestry, and reduced chemical use—have been proposed to enhance sustainability. However, adoption remains limited in the $70 billion palm oil industry (Reuters 2024a). Additionally, government policies and industry reforms are being implemented, including improved farming practices, yield enhancement, and replanting programs with high-yield varieties. Indonesia, for example, targets an 83-million-ton production increase by 2045 to meet biofuel demand while minimizing environmental harm (Reuters 2024b).

Integrating climate variables into palm oil production models can help quantify these risks and inform sustainable practices. Common approaches include incorporating temperature, rainfall, humidity, and extreme weather indices as explanatory variables in econometric models (e.g., panel data regressions or stochastic frontier analyses), which allow researchers to assess how climatic fluctuations affect yield efficiency and productivity. Crop simulation models, such as DSSAT or APSIM, can integrate soil, water, and climate data to simulate growth under different scenarios, while spatial and remote sensing models link geospatial climate data with plantation locations to capture regional heterogeneity. Moreover, risk and scenario-based modelling—for instance, combining climate projections with yield-response functions—can estimate potential future impacts of climate change, including drought, flooding, or heat stress, on palm oil output. By systematically incorporating these variables, models can better reflect both short-term fluctuations and long-term trends in productivity.

Given these complexities, bibliometric analysis is a valuable tool for identifying research trends, gaps, and contributions in palm oil production and climate change studies. Many prior reviews focus on limited time spans or specific developments, neglecting the historical integration of climate considerations in palm oil production (de Souza et al. 2023). While research clusters on sustainability and environmental quality in Southeast Asia exist, bibliometric studies often overlook how climate variables have been modelled across regions. Key themes like drought resilience and carbon sequestration remain underexplored.

Moreover, existing bibliometric reviews tend to emphasize publication trends, authorship networks, and citation patterns rather than methodologies for incorporating climate variables into palm oil production models. Identifying commonly used modelling techniques and key environmental variables is crucial. Additionally, the intersection of environmental sciences, climate studies, and agricultural economics in palm oil research remains understudied. A bibliometric review of interdisciplinary collaborations and their impact on production efficiency models could bridge this gap. While studies such as Chatra et al. (2023) explore sustainable business practices, there is limited bibliometric work linking research outputs to policy implications, particularly concerning climate-resilient strategies.

This study aims to conduct a bibliometric review of research incorporating environmental or climate change variables into palm oil production efficiency models, focusing on the Scopus database from 1989 to 2024. It seeks to identify key research trends, gaps, and clusters, analyse the evolution of modelling methodologies, and explore interdisciplinary collaborations. The findings will enhance understanding of how environmental and climate considerations have been systematically integrated into palm oil research, providing insights for future research and policymaking.

METHODOLOGY

Bibliometric network analysis was used to examine the inclusion of environmental and climate change variables in palm oil production models. This approach uncovers research trends, thematic patterns, and key relationships within the field. Bibliometric network analysis systematically reviews publications on a topic, constructing a relational and contextual intellectual framework (Chen 2001; Iqbal et al. 2019; Churruca et al. 2019). It integrates visual analysis tools with mathematical techniques to explore co-authorship networks, co-citation patterns, and keyword trends, providing insights into literature distribution and research structures.

Data Collection and Analysis

i. Database Selection: SCOPUS

SCOPUS was selected as the primary database due to its extensive coverage of high-quality, peer-reviewed literature across environmental science, agriculture, and economics. Its indexing and analytical tools support efficient trend identification and citation analysis, ensuring credibility and relevance. However, reliance on SCOPUS may exclude relevant studies from other databases, potentially limiting the comprehensiveness of the review.

ii. Publication Period: 1989–2024

The study covers publications from 1989 to 2024, capturing both historical and contemporary developments in integrating environmental and climate variables into palm oil production models. The start year coincides with growing global awareness of sustainability issues, including the Brundtland Report (1987), allowing for long-term trend analysis.

iii. Search Strategy and Document Selection

A systematic SCOPUS search using the keywords:
“palm” AND “oil” AND “production” AND “efficiency” OR “productivity” AND “environmental” AND “model” retrieved 72 documents. After excluding one Spanish-language study, 71 English-language publications were selected to ensure high-quality, linguistically accessible research. It should be noted that excluding non-English publications may omit valuable regional insights into palm oil sustainability. Additionally, variations in citation practices across disciplines may influence the perceived impact of certain research contributions.

iv. Bibliometric Analysis Using R-Studio

The selected publications were analysed using bibliometric methods to identify research trends, clusters, and methodologies for incorporating climate and environmental variables into palm oil production models. Citation analysis, co-authorship networks, and keyword co-occurrence were examined to map the evolution of modelling approaches and interdisciplinary collaborations. The analysis considered the limitations discussed above to ensure a transparent interpretation of trends and contributions.

A bibliometric analysis was conducted using R-Studio's Bibliometrix and Biblioshiny packages (Aria & Cuccurullo 2017), which offer statistical and machine-learning tools for bibliometric research. The analysis examined publication output, tracking research volume over time; average citations, assessing study impact; source impact, evaluating journal influence; authorship, identifying key researchers and collaborations; publication patterns, understanding research dissemination trends; keyword distribution, mapping thematic focus and emerging topics; and most cited articles, highlighting foundational research.

This method provides a comprehensive overview of intellectual progress in integrating environmental and climate considerations into palm oil production. The findings offer valuable insights for researchers, policymakers, and industry stakeholders in advancing sustainable palm oil and climate resilience.

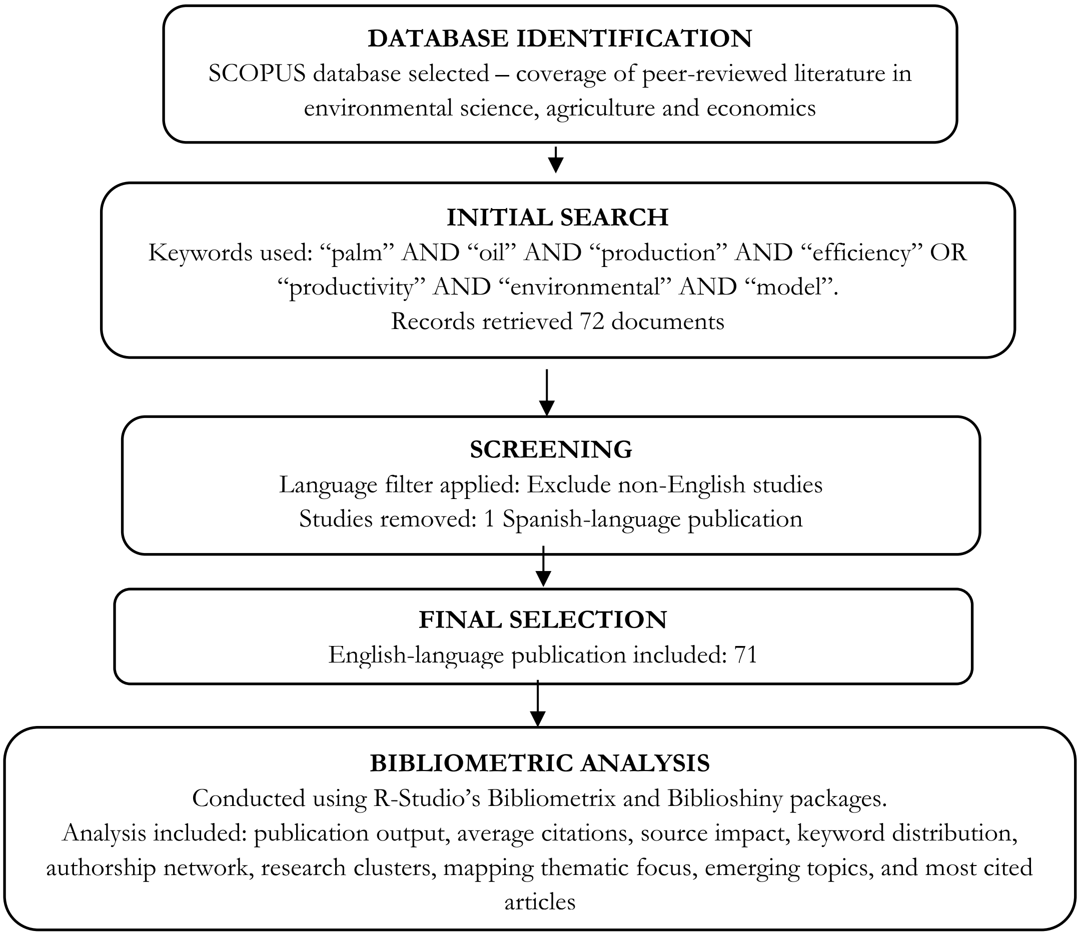

Figure 1. Flow Diagram of Document Selection Process

RESULTS AND DISCUSSION

Descriptive analysis of publications

The bibliometric analysis of research on environmental and climate change variables in palm oil production (Table 1) shows steady growth over the past 35 years. From 1989 to 2024, 71 documents were published across 56 sources, with an annual growth rate of 5.72%, reflecting sustained academic interest. The average document age of 6.65 years indicates ongoing research, while an average citation of 19.97 suggests strong academic influence. With 3,635 references, the field builds on a well-established knowledge base.

Keyword analysis revealed 832 Keywords Plus (ID), reflecting broad interdisciplinary engagement, and 263 Author's Keywords (DE), representing focused research themes. The gap between these suggests that bibliometric indexing captures a wide range of topics, while authors highlight more precise themes. This indicates the complexity of environmental and climate-related research in palm oil production.

Authorship trends indicate a highly collaborative research environment, with 330 authors and only two single-authored papers. The average co-authorship rate of 4.89 per document and an international collaboration rate of 43.66% highlight global engagement in sustainable palm oil research.

Regarding publication types, 56 of 71 documents are journal articles, demonstrating rigorous peer-reviewed contributions. Additionally, four book chapters, four conference papers, and five conference reviews support knowledge exchange beyond journals. However, only one review paper suggested a gap in comprehensive synthesis studies, highlighting the need for systematic reviews or meta-analyses. One erratum indicated minor corrections, ensuring academic accuracy.

Overall, bibliometric trends show expanding, highly collaborative, and globally relevant research on environmental factors in palm oil production. The high citation impact underlines its significance in sustainability and climate change discourse. Future research could benefit from systematic reviews, policy-focused studies, and innovations in climate-resilient agricultural practices.

Table 1. Descriptive analysis of publications

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	1989:2024
Sources (Journals, Books, etc)	56
Documents	71
Annual Growth Rate %	5.72
Document Average Age	6.65
Average citations per doc	19.97
References	3635
DOCUMENT CONTENTS	
Keywords Plus (ID)	832
Author's Keywords (DE)	263
AUTHORS	
Authors	330
Authors of single-authored docs	2
AUTHORS COLLABORATION	

Single-authored docs	2
Co-Authors per Doc	4.89
International co-authorships %	43.66
DOCUMENT TYPES	
Article	56
book chapter	4
conference paper	4
conference review	5
Erratum	1
Review	1

Annual Scientific Production and Average Article Citation

Figure 2 illustrates a consistent rise in research on environmental and climate change variables in palm oil production, with significant growth observed in recent years. This trend reflects the rising academic and policy interest in understanding palm oil's environmental impact. The first recorded study appeared in 1989, followed by a research gap between 1990 and 2005, indicating limited initial attention to this topic. A single publication emerged in 2006, but research remained sporadic until 2009, when more consistent contributions began to appear. From 2009 to 2016, research output showed gradual growth, with minor fluctuations. Notably, 2014 saw six publications, marking an increased academic focus, though output declined slightly in 2015 with only one article.

From 2017 onward, research activity maintained a consistent upward trajectory, with 5 articles published in 2017, 3 in 2018, 4 in 2019, and 6 in 2020. This period suggests a deepening engagement with environmental and climate-related challenges in palm oil production. The sharp increase in 2021, with 10 published articles, represents the highest recorded output in this dataset, likely driven by growing awareness of climate change and sustainability issues. Although there were slight fluctuations in the following years, the number of publications remained relatively high, with 7 articles in 2022, 9 in 2023, and 7 in 2024. The sustained level of research over the past four years suggests that this field has gained traction in academic and policy discussions, shifting from a niche area to a more established topic of study.

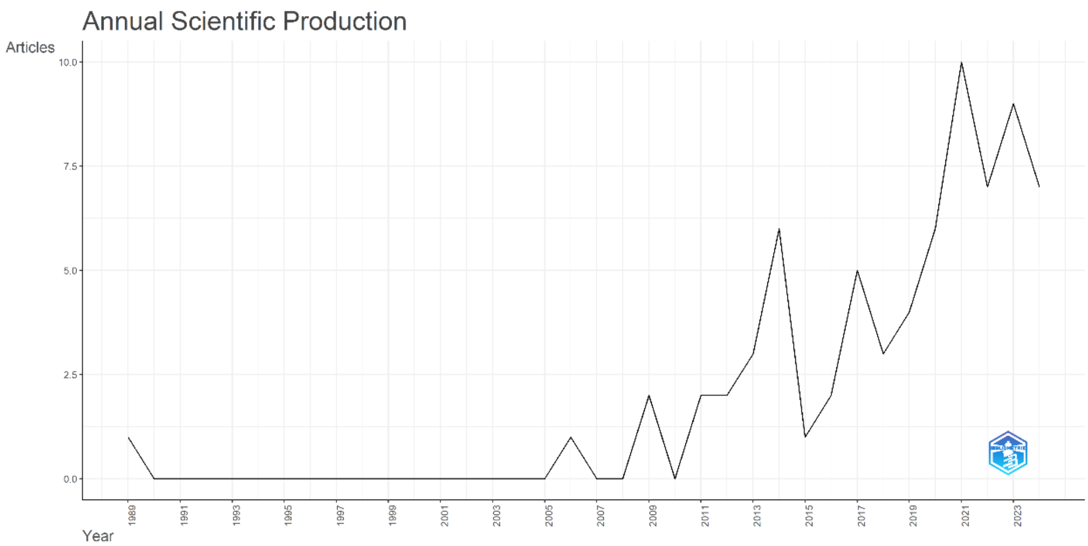

Figure 2. Volume of scientific production yearly
Source: R-Biblioshiny Outputs

Citation trends provide insight into the academic influence and longevity of research in this field. The earliest study from year 1989 remains relevant after 37 years, averaging 49 citations per article with a yearly rate of 1.32 (see Figure 3). A year 2006 publication has 25 citations over 20 years, with an annual rate of 1.25. Research activity increased between years 2009 and 2016, though citation impact varied. Studies from year 2009 had lower influence (0.38 citations per year), while those from 2011 and 2012 gained more attention, averaging 45 and 46 citations, with annual rates of 3.00 and 3.29. Research from years 2015 and 2016 saw significant citation spikes, with the 2015 study averaging 54 citations per article (4.91 per year), while year 2016 studies were the most influential, averaging 100 citations with a yearly rate of 10.00.

Between years of 2017 and 2020, research continued to expand with stable citation rates. Studies from 2017 had a moderate yearly rate of 1.67, while those from years 2018 and 2019 saw increases to 2.88 and 3.14. Research from year 2020 averaged 30 citations per article, with a yearly rate of 5.00, reflecting growing significance. Since year 2021, publications have increased, but citation impact is lower. Articles from year 2021 averaged 15.90 citations (3.18 per year), while years 2022 and 2023 studies saw declines to 12.14 and 5.78, suggesting newer research may take time to gain recognition. Studies from year 2024 currently have the lowest citation rate, averaging 1.00 citation per article with a yearly rate of 0.50, likely due to their recent publication.

Older studies, particularly from years 1989, 2006, 2011, and 2016, have demonstrated lasting academic influence, with year 2016 research standing out as the most impactful. Studies from year 2017 to 2020 maintained steady growth, while those from year 2021 onward are still accumulating citations. Research on environmental and climate change variables in palm oil production has expanded significantly, with increasing relevance in sustainability and policy discussions. As newer studies gain recognition, citation trends will offer further insights, with future research likely focusing on policy implications, technological advancements, and climate-resilient agricultural strategies.

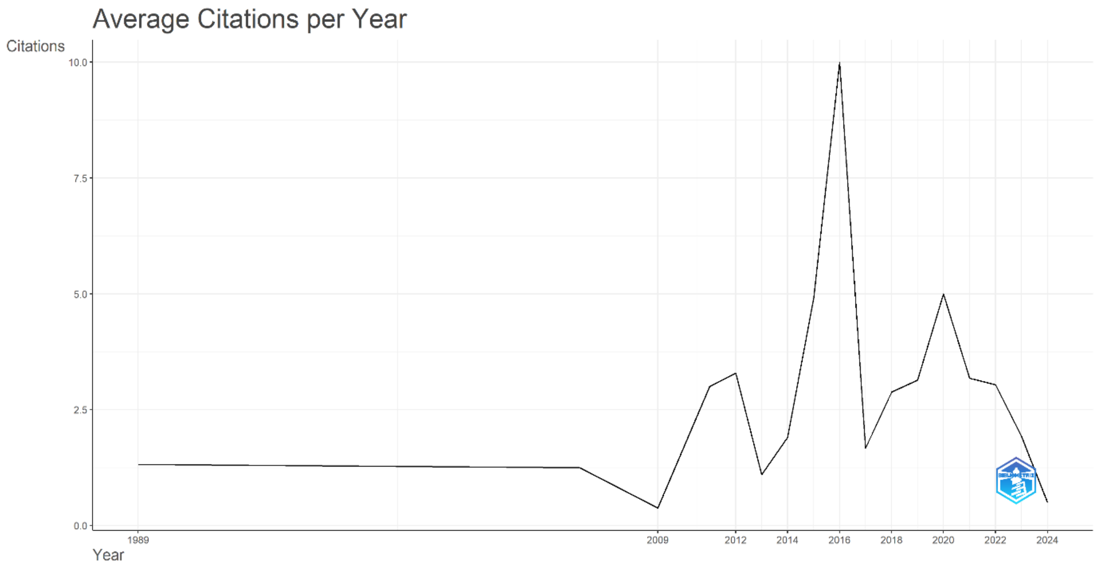

Figure 3. Average Citations Per Year
Source: R-Biblioshiny Outputs

Analysis of Research Sources

Key sources in this field reflect a diverse range of journals and conferences contributing to research on environmental and climate change variables in palm oil production. Studies are distributed across multiple platforms, with some journals publishing multiple articles while others contribute only once (see Figure 4). The most frequently appearing sources are Advanced Materials Research and the

Journal of Cleaner Production, each with five articles, highlighting their role in environmental sustainability, material science, and technological advancements in palm oil production. While the Journal of Cleaner Production emphasizes sustainability and industrial ecology, Advanced Materials Research focuses on technological and engineering aspects of palm oil's environmental impact.

Following these, IOP Conference Series: Earth and Environmental Science and PLOS ONE each contain three relevant articles. The IOP Conference Series suggests a strong presence of conference contributions, while PLOS ONE, as an open-access journal, helps widely disseminate findings on climate change and palm oil sustainability. Other key sources, such as Environmental Research Letters, Forest Policy and Economics, and Frontiers in Sustainable Food Systems, each feature two articles, reflecting an interdisciplinary approach that integrates environmental science, policy, and economics.

Many sources contribute a single article, underscoring the broad and interdisciplinary nature of palm oil research. These range from engineering (ACS Sustainable Chemistry and Engineering, Chemical Engineering Transactions), agriculture (Journal of the Saudi Society of Agricultural Sciences, Field Crops Research), and environmental science (Environmental Science and Pollution Research, Ecological Applications) to energy research (Energy Conversion and Management, Renewable Energy). High-impact journals like Nature Communications and Molecules also make contributions, alongside conference proceedings such as AIP Conference Proceedings and IOP Conference Series: Materials Science and Engineering, emphasizing the importance of conferences in ongoing sustainability discussions.

Generally, research on environmental and climate change aspects of palm oil production is widely distributed across environmental science, engineering, policy, and sustainability studies. The prominence of journals focusing on cleaner production, sustainability, and materials research highlights a strong emphasis on technological and policy-driven solutions. This diversity in publication venues underscores the complexity of the field and the need for an integrated, interdisciplinary approach to addressing sustainability challenges in palm oil production.

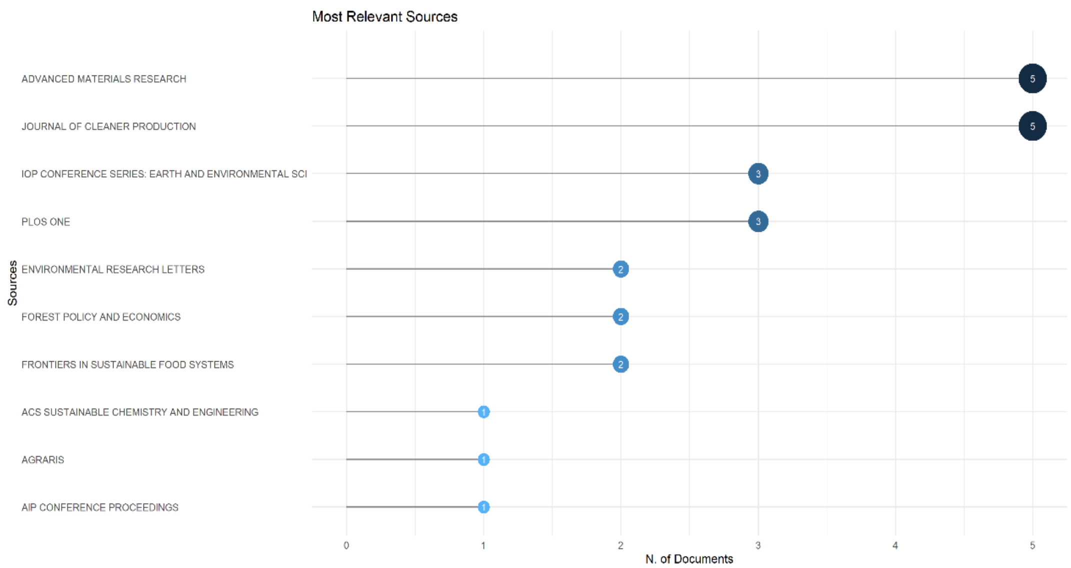

Figure 4. Most Relevant Sources
Source: R-Biblioshiny Outputs

Country Scientific Production and Country Production Overtime

Analysis of country-specific research on environmental and climate factors in palm oil production reveals notable geographical disparities (Figure 5). Malaysia (83 publications) leads due to its dominant production role, followed by Indonesia (42), reflecting both nations' focus on sustainability amid economic interests. European countries, particularly Germany (46), also contribute significantly, driven by strong policy and academic attention to deforestation, climate change, and EU regulations. Other European contributors include the UK (12), France (9), the Netherlands (8), Belgium (6), and Switzerland (6), emphasizing sustainability, carbon emissions, and alternative energy (Figure 5).

In the Americas, Brazil (38) and Colombia (18) show growing research outputs, linked to expanding palm oil industries and concerns over deforestation and biodiversity, while the US has limited engagement (2 publications). African contributions are low despite industry growth; Cameroon (9) and Nigeria (2) lead, with other nations like Egypt (3), Morocco (4), and South Africa (1) showing minimal output, likely due to funding and institutional constraints. China (12), Australia (12), and Japan (2) also contribute, reflecting global awareness, with China focusing on supply chain sustainability.

Overall, research is concentrated in major producers (Southeast Asia) and European nations with policy-driven agendas, while Africa and the Americas show potential research gaps. Malaysia's output surged from 42 publications in 2020 to 83 in 2024, driven by global pressure and sustainability initiatives; Indonesia shows a similar but later trend. Brazil's modest output rose from 11 in 2016 to 38 in 2024, linked to Amazon deforestation concerns. Germany's research jumped after 2016, reaching 46 publications by 2023–2024, reflecting EU sustainability priorities. Colombia began publishing in 2020, reaching 18 by 2024, aligning with international sustainability standards.
These trends indicate that research reflects countries' roles in the palm oil industry: Malaysia and Indonesia lead for economic and environmental reasons, Germany for sustainability policies, and Brazil and Colombia as emerging contributors, highlighting growing global attention to palm oil's environmental impact.

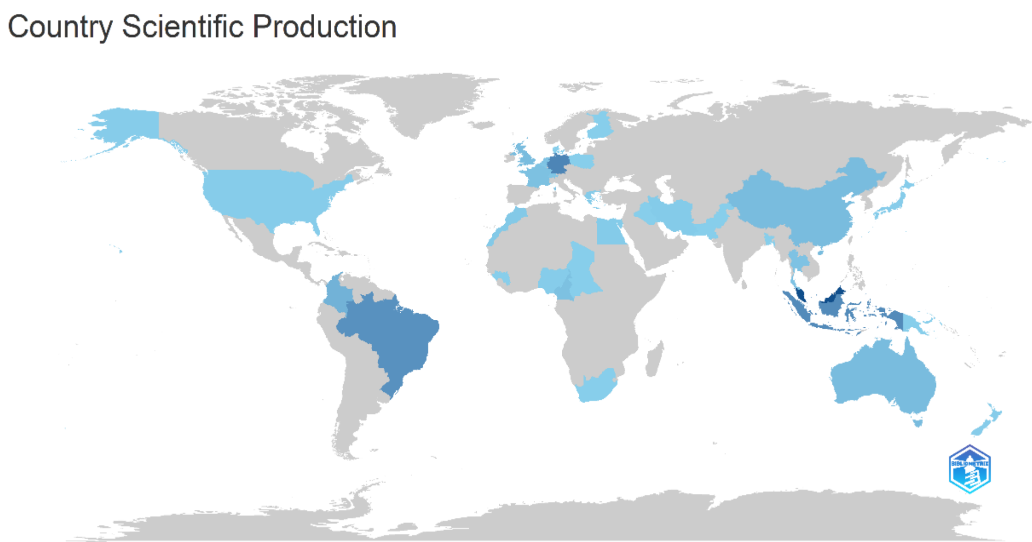

Figure 5. Country Specific Production
Source: R-Biblioshiny Outputs

Most Relevant Affiliations

The study highlights key institutions leading research on palm oil's environmental impact. Figure 6 shows the top ten contributors, with strong representation from Malaysia, Germany, Brazil, and Indonesia—major stakeholders in palm oil production and sustainability. Georg August University Göttingen (Germany) leads with 34 publications, reflecting Germany's focus on sustainability, deforestation, and climate change related to palm oil. This aligns with its role as a key consumer promoting sustainable certification.

Universiti Putra Malaysia (UPM) follows with 20 articles, reinforcing Malaysia's leadership in sustainable palm oil research. Other Malaysian universities, such as Universiti Teknologi Malaysia (8 articles) and Universiti Malaysia Pahang (7 articles), contribute significantly, showcasing a strong national research network. Brazilian universities also play a notable role. Universidade Federal do Rio de Janeiro (UFRJ) has 11 articles, while the State University of West Paraná has 7. Their research likely focuses on deforestation, biodiversity, and sustainable agriculture in response to Brazil's expanding palm oil sector.

Indonesia, the world's largest palm oil producer, is represented by Bogor Agricultural University and Universitas Gadjah Mada, each contributing 2 articles. Though lower than Malaysia's, this indicates Indonesia's growing focus on sustainability in palm oil. European institutions also contribute, including Ghent University (5 articles), Wageningen University & Research (4 articles), and Imperial College London (2 articles), reflecting the EU's engagement in sustainability policies. The Potsdam Institute for Climate Impact Research (PIK) (4 articles) likely focuses on deforestation, carbon emissions, and climate policy.

Research extends beyond traditional palm oil regions, with contributions from Chulalongkorn University (Thailand, 4 articles), University of Yaoundé I (Cameroon, 5 articles), and Politécnico Grancolombiano University (Colombia, 5 articles). Emerging research hubs, such as Cenipalma (Colombia, 2 articles), reinforce the region's growing role in palm oil sustainability. Organizations like World Agroforestry (ICRAF) and CIFOR highlight links between palm oil and global forestry conservation.

Overall, the research landscape is diverse, dominated by Malaysia and Germany, with strong contributions from Brazil, Indonesia, and European sustainability-focused institutions. The findings highlight palm oil's global environmental impact and the need for collaboration between producer and consumer nations to advance sustainable palm oil models balancing economic growth and conservation.

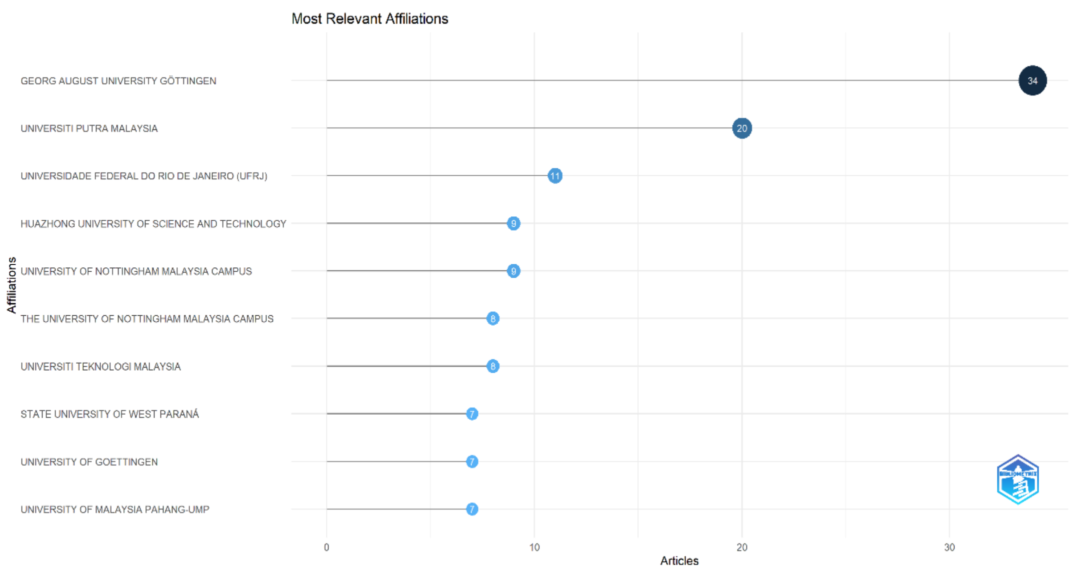

Figure 6. The First Ten Most Relevant Affiliations
Source: R-Biblioshiny Outputs

Most Cited Countries and Most Cited Documents

The analysis of the most cited countries in palm oil research highlights the top ten contributors based on total citations (TC) and average citations per article. As shown in Figure 7, Malaysia leads with 398 citations and an average of 22.10 per article, reflecting its pivotal role in palm oil production and sustainability research. Sweden follows with 199 citations but a significantly higher impact of 199 citations per article, suggesting a focus on climate change mitigation and sustainable supply chains. Brazil, with 143 citations (23.80 per article), contributes research on deforestation, biodiversity loss, and carbon footprint assessments.

European nations, including France (68 citations, 34.00 per article), Switzerland (56 citations, 56.00 per article), and Greece (34 citations, 34.00 per article), maintain strong research influence despite lower overall citations, likely focusing on policy and sustainability frameworks. Australia (55 citations, 55.00 per article) also makes a notable impact in environmental and trade-related research.

Indonesia, the largest palm oil producer, has 47 citations (9.40 per article), indicating a significant research presence but lower international visibility due to language barriers and localized studies. Colombia (42 citations, 10.50 per article), Germany (39 citations, 13.00 per article), and China (30 citations, 15.00 per article) contribute with expertise in sustainability and climate change.

Countries like the UK (9 citations), Belgium (3 citations), Morocco (2 citations), and the USA (1 citation) show minimal engagement in palm oil research, with the USA likely focusing on regulatory aspects rather than direct studies. Egypt and Nigeria have no recorded citations, highlighting research gaps in Africa despite Nigeria's expanding palm oil sector.

Thus, Malaysia, Brazil, and Indonesia dominate research output, while Sweden, France, Switzerland, and Australia achieve higher citation impact per article, emphasizing high-profile topics like climate change mitigation. Indonesia's relatively low citation influence suggests the need for greater international collaboration. As global demand for sustainable palm oil grows, stronger partnerships between producer and consumer nations will be key to shaping future policies and sustainability efforts.

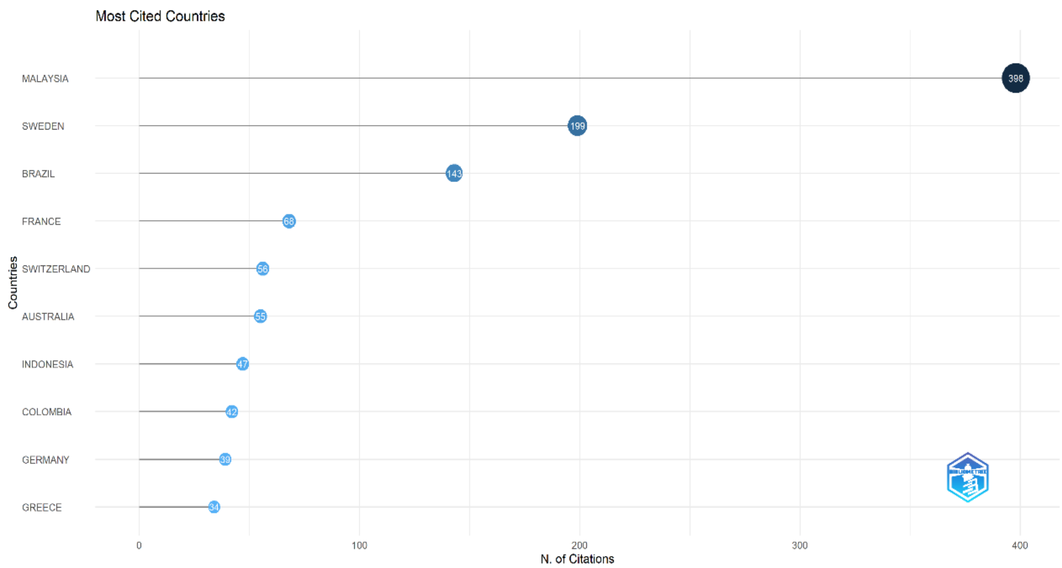

Figure 7. Most Cited Countries
Source: R-Biblioshiny Outputs

Analyzing highly cited papers is essential for identifying key trends in environmental and climate change studies related to palm oil production. These influential works shape policies, industry practices, and sustainability frameworks. By assessing them, researchers can gain insights into critical discussions and methodologies advancing this field. Globally cited papers are referenced across international sources, often covering broad topics like sustainability, deforestation, and climate change policies. Locally cited papers, in contrast, focus on country-specific case studies, local regulations, or regional socio-economic effects. Key citation metrics include Total Citations (TC), Citations per Year (TC per Year), and Normalized Total Citations (Normalized TC).

Among top studies, Clough Y (2016) in Nature Communications leads with 199 citations, averaging nearly 20 per year and a normalized TC of 1.99, showing sustained academic interest. Abram NK (2014) follows with 81 citations but a higher normalized TC of 3.55, indicating concentrated engagement in recent years. Other notable works include Cheah (2020) in Bioengineered (73 citations, 12.17 per year) and Ashrafian (2023) in Structures, which has the highest normalized TC (5.88) and a yearly rate of 11.33, reflecting rising interest in recent studies.

Moderately cited papers include Abdurahman (2011), with two works: one in Desalination (79 citations) and another in World Academy of Science, Engineering and Technology (11 citations). While influential, their normalized values suggest a more specialized impact. Garcia-Ulloa (2012) in Conservation Letters (56 citations, normalized TC of 1.22) maintains steady influence in climate research. Some recent papers, such as Bunyamin (2023) and Azodo (2023), remain uncited, likely due to their recent publication, niche focus, or limited visibility.

For locally cited papers, research spans from 1989 to 2024, showing varying degrees of international and regional recognition. Older works tend to have greater global reach, such as Lee (2014) with 27 global and 2 local citations, achieving a normalized GC of 1.18 and an LC/GC ratio of 7.41%, reflecting strong international recognition despite lower regional engagement. Abdurahman (2011) has a higher LC/GC ratio of 9.09% but lower overall impact (11 global, 1 local citation), suggesting regional relevance. Some studies, like Kerrou (2023) and Ashrafian (2023), have minimal or no local citations, indicating limited regional impact. Others, like Zahraee (2019) and Ocampo (2020), gain international traction before receiving local acknowledgment.

Recent publications, such as Azodo (2023) and Hakimi (2024), remain uncited, reflecting early academic engagement. Meanwhile, Cheah (2020) and Wen (2021) have global traction (73 and 3 citations, respectively) but low local citations.

In sum, research influence varies, with some studies gaining strong global recognition despite minimal local impact, while others achieve balance across both levels. This suggests that local and global academic communities prioritize different aspects of palm oil sustainability research. The findings highlight evolving research trends and emphasize the need for stronger integration between local and global efforts in environmental and climate change studies on palm oil production.

Most Relevant Scholars or Authors

Analysis of authors contributing to research on environmental and climate variables in palm oil production considered publication frequency and fractional contributions (see Appendix 1 for detail statistics of the total citation (TC), number of publication (NP) and start year of publication (PY_start)). Key contributors include Goh and Smith, each with a fractionalized value of 1.00, indicating major influence, while Scherr, Shirai, Reiner, Sthapit, Schneider, and Shah hold 0.50, reflecting substantial impact. Other scholars, such as Azhari, Abdurahman, and Chan, contributed more specialized insights (fractionalized 0.25–0.33), and numerous authors with lower values (0.02) provide niche perspectives, demonstrating a mix of broad and focused contributions shaping the field.

Author productivity shows fluctuating patterns. Abdurahman and Azhari published two papers in 2011, achieving 90 total citations (TC) and TC per year (TCpY) of 6. Escobar Palacio (2020–2021) maintained modest impact (TCpY 5.5–6.8), while Garcia-Ulloa's citations declined over time (56 in 2012 to 27 in 2014, TCpY 4 to 2.25). Some authors, like Hassan, saw waning relevance (6 citations in 2018, none by 2024), whereas Lim's 2021 publications achieved a modest but sustained footprint (TCpY 2.2). Others, including Ocampo Batlle, showed stable but limited impact.

Overall, author productivity is uneven, with peaks around 2011 and 2021, reflecting evolving academic interest and priorities. The field combines prolific researchers with specialized contributors, illustrating the dynamic nature of climate and environmental research in palm oil production.

Main Keywords and Key Research Areas

The analysis of key research terms on environmental and climate change in palm oil production (2006–2024) shows a steady rise in publications and shifting research focus. "Palm Oil" surged from no mentions before 2014 to 31 in 2024 (Figure 8), reflecting growing interest in its environmental effects. Research articles on these topics also increased from just one (2006–2013) to 11 by 2024. "Nitrogen" has remained steady, growing from 5 mentions per year until 2016 to 11 from 2021 onward, indicating continued focus on fertilizer and emission concerns. "Climate Change" followed a similar pattern, rising from 5 mentions until 2016 to 11 in 2024, showing increased awareness of palm oil's climate impact. "Elaeis" remained low until 2012 but reached 9 mentions in 2024, indicating more studies on its agricultural and environmental aspects.

"Sustainable Development" peaked at 9 mentions in 2021, aligning with global sustainability goals. "Biodiesel" rose from no mentions before 2014 to 8 (2021–2024), showing a cautious interest in biofuels. "Chemical Oxygen Demand" (COD), linked to water pollution, was low until 2020 but rose to 8 mentions by 2023–2024, highlighting growing concerns about wastewater from palm oil mills. "Effluents" stayed at 4 mentions until 2020 but sharply increased from 2021, reflecting rising interest in wastewater management. "Environmental Impact," absent in early years, grew after 2017, stabilizing at 8 mentions by 2022. These trends indicate a shift from basic agricultural and chemical studies to broader sustainability themes, likely driven by global policies and regulations.

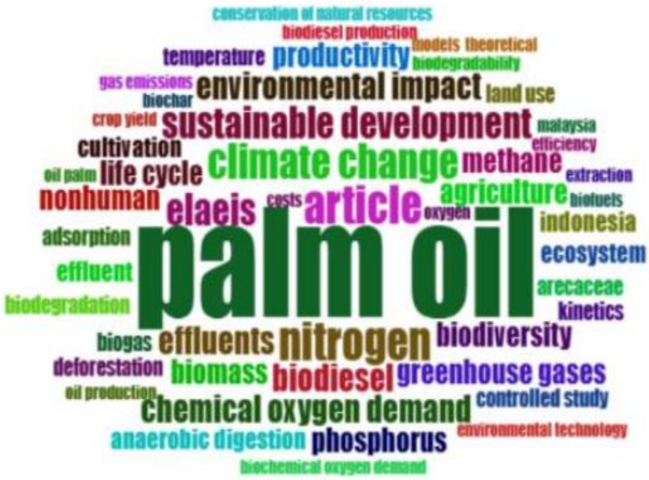

Figure 8. Main Keywords Used
Source: R-Biblioshiny Outputs

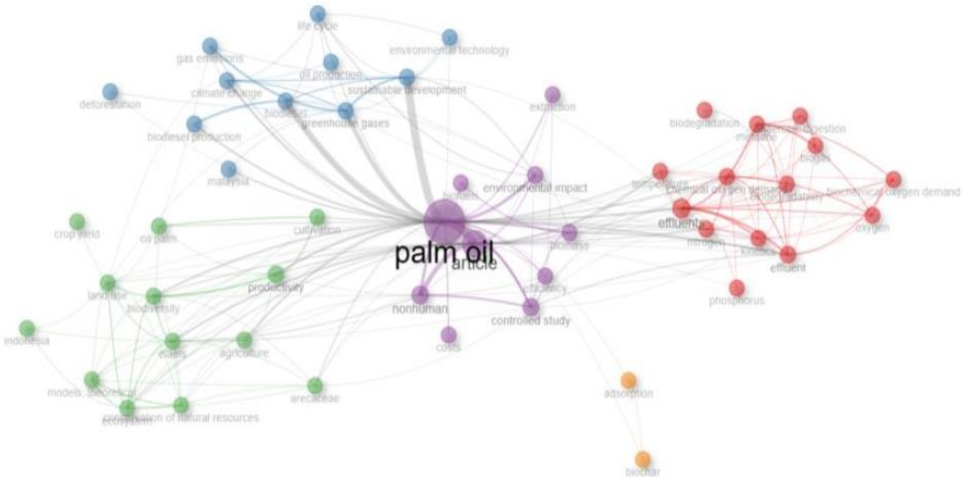

Figure 9. Key Research Areas
Source: R-Biblioshiny Outputs

Figure 9 categorizes research into five clusters, showing their interconnections. The first cluster, “waste management and pollution,” includes terms like "nitrogen," "COD," "effluents," "methane," and "biogas." High centrality values for "effluents" (Betweenness: 35.247, PageRank: 0.037) and "COD" (Betweenness: 21.793, PageRank: 0.029) highlight concerns over untreated wastewater. The presence of "biodegradability" and "anaerobic digestion" indicates growing interest in biological treatment methods.

The second cluster, “climate change and sustainability,” features "Climate Change" (Betweenness: 50.018, PageRank: 0.023) as a key theme, reflecting palm oil’s role in carbon emissions. Terms like "greenhouse gases," "biodiesel," and "sustainable development" suggest research into alternative energy and sustainability. "Deforestation" and "gas emissions" emphasize palm oil’s environmental costs, while keywords like "biodiesel production" and "environmental technology" highlight eco-friendly solutions.

The third cluster, “agriculture and ecosystems,” is centered on "elaeis" (Betweenness: 67.548, PageRank: 0.03). Terms like "biodiversity," "land use," and "ecosystem" show concern for palm oil’s environmental impact, while "productivity," "crop yield," and "cultivation" reflect efforts to balance production with conservation.

The fourth cluster, “industrial and economic aspects,” is dominated by "Palm Oil" (Betweenness: 691.759, PageRank: 0.122), highlighting research on production, trade, and sustainability. "Article" (Betweenness: 149.281, PageRank: 0.06) suggests many studies involve literature reviews. Other key terms include "environmental impact," "biomass," and "efficiency," pointing to sustainability assessments. "Biofuels" and "costs" indicate interest in financial feasibility.

The fifth cluster, “emerging environmental technologies,” focuses on “adsorption and biochar,” suggesting a rising interest in carbon sequestration and pollution control. Though less central, these terms indicate a growing push for advanced environmental solutions in palm oil production.

In general, research spans environmental science, agriculture, industrial economics, and sustainability. The prominence of pollution-related terms underscores the need for better waste management. The strong presence of climate and sustainability terms reflects global concerns, while agricultural studies focus on balancing productivity with biodiversity. Industrial research examines economic viability, and emerging technologies like biochar suggest innovation will shape future environmental strategies in palm oil production.

Trend Topics

The study identifies evolving research trends on environmental and climate variables in palm oil production (Figure 10). Early studies (2006–2010) focused on pollution and waste management, with key terms like "phosphorus," "biodegradation," "nitrogen," and "chemical oxygen demand," highlighting concerns over water contamination and waste treatment. The continued presence of "biodegradation" in recent years (Q3: 2023) suggests a shift toward long-term sustainability and biological waste solutions.

Between year 2014 and 2018, research expanded to agricultural and ecological sustainability. Terms like "elaeis," "ecosystem," "land use," "biodiversity," and "cultivation" reflect a growing interest in balancing palm oil productivity with conservation. "Indonesia" (Q1: 2015) emerged as a key term, underscoring the country's central role in palm oil production. "Deforestation" appeared in 2019 and remains a key focus, signalling continued concerns over forest loss.

From 2018 onward, research increasingly addressed sustainability and climate-related issues. Terms such as "palm oil" (Q1: 2018, Median: 2020), "sustainable development," "environmental impact," and "biomass" indicate a shift toward reducing the carbon footprint of palm oil production. Interest in "biodiesel" peaked around 2017–2018, reflecting exploration of alternative fuels, while "life cycle" (Q1: 2019, Median: 2021) points to studies assessing palm oil's full environmental impact.

Recent trends (2020–2024) show a stronger emphasis on climate change and carbon emissions. The prominence of "greenhouse gases," "climate change," and "life cycle" suggests increasing relevance in global sustainability discussions. "Climate change" (Q1: 2020, Median: 2023, Q3: 2024) appears later in the timeline, reflecting its rising importance. Growing mentions of "environmental impact" and "biomass" indicate a focus on innovative solutions to mitigate palm oil's effects on climate.

Overall, research has transitioned from pollution control (2006–2010) to agricultural sustainability (2014–2018) and then to climate change and sustainability (2018–2024). This shift reflects increasing awareness of palm oil's global environmental impact and the push for greener production practices.

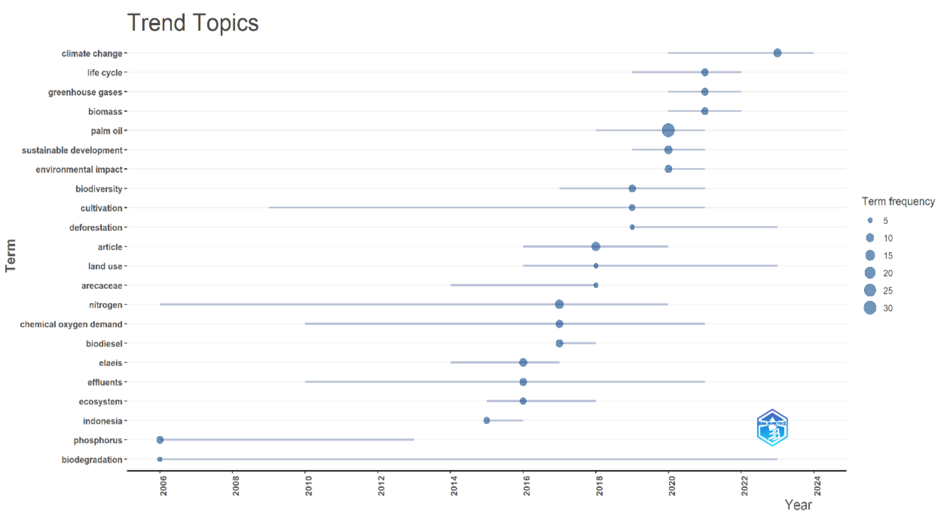

Figure 10. Trending Topics in Research of Environmental and Climate Change Variables in Palm Oil Production Models
Source: R-Biblioshiny Outputs

DISCUSSION

The bibliometric analysis of research on environmental and climate change variables in palm oil production highlights significant growth, collaboration, and evolving research priorities over the past 35 years. From 1989 to 2024, 71 documents were published across 56 sources, with a 5.72% annual growth rate, indicating sustained academic interest. The field's strong academic influence is reflected in an average of 19.97 citations per document and 3,635 references, suggesting that research builds on a well-established knowledge base.

Keyword and trend analyses show a shift from early focus on pollution and waste management (e.g., "nitrogen," "COD," "effluents") to broader sustainability and climate-related issues. Early studies (2006–2010) concentrated on chemical and waste concerns, while research between 2014–2018 emphasized agricultural and ecological sustainability, including biodiversity, land use, and ecosystem management. More recent publications (2018–2024) increasingly address climate change, carbon emissions, life cycle assessment, and sustainable development, reflecting global awareness and policy-driven priorities. Emerging topics like biochar and adsorption highlight innovation in environmental technologies.

Authorship and collaboration trends underscore the field's highly collaborative nature, with 330 authors, an average of 4.89 co-authors per document, and a 43.66% rate of international collaboration. Leading scholars such as Goh and Smith demonstrate high influence, while other contributors provide specialized insights, reflecting a blend of broad and focused expertise. Author productivity is uneven, with peaks around 2011 and 2021, indicating shifts in academic focus and research priorities.

Geographically, research is concentrated in major palm oil-producing countries—Malaysia and Indonesia—reflecting economic stakes and environmental responsibilities. European countries, notably Germany, contribute strongly from a sustainability and policy perspective, while Brazil and Colombia are emerging contributors. Africa and some parts of the Americas show research gaps, highlighting the need for greater global engagement. Leading affiliations include Universiti Putra Malaysia, Georg August University Göttingen, and Universidade Federal do Rio de Janeiro, demonstrating the interplay between producer and consumer nations in driving sustainability research.

Citation analysis further highlights the global influence of seminal studies, with older works maintaining lasting impact and newer studies gradually gaining recognition. High-profile journals such as Journal of Cleaner Production and Advanced Materials Research dominate, emphasizing both technological and policy-oriented approaches. The distribution across diverse journals underlines the interdisciplinary nature of palm oil research, integrating environmental science, agriculture, industrial economics, and sustainability studies.

Overall, the findings indicate a dynamic and growing research landscape, transitioning from local environmental management to global sustainability and climate resilience. The field has become increasingly collaborative, interdisciplinary, and policy-relevant. Future research should address gaps in African and emerging producer nations, emphasize systematic reviews and meta-analyses, and explore technological innovations and climate-resilient agricultural practices to support sustainable palm oil production.

CONCLUSION

The bibliometric analysis in this study provides a comprehensive overview of research trends, key contributions, and methodological gaps in integrating environmental and climate change variables into palm oil production models from 1989 to 2024. The findings reveal a consistent increase in research output, driven by growing international collaboration and interdisciplinary engagement across environmental science, engineering, policy, and sustainability studies. Since 2009, research on palm oil sustainability has gained momentum, with significant expansion from 2017 onward. While Malaysia, Indonesia, and Brazil dominate in publication volume, European and Australian institutions exhibit higher citation impacts, reflecting their focus on climate change mitigation, regulatory frameworks, and sustainability strategies. However, research contributions remain geographically uneven, with limited representation from Africa and the Americas, highlighting the need for broader global engagement.

A key insight is the limited integration of climate-related variables—such as drought resilience and carbon sequestration—into palm oil production models. Although previous bibliometric studies have largely examined publication trends and citation metrics, this study identifies a gap in systematic methodological analyses related to environmental factors. The increasing prominence of sustainability-related keywords and the emergence of innovative approaches, such as biochar applications and adsorption technologies, suggest a growing emphasis on greener production practices.

The findings of this bibliometric analysis provide actionable guidance for policymakers in Malaysia and Indonesia to enhance sustainability strategies in the palm oil sector. First, the consistent growth in research output and international collaboration highlights the availability of a strong domestic knowledge base. Policymakers can leverage these insights to design evidence-based interventions addressing environmental and climate challenges, such as deforestation, greenhouse gas emissions, and water pollution from palm oil production.

Second, the study identifies a limited integration of climate-related variables, including drought resilience, carbon sequestration, and ecosystem services, into existing palm oil production models. This gap suggests opportunities for policymakers to support research and development initiatives that embed climate adaptation and mitigation strategies into agricultural planning, promoting resilience in the face of climate change. Incentive programs could encourage adoption of practices such as biochar application, improved effluent management, and other environmentally innovative technologies.

Third, the higher citation impact of European and Australian institutions indicates the value of international knowledge exchange. Malaysian and Indonesian authorities can strengthen partnerships with global research hubs to align domestic sustainability policies with international standards, enhance supply chain transparency, and improve access to markets demanding certified sustainable palm oil (CSPO).

Finally, the emergence of sustainability-focused research and innovative technologies highlights the need for policy frameworks that integrate economic growth with environmental stewardship. Strategic funding for applied research and pilot programs can accelerate the adoption of greener production methods, optimize resource use, and reduce environmental impacts, ensuring long-term viability and global competitiveness of the palm oil industry.

Despite these advancements, certain limitations persist. The reliance on Scopus data may exclude relevant studies from other databases, potentially affecting the comprehensiveness of the review. Additionally, variations in citation practices across disciplines may influence the perceived impact of certain research contributions. The study also does not account for non-English publications, which may provide valuable regional insights into palm oil sustainability.

Future research should prioritize systematic reviews and meta-analyses to deepen understanding of methodological frameworks for integrating climate-related factors into palm oil production models. Strengthening interdisciplinary collaborations will be essential in bridging research gaps and fostering holistic approaches to sustainability. As climate challenges escalate, further studies should explore policy implications, technological innovations, and climate-resilient agricultural strategies. Expanding research networks, particularly in underrepresented regions, will be critical in ensuring that palm oil production aligns with global sustainability and climate adaptation goals.

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APPENDIX 1

Authors' Index, Total citation (TC), Number of Publication (NP) and Start Year of Publication (PY_start)

Author	h_index	g_index	m_index	TC	NP	PY_start
ABDURAHMAN NH	2	2	0.133	90	2	2011
AZHARI NH	2	2	0.133	90	2	2011
CHAN YJ	2	2	0.4	52	2	2021
ESCOBAR PALACIO JC	2	2	0.333	67	2	2020
GARCIA-ULLOA J	2	2	0.143	83	2	2012
GHAZOUL J	2	2	0.143	83	2	2012
KOH LP	2	2	0.143	83	2	2012
OCAMPO BATLLE EA	2	2	0.333	67	2	2020
ROSLI YM	2	2	0.133	90	2	2011
SHOW PL	2	2	0.333	103	2	2020
SILVA LORA EE	2	2	0.333	67	2	2020
ABDULLAH MA	1	1	0.111	5	1	2017
ABDULLAH SSS	1	1	0.125	6	1	2018
ABIDIN ZZ	1	1	0.111	34	1	2017
ABRAM NK	1	1	0.083	81	1	2014
ADNAN O	1	1	0.111	34	1	2017
AHMAD A	1	1	0.05	25	1	2006
AL-QUBAISI MS	1	1	0.111	34	1	2017
ALARCÓN-SUESCA C	1	1	0.167	23	1	2020
ALBIS ARRIETA AR	1	1	0.167	33	1	2020
ALLEN K	1	1	0.1	199	1	2016
AMBU L	1	1	0.083	81	1	2014
AMEER ABBAS BIN AIT	1	1	0.2	30	1	2021
ANCRENAZ M	1	1	0.083	81	1	2014
ANDIAPPAN V	1	1	0.2	10	1	2021
ANGELKORTE G	1	1	0.333	7	1	2023
ARAUJO LGD	1	1	0.2	39	1	2021
ARGOTI MAA	1	1	0.2	5	1	2021
ARKEMAN Y	1	1	0.111	2	1	2017
ARPORNWICHANOP A	1	1	0.25	25	1	2022
ARUMUGASAMY SK	1	1	0.333	4	1	2023
ASHRAFIAN A	1	1	0.333	34	1	2023
ASTERIS PG	1	1	0.333	34	1	2023
ATIQUR RAHMAN KHAN M	1	1	0.125	42	1	2018
AZNAR M	1	1	0.083	29	1	2014
BABIKIR MH	1	1	0.5	5	1	2024
BAKRAOUI M	1	1	0.333	2	1	2023
BANABAS M	1	1	0.111	25	1	2017
BARI HE	1	1	0.333	2	1	2023
BARNES AD	1	1	0.1	199	1	2016
BERGMAN-FONTE C	1	1	0.333	7	1	2023

BERINGER T	1	1	0.333	5	1	2023
BESSOU C	1	1	0.111	25	1	2017
BRACONNIER S	1	1	0.077	43	1	2013
BREIDENBACH N	1	1	0.1	199	1	2016
BROSE U	1	1	0.1	199	1	2016
BRYAN BA	1	1	0.091	54	1	2015
BUCHORI D	1	1	0.1	199	1	2016
BUNYAMIN AA	1	1	0.333	4	1	2023
CALIMAN J-P	1	1	0.077	43	1	2013
CARRILLO CABALLERO GE	1	1	0.2	34	1	2021
CARVALHO L	1	1	0.333	7	1	2023
CASTILLO SANTIAGO Y	1	1	0.167	33	1	2020
CAÑON-AYALA MJ	1	1	0.5	1	1	2024
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CHATTERTON J	1	1	0.333	5	1	2023
CHEAH WY	1	1	0.167	73	1	2020
CHEW CL	1	1	0.2	30	1	2021
CHEW JJ	1	1	0.2	3	1	2021
CHONG S	1	1	0.2	30	1	2021
CHUNG R	1	1	0.083	81	1	2014
CLOUGH Y	1	1	0.1	199	1	2016
COMBRES J-C	1	1	0.077	43	1	2013
CORRE MD	1	1	0.1	199	1	2016
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DA CRUZ SIQUEIRA JA	1	1	0.1	1	1	2016
DAMAI RGMF	1	1	0.143	4	1	2019
DANIEL R	1	1	0.1	199	1	2016
DARR D	1	1	0.143	21	1	2019
DARRAS K	1	1	0.1	199	1	2016
DE ANDRADE MG	1	1	0.1	1	1	2016
DE MEESTER S	1	1	0.2	3	1	2021
DE SOUZA SNM	1	1	0.1	1	1	2016
DENMEAD LH	1	1	0.1	199	1	2016
DETCHUSANANARD T	1	1	0.25	25	1	2022
DEWULF J	1	1	0.2	3	1	2021
DINGKUHN M	1	1	0.077	43	1	2013
DISLICH C	1	1	0.125	21	1	2018
DUVOISIN JR S	1	1	0.083	29	1	2014
ESCORCIA YC	1	1	0.2	34	1	2021
FINKELDEY R	1	1	0.1	199	1	2016
FIORINI ACO	1	1	0.333	7	1	2023
FOLLEGATTI-ROMERO LA	1	1	0.083	29	1	2014
FORERO DC	1	1	0.25	13	1	2022
FORONDA-TOBÓN Y	1	1	0.5	1	1	2024

FRIGO EP	1	1	0.1	1	1	2016
GABRIELLE B	1	1	0.111	25	1	2017
GALVEZ-VALENCIA AM	1	1	0.2	5	1	2021
GARCÉS-GÓMEZ YA	1	1	0.2	5	1	2021
GOH CS	1	1	0.167	8	1	2020
GOLROUDBARY SR	1	1	0.143	55	1	2019
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GONZÁLEZ-DELGADO AD	1	1	0.167	23	1	2020
GOOSSENS B	1	1	0.083	81	1	2014
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GUILHEN SN	1	1	0.2	39	1	2021
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HASSAN MA	1	2	0.125	6	2	2018
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HETTIG E	1	1	0.125	21	1	2018
HO Y-C	1	1	0.167	73	1	2020
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IBRAHIM KN	1	1	0.125	6	1	2018
IDRIS A	1	1	0.111	34	1	2017
IRAWAN B	1	1	0.1	199	1	2016
JANS Y	1	1	0.333	5	1	2023
JAYA INS	1	1	0.1	199	1	2016
JAZA FOLEFACK AJ	1	1	0.143	21	1	2019
JIANG L	1	1	0.25	15	1	2022
JOCHUM M	1	1	0.1	199	1	2016
JR	1	1	0.25	13	1	2022
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KERROU O	1	1	0.333	2	1	2023
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KOTOWSKA MM	1	1	0.1	199	1	2016
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KREFT H	1	1	0.1	199	1	2016
KRISHNA VV	1	1	0.1	199	1	2016
KULAK M	1	1	0.333	5	1	2023
KURNIAWAN S	1	1	0.1	199	1	2016
LACKMAN I	1	1	0.083	81	1	2014
LAHBOUBI N	1	1	0.333	2	1	2023
LAM MK	1	1	0.167	73	1	2020
LAUWAERT J	1	1	0.2	3	1	2021
LAW EA	1	1	0.091	54	1	2015
LAY J	1	1	0.125	21	1	2018
LEE JSH	1	1	0.083	27	1	2014
LEE SH	1	1	0.25	15	1	2022
LEONG H	1	1	0.25	15	1	2022
LEUSCHNER C	1	1	0.1	199	1	2016
LI J	1	1	0.25	15	1	2022
LIEW ZK	1	1	0.2	30	1	2021
LIM JS	1	2	0.2	11	2	2021
LIM JW	1	1	0.167	73	1	2020
LIM YF	1	1	0.2	22	1	2021
LIMLEAMTHONG P	1	1	0.25	25	1	2022
LOCK SSM	1	1	0.2	3	1	2021
MACMILLAN DC	1	1	0.083	81	1	2014
MAIA PL	1	1	0.333	7	1	2023
MALLAWAARACHCHI T	1	1	0.091	54	1	2015
MARAUN M	1	1	0.1	199	1	2016
MARÉCHAL F	1	1	0.25	25	1	2022
MAŠEK O	1	1	0.2	39	1	2021
MD DIN MF	1	1	0.05	25	1	2006
MEIJAARD E	1	1	0.091	54	1	2015
MEIJIDE A	1	1	0.1	199	1	2016
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MEYER KM	1	1	0.125	21	1	2018
MIALET-SERRA I	1	1	0.077	43	1	2013
MIGEON AF	1	1	0.167	43	1	2020
MO W	1	1	0.25	15	1	2022
MOHAMED MS	1	1	0.143	8	1	2019
MOHD ZAID HF	1	1	0.167	73	1	2020
MOLUA EL	1	1	0.25	13	1	2022
MORAIS T	1	1	0.333	7	1	2023
MORENO-SADER K	1	1	0.167	23	1	2020
MOSER S	1	1	0.1	199	1	2016
MUSSHOFF O	1	1	0.1	199	1	2016

MÜLLER C	1	1	0.333	5	1	2023
NACHTERGAELE P	1	1	0.2	3	1	2021
NEMATCHOUA MK	1	1	0.5	5	1	2024
NETELENBOS NELSON P	1	1	0.111	25	1	2017
NG SC	1	1	0.2	22	1	2021
NGO NJIKI MG	1	1	0.143	21	1	2019
NKONGHO RN	1	1	0.25	13	1	2022
NOGUEIRA CEC	1	1	0.1	1	1	2016
NURFARAHIN AH	1	1	0.143	8	1	2019
OBIDZINSKI K	1	1	0.083	27	1	2014
ONG R	1	1	0.083	81	1	2014
OPFERMANN N	1	1	0.1	199	1	2016
ORDWAY EM	1	1	0.25	13	1	2022
OSTFELD R	1	1	0.5	1	1	2024
PACHECO P	1	1	0.071	56	1	2012
PAEZ-RICARDO JA	1	1	0.5	1	1	2024
PALLAS B	1	1	0.077	43	1	2013
PANAHI E	1	1	0.333	34	1	2023
PARDON L	1	1	0.111	25	1	2017
PARRA-HERRERA JE	1	1	0.5	1	1	2024
PEKAROU PEMI BA	1	1	0.5	5	1	2024
PETER L	1	1	0.083	81	1	2014
PHANG LY	1	1	0.143	8	1	2019
PORTUGAL-PEREIRA J	1	1	0.333	7	1	2023
PRABOWO WE	1	1	0.1	199	1	2016
PRASERTCHAROENSUK P	1	1	0.25	25	1	2022
PTASINSKI KJ	1	1	0.059	9	1	2009
PURATHANUNG T	1	1	0.25	4	1	2022
PÉREZ-CRUZADO C	1	1	0.1	199	1	2016
RAHMAN T	1	1	0.111	2	1	2017
REINER DM	1	1	0.5	1	1	2024
REMBOLD K	1	1	0.1	199	1	2016
RIZALI A	1	1	0.1	199	1	2016
ROCHA EGDA	1	1	0.083	29	1	2014
RODRÍGUEZ ELL	1	1	0.2	5	1	2021
ROMERO HM	1	1	0.25	13	1	2022
ROSA HA	1	1	0.1	1	1	2016
ROSLAN AM	1	1	0.125	6	1	2018
ROUAN L	1	1	0.077	43	1	2013
ROVANI S	1	1	0.2	39	1	2021
RUBIANA R	1	1	0.1	199	1	2016
RUYSBERGH E	1	1	0.2	3	1	2021
SAIRAN MF	1	1	0.05	25	1	2006
SALECKER J	1	1	0.125	21	1	2018
SALEHI S	1	1	0.333	34	1	2023
SAPARITA R	1	1	0.111	2	1	2017

SATO M	1	1	0.1	1	1	2016
SCHAEFFER R	1	1	0.333	7	1	2023
SCHAPHOFF S	1	1	0.333	5	1	2023
SCHERR SJ	1	1	0.059	4	1	2009
SCHEU S	1	1	0.1	199	1	2016
SCHNEIDER D	1	1	0.1	199	1	2016
SELVARAJOO A	1	1	0.333	4	1	2023
SETHU V	1	1	0.333	4	1	2023
SETYANINGSIH D	1	1	0.111	2	1	2017
SHAH SMU	1	1	0.111	5	1	2017
SHIRAI Y	1	2	0.125	6	2	2018
SHIWAKOTI N	1	1	0.143	55	1	2019
SIMO E	1	1	0.5	5	1	2024
SIN G	1	1	0.2	3	1	2021
SLINGERLAND M	1	1	0.167	43	1	2020
SLOAN S	1	1	0.071	56	1	2012
SMITH BG	1	1	0.027	49	1	1989
SOFIYUDIN M	1	1	0.167	43	1	2020
SOM AM	1	1	0.2	12	1	2021
SOULIÉ J-C	1	1	0.077	43	1	2013
STASINOPOULOS P	1	1	0.143	55	1	2019
STEINEBACH S	1	1	0.1	199	1	2016
STHAPIT S	1	1	0.059	4	1	2009
STOMPH D	1	1	0.167	43	1	2020
STRUEBIG M	1	1	0.091	54	1	2015
SU S	1	1	0.25	15	1	2022
SUES A	1	1	0.059	9	1	2009
SZKLO A	1	1	0.333	7	1	2023
SZULCZYK KR	1	1	0.125	42	1	2018
TABE-OJONG MPJ	1	1	0.25	13	1	2022
TALLA KONCHOU FA	1	1	0.5	5	1	2024
TAM SF	1	1	0.067	11	1	2011
TAN KP	1	1	0.071	36	1	2012
TAN YD	1	2	0.2	11	2	2021
TAO Y	1	1	0.167	73	1	2020
TARIGAN S	1	1	0.125	21	1	2018
TENG MC	1	1	0.2	30	1	2021
TENÓRIO JAS	1	1	0.2	39	1	2021
THYBAUT JW	1	1	0.2	3	1	2021
TJITROSOEDIRDJO SS	1	1	0.1	199	1	2016
TJOA A	1	1	0.1	199	1	2016
TSCHARNTKE T	1	1	0.1	199	1	2016
TZANOPOULOS J	1	1	0.083	81	1	2014
UJANG Z	1	1	0.05	25	1	2006
VAN LOOSDRECHT MCM	1	1	0.05	25	1	2006
VAN NOORDWIJK M	1	1	0.167	43	1	2020

VELDKAMP E	1	1	0.1	199	1	2016
VENTURINI OJ	1	1	0.167	33	1	2020
VICENTE C	1	1	0.333	7	1	2023
VITORIANO JULIO AA	1	1	0.2	34	1	2021
WALMSLEY TG	1	1	0.2	1	1	2021
WAN ALWI SR	1	2	0.2	11	2	2021
WANG X	1	1	0.25	15	1	2022
WANG Y	1	1	0.25	15	1	2022
WATTANA B	1	1	0.25	4	1	2022
WATTANA S	1	1	0.25	4	1	2022
WEN ALK	1	1	0.2	3	1	2021
WIDI TSM	1	1	0.143	4	1	2019
WIDYAS N	1	1	0.143	4	1	2019
WIEGAND K	1	1	0.125	21	1	2018
WILSON KA	1	1	0.091	54	1	2015
WUTTIPISAN N	1	1	0.25	25	1	2022
XIANG J	1	1	0.25	15	1	2022
XIONG Z	1	1	0.25	15	1	2022
XOFIS P	1	1	0.083	81	1	2014
XU J	1	1	0.25	15	1	2022
YAHYA A	1	1	0.2	12	1	2021
YANG K-L	1	1	0.25	15	1	2022
YAP YJ	1	1	0.167	73	1	2020
YEPES MAYA DM	1	1	0.167	33	1	2020
YIIN CL	1	1	0.2	3	1	2021
YIP YH	1	1	0.2	30	1	2021
YUSOF SJHM	1	1	0.125	6	1	2018
ZAHRAEE SM	1	1	0.143	55	1	2019
ZAKARIA MR	1	2	0.125	6	2	2018
ZANON-ZOTIN M	1	1	0.333	7	1	2023