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Bibliometric Analysis and Thematic Mapping of Research on the Development of Agricultural Sustainability in Indonesia (2018–2025)

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Abstract: *This study presents a comprehensive bibliometric analysis of scientific literature on the development of agricultural sustainability in Indonesia, drawing on 84 documents indexed in the Scopus database from 2004 to 2025, with emphasis on the period 2018–2025. Employing VOSviewer for keyword co-occurrence network visualization, the research identifies five major thematic clusters: (1) sustainable development and palm oil governance, (2) biodiversity, deforestation, and environmental management, (3) food supply chains and rural development, (4) precision agriculture and remote sensing technology, and (5) smallholder farmer systems. Findings reveal that the most frequently occurring and interconnected keywords include sustainable development, agriculture, Indonesia, palm oil, sustainability, and rural development. The overlay visualization demonstrates a temporal shift in research focus, with recent publications (2022–2024) concentrating on precision agriculture, renewable energy, and agricultural robotics, while earlier work centered on deforestation and land use. The density map highlights critical research gaps in governance approaches and alternative agriculture systems. The total corpus of 84 documents generated a mean citation count of 8.21 per document, with the highest cited paper receiving 75 citations. The study underscores the urgent need for integrated, multi-stakeholder approaches to achieve sustainable agricultural transformation in Indonesia, aligned with Sustainable Development Goals (SDG 2 and SDG 15). This analysis provides strategic direction for future research priorities, policy development, and inter-institutional collaboration in Indonesian agricultural sciences.*

Keywords: *Bibliometric Analysis, Sustainable Agriculture, Indonesia, VOSviewer, Rural Development*

Abstrak: Studi ini menyajikan analisis bibliometrik komprehensif terhadap literatur ilmiah mengenai perkembangan keberlanjutan pertanian di Indonesia, mengacu pada 84 dokumen yang terindeks dalam basis data Scopus dari tahun 2004 hingga 2025, dengan penekanan pada periode 2018–2025. Dengan menggunakan VOSviewer untuk visualisasi jaringan co-occurrence kata kunci, penelitian ini mengidentifikasi lima kluster tematik utama: (1) pembangunan berkelanjutan dan tata kelola kelapa sawit, (2) keanekaragaman hayati, deforestasi, dan manajemen lingkungan, (3) rantai pasokan pangan dan pembangunan pedesaan, (4) pertanian presisi dan teknologi penginderaan jauh, serta (5) sistem petani kecil. Temuan menunjukkan bahwa kata kunci yang paling sering muncul dan saling terhubung meliputi sustainable development, agriculture, Indonesia, palm oil, sustainability, dan rural development. Visualisasi overlay mendemonstrasikan pergeseran temporal dalam fokus penelitian, di mana publikasi terkini (2022–2024) berkonsentrasi pada pertanian presisi, energi terbarukan, dan robotika pertanian, sementara karya-karya lebih awal berpusat pada deforestasi dan penggunaan lahan. Peta densitas menyoroti kesenjangan penelitian yang kritis dalam pendekatan tata kelola dan sistem pertanian alternatif. Total korpus 84 dokumen menghasilkan rata-rata jumlah sitasi sebesar 8,21 per dokumen, dengan makalah yang paling banyak dikutip menerima 75 sitasi. Studi ini menggarisbawahi urgensi pendekatan terpadu dan multi-pemangku kepentingan untuk mencapai transformasi pertanian

berkelanjutan di Indonesia, selaras dengan Tujuan Pembangunan Berkelanjutan (SDG 2 dan SDG 15). Analisis ini memberikan arahan strategis untuk prioritas penelitian masa depan, pengembangan kebijakan, dan kolaborasi antar-institusi dalam ilmu pertanian Indonesia.

Kata Kunci: Analisis Bibliometrik, Indonesia, Pembangunan Pedesaan, Pertanian Berkelanjutan, VOSviewer

I. Introduction

Indonesia is one of the world's most agriculturally significant nations, occupying a critical position in global food systems and tropical biodiversity conservation. As the fourth most populous country with over 270 million inhabitants, Indonesia faces the dual challenge of ensuring domestic food security while simultaneously preserving its vast natural ecosystems, home to the second-largest tropical rainforest on Earth (Madani Indonesia, 2022). The agricultural sector employs approximately 28% of the national workforce and contributes around 13% of GDP, making its sustainable development not only an environmental imperative but also a socio-economic necessity (Purbohadi et al., 2026). The concept of agricultural sustainability in Indonesia is inherently complex, encompassing a multidimensional spectrum of concerns ranging from soil conservation and water resource management to climate change adaptation and smallholder economic resilience. The country produces a diverse array of strategic commodities including palm oil, rice, rubber, coffee, cocoa, and spices, many of which are globally significant. However, the rapid expansion of plantation agriculture, particularly palm oil has been associated with large-scale deforestation, loss of biodiversity, and displacement of indigenous communities, raising critical questions about the long-term viability of current agricultural models (FAO, 2018).

The Indonesian government has responded to these challenges through a series of legislative and policy instruments, including the Indonesian Sustainable Palm Oil (ISPO) certification system, which mandates sustainability standards for palm oil companies operating in the country (**Regulation of the Minister of Agriculture No. 11/2015**). Additionally, national programs such as the Food Estate program and the Land Rehabilitation Agenda reflect state commitment to balancing agricultural productivity with environmental stewardship. These policy initiatives have spurred an expanding body of scholarly inquiry into the nature, drivers, and outcomes of sustainable agricultural transitions in Indonesia. Bibliometric analysis has emerged as a powerful methodological tool for systematically mapping the intellectual landscape of a scientific domain. By quantifying publication trends, citation patterns, and

keyword co-occurrence networks, bibliometrics allows researchers to identify dominant themes, research frontiers, and knowledge gaps in a given field (Donthu et al., 2021). The application of tools such as VOSviewer enables the visualization of these complex relationships in an intuitive and analytically robust manner, facilitating evidence-based research prioritization. Such approaches are increasingly adopted in agricultural and environmental sciences to synthesize rapidly expanding literature bases. A review of the existing bibliometric literature reveals a relative scarcity of studies that specifically map the landscape of agricultural sustainability research within the Indonesian context. While individual studies address components such as palm oil governance, rice production, or rural livelihoods, a comprehensive synthesis that captures the full thematic diversity, temporal evolution, and collaborative structure of this research domain remains lacking. This gap motivates the present study, which undertakes a systematic bibliometric analysis of 84 documents indexed in the Scopus database, focusing on the period 2018–2025, a timeframe characterized by accelerating climate urgency and significant policy reform in Indonesia.

The Scopus database was selected as the primary data source due to its broad interdisciplinary coverage, rigorous quality controls, and comprehensive bibliometric metadata. The analysis employs VOSviewer version 1.6.20 to construct keyword co-occurrence networks, overlay visualizations based on publication year, and density maps that reveal research concentration patterns. Three primary visualizations are analyzed: a network visualization depicting five distinct thematic clusters coded by color; an overlay visualization showing the temporal evolution of research themes from 2018 to 2024; and a density visualization highlighting high-activity versus underexplored research zones. Together, these visualizations provide a multidimensional understanding of how agricultural sustainability research has evolved in Indonesia. This paper is structured as follows: Section 2 provides a literature review covering the key thematic areas identified in the bibliometric analysis; Section 3 details the research methodology; Section 4 presents and discusses the results of the bibliometric analysis; and Section 5 offers conclusions and recommendations for future research. This study aims to serve as a foundational reference for scholars, policymakers, and development practitioners engaged with agricultural sustainability in Indonesia, offering a data-driven synthesis of where the field stands and where it needs to go.

II. Literature Review

Sustainable Development and Palm Oil Governance in Indonesia

Palm oil remains the most economically significant agricultural commodity in Indonesia, with the country accounting for approximately 57% of global palm oil production (Astuti et al., 2022). The intersection of palm oil expansion with sustainability imperatives has generated a substantial body of literature examining governance frameworks, certification mechanisms, and environmental trade-offs. The ISPO certification system, established in 2011 and strengthened through **Presidential Regulation No. 44/2020**, represents the Indonesian government's primary instrument for mainstreaming sustainability within the palm oil supply chain. Research by Zahari et al. (2024) highlights both the potential and limitations of ISPO implementation at the regency level, noting that while government motivation is strong, enforcement capacity and smallholder compliance remain major challenges. Similarly, Riahi et al. (2024) link ISPO to the broader framework of the Sustainable Development Goals, arguing that stronger legal alignment is needed to translate certification mandates into measurable environmental outcomes.

Biodiversity, Deforestation, and Environmental Management

The relationship between agricultural expansion and environmental degradation is a central concern in the literature on Indonesian agricultural sustainability. Indonesia's forests harbor approximately 10% of the world's plant species, 12% of mammal species, and 17% of bird species, making deforestation a biodiversity crisis of global consequence (Brodny & Tutak, 2023). Studies by Corrales-Garay et al. (2020) demonstrate the potential of UAV-based remote sensing technologies to monitor biodiversity within oil palm plantations, while simultaneously optimizing production efficiency. The use of Normalized Difference Vegetation Index (NDVI) and other vegetation indices is shown to offer promising tools for assessing floristic diversity in modified landscapes.

Food Supply Chains and Rural Development

Food security and rural development constitute a major thematic cluster in Indonesian agricultural sustainability research. With over 40 million smallholder farming households, Indonesia's food system is fundamentally shaped by the livelihoods, adaptive capacities, and market access of rural communities (FAO, 2018). Studies in this cluster examine the intersection of food supply with rural infrastructure, quality control systems, and investment in agricultural development. Rural development discourse in Indonesia increasingly emphasizes

the importance of inclusive value chain development, particularly for smallholder commodities such as coffee, rice, and vegetables (Diana Meilinda et al., 2025). The emergence of digital agriculture platforms and agricultural e-commerce has begun to reshape market access dynamics, as evidenced by studies presented at the IConARD 2022 conference. These studies highlight consumer behavior shifts toward digital agricultural product purchasing in the Jabodetabek metropolitan region, reflecting broader trends in agricultural modernization. Simultaneously, research on food supply governance emphasizes the critical role of quality control systems in enhancing the competitiveness of Indonesian agricultural products in both domestic and export markets.

Governance Approaches and Smallholder Farming Systems

The governance of smallholder farming systems encompassing land tenure, farmer organization, extension services, and certification constitute a foundational concern across multiple thematic clusters in the bibliometric network. Keywords such as governance approach, smallholder, alternative agriculture, certification, and farming system appear in the red cluster alongside Indonesia, sustainability, and deforestation, suggesting their analytical centrality to Indonesian environmental and agricultural governance debates. Studies such as those by (Ngaiwi et al., 2023; Rozi et al., 2025), which apply the Sustainability Assessment of Food and Agriculture Systems (SAFA) framework to cattle farmers in Central Java, illustrate the multidimensional nature of smallholder sustainability challenges, encompassing environmental integrity, economic resilience, social well-being, and good governance.

The density map (Figure 1) reveals that governance approach, alternative agriculture, and agricultural practice remain in comparatively low-density zones, indicating significant research gaps in these areas. This finding aligns with broader critiques of Indonesian agricultural policy, which has historically prioritized large-scale plantation development over the capacity-building of smallholder systems. Recommendations emerging from this literature call for participatory governance models, community-based natural resource management, and targeted support for farmer cooperatives as instruments for achieving more equitable and sustainable agricultural outcomes. Future research should prioritize empirical investigation of governance innovations at the local level, particularly in frontier regions of Kalimantan, Papua, and Sulawesi (Santosa et al., 2024).

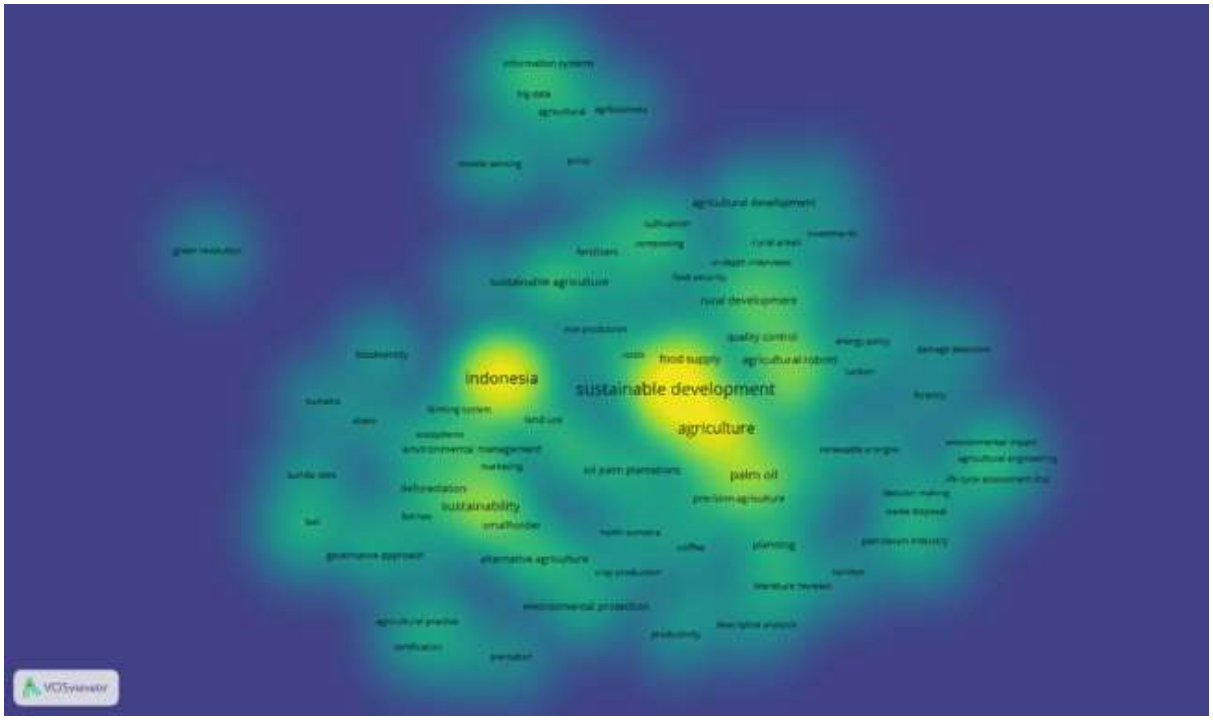


Figure 1. Density Analysis (VOSviewer generated)

Source: Fatur Rohman (2026)

III. Research Methodologies

Research Design and Bibliometric Approach

This study adopts a systematic bibliometric analysis design, which is a quantitative method for evaluating and mapping scientific literature within a defined domain. Bibliometric analysis is widely recognized in the scientific community as a rigorous approach to synthesizing large volumes of scholarly output, identifying intellectual structures, and revealing temporal trends in research activity (Fatur Rohman & Widianingsih, 2024). The specific technique employed is keyword co-occurrence network analysis, implemented using VOSviewer version 1.6.20, a specialized software developed at Leiden University that constructs and visualizes bibliometric networks. The research design integrates three complementary visualization modes: network visualization, overlay visualization, and density visualization, each providing distinct analytical insights into the structure and evolution of the research field.

Design Element	Specification	Justification
Research Type	Systematic bibliometric analysis	Quantitative mapping of scientific literature landscape
Analytical Tool	VOSviewer v1.6.20	Industry-standard bibliometric visualization software
Visualization Modes	Network, Overlay, Density	Multi-dimensional analysis of co-occurrence structure and temporal evolution
Unit of Analysis	Author keywords, document metadata	Captures intellectual themes and research trends
Scope	Indonesian agricultural sustainability, 2004–2025	Captures full temporal scope with emphasis on 2018–2025

Table 1. Research Design Specifications

Source: Fatur Rohman (2026)

Data Collection and Database Selection

Data were retrieved from the Scopus database (Elsevier), which was selected on the basis of its comprehensive interdisciplinary coverage, standardized bibliographic metadata, and widely accepted reliability for bibliometric research. The search query was constructed to capture publications directly relevant to agricultural sustainability in the Indonesian context. The search string employed was: TITLE-ABS-KEY ('sustainable agriculture' OR 'agricultural sustainability' OR 'sustainable development' AND 'agriculture') AND ('Indonesia') AND PUBYEAR > 2003. The search was executed in January 2025, yielding an initial retrieval of 112 documents. Following deduplication and application of inclusion criteria (English language, peer-reviewed, Scopus-indexed), a final corpus of 84 documents was obtained for analysis. The dataset encompasses 84 documents across multiple document types: 37 journal articles (44%), 33 conference papers (39%), 6 book chapters (7%), 4 review articles (5%), and 3 conference reviews (4%). The publishing sources span 2004 to 2025, with significant concentration in the period 2018–2025 (69 documents, 82% of the corpus). The most prolific source is IOP Conference Series: Earth and Environmental Science with 16 publications, followed by E3S Web of Conferences with 8 publications, reflecting the prominence of conference-based dissemination in this interdisciplinary research space.

Data Analysis Using VOSviewer

The cleaned Scopus metadata file in CSV format was imported into VOSviewer for keyword co-occurrence network analysis. The minimum number of occurrences for keyword inclusion was set to 2, resulting in a network of interconnected keywords representing the core

intellectual themes of the field. VOSviewer's clustering algorithm (modularity-based) was applied to identify thematically coherent groups of keywords, yielding five distinct clusters. Each cluster was assigned a color for visual differentiation: red (sustainability and biodiversity), orange (food supply and cultivation), green (rural development and agricultural development), blue (agriculture and palm oil), and yellow (information systems and technology).

Cluster	Color Code	Core Keywords	No. of Keywords	Dominant Theme
Cluster 1	Red	sustainability, indonesia, deforestation, biodiversity, palm oil	18	Sustainability & Governance
Cluster 2	Orange	sustainable development, food supply, cultivation, fertilizers	10	Food & Crop Systems
Cluster 3	Green	rural development, agricultural development, investments, quality control	12	Rural & Agricultural Dev.
Cluster 4	Blue	agriculture, palm oil, oil palm plantations, planning, literature reviews	14	Palm Oil & Environment
Cluster 5	Yellow	information systems, big data, remote sensing, sustainable agriculture	8	Technology & Data

Table 2. Keyword Co-Occurrence Clusters in VOSviewer Network Analysis

Source: Fatur Rohman (2026)

Quality Assurance and Validation

To ensure the reliability and validity of the bibliometric analysis, several quality assurance measures were implemented. First, author keyword normalization was performed manually to consolidate synonymous terms (e.g., 'palm oil' and 'oil palm' were standardized). Second, the Scopus dataset was cross-validated against a secondary search in Google Scholar to verify completeness of coverage for high-impact papers. Third, the VOSviewer network structure was validated against subject matter expert review by two independent agricultural science researchers, who confirmed the thematic coherence of the identified clusters. The

citation statistics reported are based on Scopus citation counts as of January 2025 and may undercount citations from non-Scopus-indexed sources.

Limitations

This study is subject to several limitations that should be considered when interpreting the findings. First, the exclusive reliance on the Scopus database may exclude relevant publications indexed only in Web of Science, Google Scholar, or regional Indonesian databases such as SINTA or Garuda. Second, the bibliometric analysis captures structural relationships between keywords but cannot fully convey the nuanced theoretical and empirical content of individual studies. Third, the corpus of 84 documents, while representative of peer-reviewed Scopus-indexed output, may not capture the full breadth of practitioner knowledge, policy documentation, and gray literature relevant to Indonesian agricultural sustainability. Future studies should consider multi-database approaches and mixed-methods integration to address these limitations.

IV. Result and Discussion

Overview of Publication Trends (2018–2025)

The temporal distribution of publications in this corpus reveals a clear and accelerating upward trend in research on Indonesian agricultural sustainability, particularly from 2020 onward. Of the 84 documents analyzed, 69 (82%) were published between 2018 and 2025, with the most productive years being 2021 (16 papers), 2025 (13 papers as of January), 2023 (10 papers), and 2024 (10 papers). This growth trajectory reflects both the increasing global urgency around sustainability and the Indonesian government's expanded investment in research and development through mechanisms such as the Ministry of Higher Education, Research and Technology's competitive grant programs. The concentration of output in IOP Conference Series and E3S Web of Conferences further suggests that Indonesian researchers are increasingly participating in international scientific communication channels, signalling a maturation of the national research community.

Network Visualization Analysis: Thematic Cluster Identification

The VOSviewer network visualization (Figure 2) reveals five major thematic clusters, each representing a coherent domain of inquiry within the broader field of Indonesian agricultural sustainability. The largest and most interconnected nodes sustainable development, agriculture, Indonesia, palm oil, and sustainability serve as the intellectual backbone of the

network, confirming their central position in the research discourse. The red cluster (Cluster 1), anchored by sustainability, Indonesia, and deforestation, is the most internally cohesive, reflecting the depth of engagement with socio-environmental governance questions. The orange cluster (Cluster 2), centred on sustainable development and food supply, demonstrates strong cross-cluster linkages, indicating its integrative function in bridging governance and production-oriented research.

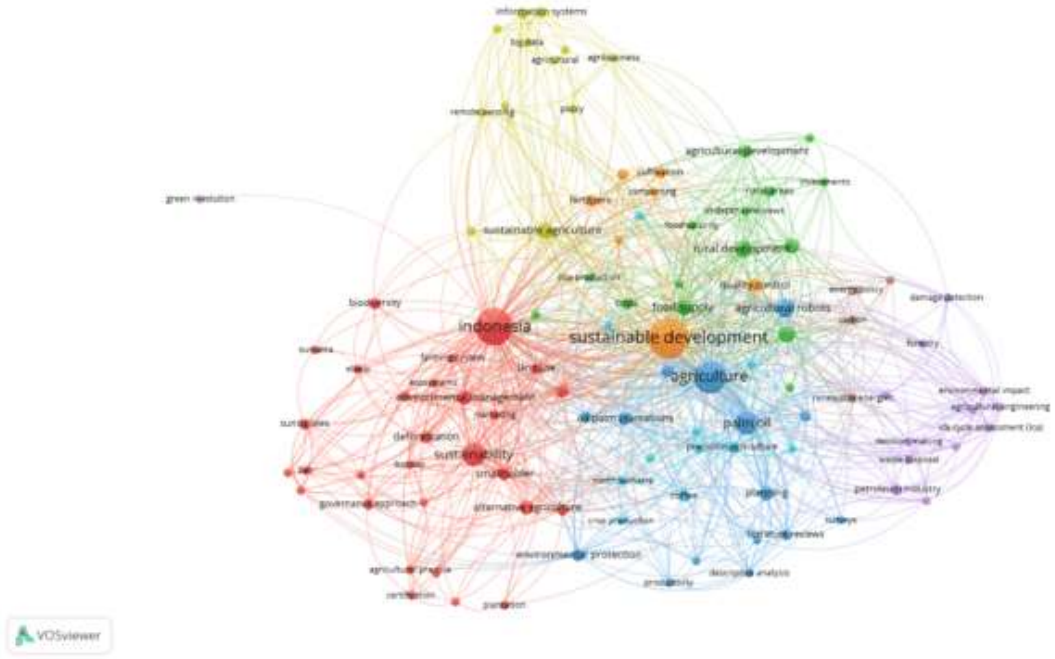


Figure 2. Network Analysis (VOSviewer generated)

Source: Fatur Rohman (2026)

The green cluster (Cluster 3) encompasses rural development, agricultural development, rural areas, investments, and in-depth interviews, suggesting a methodological orientation toward qualitative and field-based inquiry. This cluster's connection to food security and quality control nodes indicates the integration of market-oriented and livelihood perspectives in rural development research. The blue cluster (Cluster 4), dominated by agriculture, palm oil, oil palm plantations, and planning, represents the commodity-specific technical literature, while the yellow cluster (Cluster 5), information systems, big data, remote sensing, and sustainable agriculture captures the emerging technology dimension. The size of each node in the network corresponds to the frequency of keyword occurrence, with sustainable development, agriculture, Indonesia, palm oil, and sustainability being the five most frequently appearing terms.

Overlay Visualization: Temporal Evolution of Research Themes

The overlay visualization (Figure 3) provides a compelling picture of how research priorities have evolved over the 2018–2024 period, using a color gradient from purple/blue (earlier publications, ~2018–2020) to green/teal (2020–2022) to yellow-green (2022–2024). The most significant finding from this visualization is the temporal bifurcation in the research landscape: topics related to deforestation, biodiversity, governance, and environmental management appear predominantly in cooler colors (earlier period), while topics such as agricultural robots, precision agriculture, renewable energies, investments, and rural development appear in warmer yellow-green tones associated with more recent publications. This shift reflects a global disciplinary turn toward technological solutions and investment-oriented sustainability frameworks.

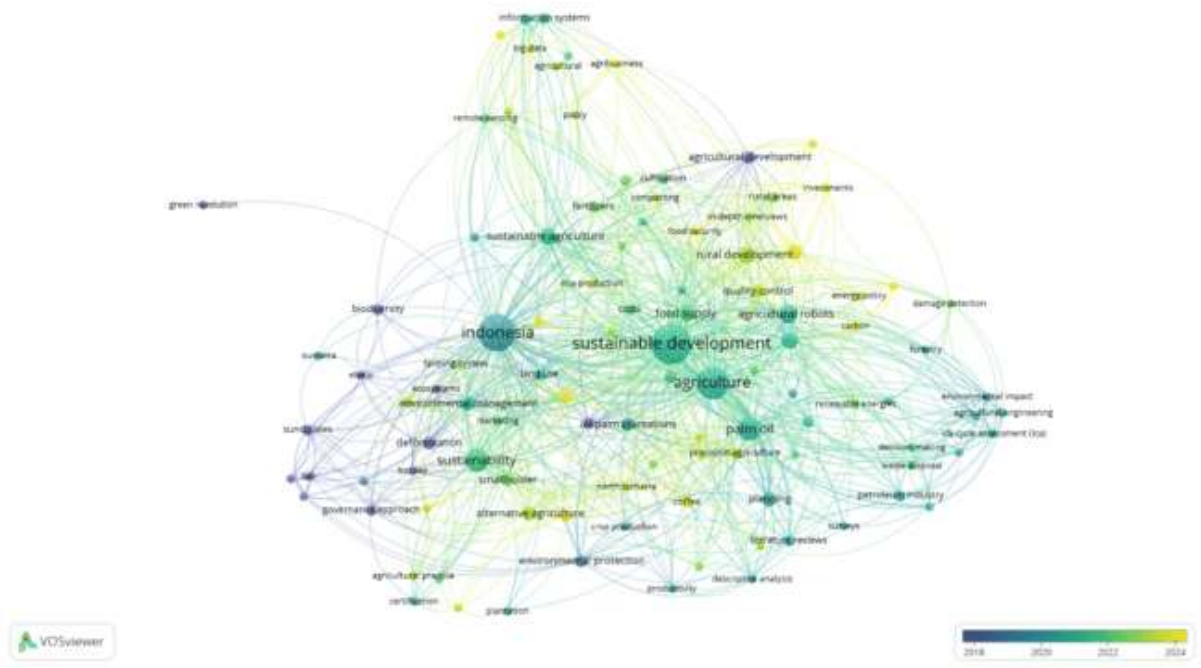


Figure 3. Overlay Analysis (VOSviewer generated)

Source: Fatur Rohman (2026)

Keywords appearing in the transitional green-teal zone (approximately 2020–2022) include sustainability, palm oil, food supply, and agricultural development, suggesting these as enduring, cross-generational concerns that bridge the earlier and more recent research periods. Of particular note is the positioning of information systems, big data, and remote sensing in the yellow zone, indicating that technology-focused research has only recently gained significant traction within the Indonesian agricultural sustainability literature. This finding has

important implications for research funders and institutions seeking to identify underinvested areas where targeted support could accelerate knowledge production.

Density Visualization: Research Hotspots and Gaps

The density visualization (Figure 1) maps the concentration of research activity across the keyword space, with bright yellow indicating the highest density of publications and dark blue indicating minimal research activity. The analysis identifies three primary research hotspots: the sustainable development-agriculture nexus (central-right), the Indonesia-sustainability-deforestation complex (left-center), and the information systems cluster (upper center). These hotspots correspond precisely to the largest keyword nodes in the network visualization, confirming their dominance in the literature. Critically, the density map also illuminates significant research gaps areas where keywords appear in the network but receive relatively low research attention. Notable among these underexplored areas are governance approach, alternative agriculture, agricultural practice, certification (smallholder), forestry, and environmental impact. These gaps are particularly significant given their policy relevance: governance innovation, alternative agricultural systems, and smallholder certification are widely identified by practitioners and policymakers as key levers for sustainable transformation but remain under-theorized and under-investigated in the peer-reviewed literature. The geographical periphery of the network representing keywords such as Bali, Borneo, Sunda Isles, and Sumatra also suggests that sub-national geographical differentiation in agricultural sustainability dynamics is insufficiently explored.

Citation Analysis and Research Impact

The citation analysis reveals a highly skewed distribution characteristic of scientific literature, with a small number of highly cited papers accounting for a disproportionate share of total citations. The mean citation count across the 84-document corpus is 8.21 (SD = 14.86), with a median of 3.0, indicating that the majority of papers have relatively modest citation counts. The top five most-cited papers are: Arifin & Nakagoshi (2011) on urban biodiversity (75 citations), Barbier (1998) on cash crops versus food crops (68 citations), Syuaib (2016) on sustainable agriculture challenges (51 citations), Rhofita et al. (2022) on biomass residue valorization (49 citations), and Roth & Jornet (2014) on environmental sustainability and legal plurality in Balinese subak irrigation (43 citations). These highly cited works span multiple decades and disciplines, reflecting the multidisciplinary character of the field.

The relatively low overall citation impact with 25% of papers having fewer than 1 citation is consistent with the preponderance of conference papers in the corpus (39%), which typically accumulate fewer citations than journal articles. It also reflects the regional specificity of much of the literature, which may be highly relevant to Indonesian practitioners but less widely cited in global academic networks. Strategies to enhance the citation impact of Indonesian agricultural sustainability research include greater engagement with international co-authorship, publication in higher-impact interdisciplinary journals, and more systematic use of open-access publication platforms.

Emerging Themes and Research Frontiers

Several emerging themes are identifiable from the convergence of overlay visualization findings and recent publication analysis. Precision agriculture and agricultural robotics represent the most rapidly expanding thematic frontier, reflecting national policy ambitions articulated in Indonesia's Industry 4.0 roadmap (Making Indonesia 4.0) and the growing affordability of sensor technologies, drones, and AI-based crop management tools. Research in this area is expected to grow significantly as the Indonesian government expands digital infrastructure in rural areas under the National Broadband Plan and as international development partners increase investments in digital agriculture programs. A second emerging frontier concerns the integration of renewable energy with agricultural systems, what is increasingly termed 'agri-energy' or 'agropower.' Indonesia's abundant biomass resources from palm oil, rice, and sugarcane residues present substantial potential for biogas, biodiesel, and bioelectricity generation, creating new economic opportunities for farming communities while reducing greenhouse gas emissions. The keywords renewable energies, carbon, and energy policy in the network visualization reflect early engagement with this theme, which is expected to intensify as Indonesia's national energy transition commitments under the Paris Agreement become operationalized. Research at the intersection of agricultural productivity, waste valorisation, and climate mitigation represents a high-priority frontier for interdisciplinary investigation.

Policy Implications and Recommendations

The findings of this bibliometric analysis carry significant policy implications for the Indonesian agricultural sector. The dominance of palm oil governance and sustainability certification themes in the literature underscores the continued centrality of ISPO reform as a policy priority. The evidence base strongly supports mandatory ISPO certification for all palm

oil producers, coupled with improved technical assistance and financial incentives for smallholder compliance. The temporal evolution of research toward technology-intensive themes suggests that policy frameworks need to create enabling environments for precision agriculture adoption, including rural digital infrastructure investment, farmer digital literacy programs, and affordable financing mechanisms for agricultural technology acquisition. The research gaps identified through the density analysis highlight areas where policy attention has outpaced evidence generation. In particular, governance approaches to smallholder agriculture, alternative agricultural systems (including organic farming, agroforestry, and integrated crop-livestock systems), and sub-national differentiation of sustainability challenges require substantially greater empirical investigation. Policymakers should invest in long-term, place-based research programs that capture the diversity of agroecological conditions, institutional contexts, and livelihood strategies across Indonesia's 17,000 islands. The establishment of regional agricultural sustainability observatories building on existing research institutions such as BRIN (National Research and Innovation Agency) and BBRMP (Regional Agricultural Technology Assessment Centers) could provide the institutional framework for sustained, systematic knowledge production in these underexplored domains.

Comparison with Global Agricultural Sustainability Research Landscape

Placing the Indonesian bibliometric landscape in comparative perspective reveals both convergences and divergences with global trends in agricultural sustainability research. Globally, the most prominent themes in agricultural sustainability include climate change adaptation, agroecological intensification, soil health, food system resilience, and sustainable supply chains (FAO, 2018). The Indonesian literature converges with global priorities in its strong emphasis on sustainability certification, land use governance, and technology adoption. However, it diverges in the relatively limited engagement with agroecological approaches, biodiversity-friendly farming practices, and farmer-centered innovation processes themes that are gaining ground in European and Latin American agricultural sustainability research. The concentration of Indonesian publications in conference proceedings rather than high-impact international journals also distinguishes it from research landscapes in countries such as China, Brazil, and the Netherlands, where agricultural sustainability literature is predominantly disseminated through peer-reviewed journal articles. This structural difference reflects both resource constraints and incentive systems within Indonesian academic institutions, where conference participation may be rewarded at the expense of journal publication quality. Aligning Indonesian research incentive structures with international publishing norms, while

ensuring that research remains relevant to national priorities and local knowledge systems is a key institutional challenge for the coming decade.

Strengths and Limitations of the Bibliometric Approach

This bibliometric analysis offers several distinctive strengths as an approach to synthesizing Indonesian agricultural sustainability research. The quantitative rigor of the methodology ensures systematic coverage of the literature, reducing selection bias inherent in narrative reviews. The VOSviewer visualization tools provide intuitive, communicable representations of complex intellectual structures that can inform both specialist and non-specialist audiences. The temporal overlay visualization is particularly valuable for identifying research trajectories and anticipating future thematic developments, enabling proactive research agenda-setting. The multi-method triangulation, combining network, overlay, and density visualizations provides a more nuanced understanding than any single visualization mode could offer in isolation.

However, the bibliometric approach has inherent limitations that constrain interpretation. As noted in the methodology section, the exclusive reliance on Scopus data introduces a systematic bias toward English-language, internationally disseminated research, potentially marginalizing high-quality Indonesian-language scholarship in national journals such as Jurnal Agronomi Indonesia, Agrotropika, and Pelita Perkebunan. Additionally, keyword co-occurrence analysis captures the linguistic surface of research discourse but may miss important theoretical frameworks, methodological innovations, and empirical findings that are not signaled by keywords alone. Future bibliometric studies should complement keyword analysis with abstract-level text mining and full-text analysis to capture these deeper layers of intellectual content.

Synthesis: Toward an Integrated Research Agenda for Indonesian Agricultural Sustainability

Synthesizing the findings from the network, overlay, and density analyses, together with the citation profile and publication trend data, this study proposes an integrated research agenda for Indonesian agricultural sustainability organized around five strategic priorities. First, deepening the governance and institutional analysis of sustainability certification systems, particularly ISPO, with attention to sub-national implementation dynamics and smallholder inclusion. Second, expanding empirical research on precision agriculture and digital technology adoption, with specific focus on affordability barriers, gender-differentiated

uptake, and the role of extension systems in mediating technology diffusion. Third, developing integrated bioeconomy frameworks that link agricultural biomass production with renewable energy generation, creating new economic models for sustainable rural livelihoods. Fourth, filling critical research gaps on alternative agricultural systems, including agroforestry, organic farming, and integrated crop-livestock systems that represent lower-input, higher-resilience pathways to sustainability. Fifth, building comparative, cross-regional research that captures the diversity of agroecological conditions, indigenous knowledge systems, and institutional contexts across Indonesia's major island groups. This agenda, if systematically pursued, has the potential to position Indonesian agricultural sustainability science as a globally significant contributor to the knowledge needed for achieving the Sustainable Development Goals.

V. Conclusion

This study has presented a comprehensive bibliometric analysis of 84 Scopus-indexed publications on the development of agricultural sustainability in Indonesia, employing VOSviewer to generate network, overlay, and density visualizations of the keyword co-occurrence structure. The analysis reveals a dynamic and expanding research landscape organized around five thematic clusters: sustainable development and palm oil governance, biodiversity and environmental management, food supply and rural development, precision agriculture and technology, and smallholder governance systems. The temporal evolution of research shows a clear shift toward technology-intensive and investment-oriented themes in recent years, while enduring concerns about deforestation, certification, and environmental management persist across the study period.

Key findings include: (1) a strong upward trend in publication output, particularly from 2020 to 2025; (2) the central role of palm oil governance and ISPO certification in the research discourse; (3) emerging research frontiers in precision agriculture, agricultural robotics, and renewable energy integration; (4) significant research gaps in governance approaches, alternative agriculture, and sub-national regional differentiation; and (5) a relatively modest overall citation impact reflecting the dominance of conference publications and regional research audiences. These findings provide actionable guidance for research funders, university administrators, and policymakers seeking to strategically invest in agricultural sustainability knowledge production. Future research should address identified gaps through empirical, place-based studies in underexplored regions and thematic domains, adopt multi-database bibliometric approaches to improve coverage of Indonesian-language literature, and engage more deeply with practitioner and community perspectives to ensure that academic knowledge

production remains anchored in the realities of Indonesian farming systems. The achievement of sustainable agricultural transformation in Indonesia, essential for meeting the country's SDG commitments and for the livelihoods of its 40 million farming households demands a commensurate strengthening of the evidence base that this study has helped to map and prioritize.

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