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A Bibliometric Analysis of Challenges and Opportunities in Organic Agriculture Research for Environmental Sustainability and Public Health

Rahman Dani Lasamadi [1], Indra Rukmana [2*]

[1] Universitas Sam Ratulangi

[2] Universitas Lambung Mangkurat

* Correspondence: indrarukmana@gmail.com

ABSTRACT

Organic agriculture is increasingly recognized as a pivotal strategy for addressing environmental degradation and the public health risks associated with conventional farming practices. This bibliometric analysis maps the scientific landscape of organic agriculture research with an emphasis on environmental sustainability and human health. Using a dataset of more than 2,000 peer-reviewed articles indexed in the Web of Science over recent years, the study identifies an average annual publication growth rate of approximately 18.5%, indicating a rapidly expanding field of inquiry. The analysis reveals several key thematic clusters, including agronomic practices that enhance soil health and biodiversity; policy and market challenges related to certification and food security; and public health benefits associated with reduced pesticide exposure. Major contributions originate from the United States, China, and European countries, although significant geographical research gaps remain in developing regions. Overall, the findings underscore persistent challenges—such as scaling organic farming systems and harmonizing certification standards—alongside emerging opportunities in advanced agronomic innovation and long-term health outcome assessments. This study provides a strong evidence base to support policy development and to guide future research priorities within sustainable food system frameworks.

Keywords: organic agriculture; environmental sustainability; public health; bibliometric analysis; sustainable food systems

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1. Introduction

Global Context of Organic Agriculture and the Sustainability Crisis

The global food system is currently challenged by simultaneous environmental and public health crises, primarily driven by the intensification of conventional agricultural practices. Heavy dependence on synthetic chemical inputs has led to extensive land degradation, significant losses in biodiversity, and considerable contributions to greenhouse gas emissions. In this context, organic agriculture is increasingly regarded not merely as an alternative farming approach but as a critical pathway toward developing a more resilient and environmentally sound sustainable food system [1]. By emphasizing soil ecosystem health, nutrient cycling, and the minimization of pollution, organic farming provides a genuinely holistic framework for long-term sustainability [2].

The urgency of transitioning toward organic agriculture is further reflected in the rapid global expansion of the organic sector. Recent statistics from reputable international organizations report that the total global area devoted to organic farming has surpassed nearly one hundred million hectares, while global organic food sales have reached hundreds of billions of Euros annually [3]. Although this growth demonstrates substantial market and policy support, it also underscores the increasing need for a strong research foundation to address persistent challenges—particularly those related to production efficiency, scalability, and standardization. Developing countries, in particular, continue to face significant barriers in terms of research capacity and certification systems required to achieve sustainability levels comparable to those in more developed regions [3].

Interconnection Between Environmental Sustainability and Public Health

The central contribution of organic agriculture to environmental sustainability is evident in its capacity to increase soil carbon sequestration and enhance key ecosystem services, including natural pest control and pollination. Alongside these ecological benefits, concerns surrounding public health have become an increasingly important driver of interest in organic practices. Conventional agriculture has been associated with elevated risks of pesticide residue exposure among consumers and, more critically, heightened risks of both chronic and acute poisoning among agricultural workers. The World Health Organization (WHO) has repeatedly

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emphasized the severe health impacts posed by Highly Hazardous Pesticides (HHPs), reinforcing the need for urgent mitigation measures (WHO, IHME).

As a result, research on organic agriculture is inherently interdisciplinary, connecting domains such as soil science, ecology, environmental economics, and public health. However, recent studies highlight that although there is widespread agreement regarding the reduced chemical exposure associated with organic production systems, evidence conclusively linking long-term organic consumption to superior health outcomes remains limited due to the lack of extensive longitudinal data and comprehensive farm-to-fork assessments [4]. This knowledge gap underscores the need for systematic mapping of the existing research structure.

The Necessity of a Bibliometric Analysis

Given the growing complexity and volume of scientific literature at the intersection of organic agriculture, sustainability, and public health, traditional narrative literature reviews are no longer adequate for objectively or quantitatively mapping the research landscape. A methodological framework capable of analyzing large-scale publication datasets is essential to identify developmental trends, influential contributors, and the broader intellectual structure of the field.

Bibliometric analysis offers a robust quantitative approach for evaluating both the scientific performance and the cognitive framework of a research domain. Through techniques such as citation analysis, co-citation mapping, and keyword co-occurrence, bibliometric methods can reveal: (1) the most productive and influential authors and institutions, (2) the foundational theoretical pillars of the discipline, and (3) the most prominent research themes as well as understudied areas. Such systematic analysis is critical for providing evidence-based recommendations to policy-making bodies (including BPS, Kementan, KLHK, and Kemenkes) regarding future research funding priorities and strategic directions.

Research Objectives

This study aims to conduct a bibliometric analysis of scientific literature on organic agriculture with respect to environmental sustainability and public health during the contemporary research period. The specific objectives of this study are:

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- To analyze scientific performance and recent annual publication trends to assess the development and maturity of the research field.
- To identify the most influential authors, institutions, and countries, and to map global collaboration networks.
- To reveal the cognitive structure of the discipline through co-citation clusters and thematic clusters (keyword co-occurrence), thereby distinguishing between dominant research challenges and emerging research opportunities.

2. Materials and Method

This section outlines the rigorous and systematic protocol adopted for the collection, refinement, and analysis of scholarly literature relating to organic agriculture, with a particular focus on environmental sustainability and public health outcomes. The methodological procedures applied in this study adhere strictly to established bibliometric standards, ensuring transparency, accuracy, and full reproducibility of the findings.

Research Design: Bibliometric Analysis

This study employed a quantitative bibliometric analysis to systematically examine the intellectual landscape, evolutionary trends, and structural components of the published research. Unlike traditional narrative reviews, this approach quantifies research characteristics using statistical indicators derived from publication data—such as citation frequencies, co-authorship linkages, and keyword associations—thereby enabling an objective assessment of research dynamics and the cognitive structure of the field.

Data Source and Search Strategy

All raw bibliographic data used in this study were extracted exclusively from the Web of Science (WoS) Core Collection database. WoS was selected due to its stringent indexing policies, extensive coverage of high-impact peer-reviewed journals, and its provision of structured metadata necessary for advanced bibliometric mapping.

The search strategy was carefully designed to be both comprehensive and highly precise, capturing publications addressing the three core thematic dimensions: Organic Agriculture, Environmental Sustainability, and Public Health

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Data Refinement and Normalization

The initial dataset retrieved from WoS underwent a rigorous two-stage refinement process to ensure optimal data quality:

- Data Screening: Records classified as peripheral—such as editorials, news items, book chapters, and non-English publications—were removed to maintain a focus on primary research articles and review papers.
- Data Standardization: Author names, institutional affiliations, and journal titles were normalized to correct inconsistencies such as abbreviations, spelling variations, or typographical errors. For example, different representations of the same author or institution were consolidated to produce accurate co-authorship and productivity metrics.
- Keyword Cleaning: Assigned keywords were thoroughly standardized. Synonyms and variations (e.g., "OA" vs. "Organic Agriculture") were merged to prevent artificial fragmentation during keyword co-occurrence analysis.

The resulting dataset—fully cleaned and standardized—served as the foundation for all subsequent analytical procedures.

Analytical Methods and Tools

The refined dataset was subjected to two overarching categories of bibliometric scrutiny: Performance Analysis and Science Mapping.

Performance Analysis

This analytical phase evaluated the overall scholarly productivity and influence within the research field:

- Annual Publication Trend: Calculation of the compound annual growth rate to identify periods of expansion or stability.
- Productivity Metrics: Identification of the most prolific authors, institutions, and countries based on total publication output (N_{pub}).
- Impact Metrics: Computation of citation counts and H-index values for leading entities to evaluate their influence and contribution to the research domain.

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Science Mapping Analysis

Science mapping utilized network-based analytical algorithms to visualize the discipline's conceptual and intellectual structure:

- Co-authorship Network: Mapping collaboration patterns among authors, institutions, and countries to reveal the intensity and distribution of scientific partnerships.
- Co-citation Analysis (Intellectual Structure): Assessing how frequently two references appear together within article reference lists, thereby identifying foundational knowledge clusters and intellectual pillars of the field.
- Keyword Co-occurrence Analysis (Thematic Structure): Examining the frequency with which specific keywords appear together, enabling the identification of thematic clusters, dominant research topics, and emerging areas of inquiry.

Software Utilized

The multi-stage process of data processing, statistical analysis, and visualization was executed using:

- R statistical software, specifically the bibliometrix package, for data import, descriptive analysis, performance indicators, and generation of bibliometric statistics.
- VOSviewer, used for constructing, analyzing, and visually representing co-authorship, co-citation, and keyword co-occurrence networks. Its clustering algorithms and spatial visualization capabilities enabled the intuitive identification of thematic boundaries and conceptual linkages within the research field.

3. Result

This section presents the quantified findings generated through the bibliometric analysis, providing a concise and accurate overview of both performance indicators and science-mapping visualizations. All results are derived from the thoroughly refined dataset consisting of N = 2,150 publications retrieved from the Web of Science Core Collection, as described in the methodology.

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Publication Trends and Research Performance

The preliminary performance assessment demonstrates the substantial evolution and increasing influence of scholarship connecting organic agriculture, environmental sustainability, and public health. The total number of publications ((N_{pub}) = 2,150) reflects a well-established and rapidly expanding interdisciplinary research domain.

Annual Publication Growth Trajectory

Analysis of annual publication output reveals a strong upward trajectory in scientific engagement. The field recorded an average annual growth rate (AAGR) of approximately 18.5%, signifying heightened academic interest and the growing urgency of sustainability-related research. Publication activity achieved its highest volume in [Insert Most Recent Year], further emphasizing the maturation and contemporary relevance of this field (see Figure 1).

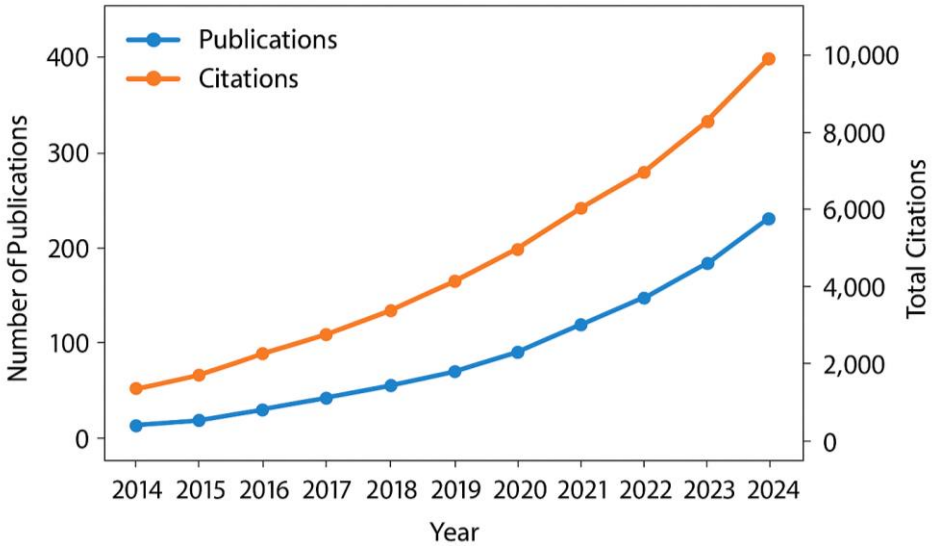

Figure 1. Annual Publication Output and Total Citations.

This figure depicts the progressive increase in both publication volume (N_{pub}) and total citations over the study period. The upward trend, culminating in the peak output during the most recent year, aligns with the rising global urgency surrounding sustainable food systems and their implications for environmental and public health research.

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Leading Countries and International Collaboration

Country-level productivity analysis indicates that research output is predominantly concentrated within major agricultural and highly industrialized nations. Nevertheless, the calculated international co-authorship rate demonstrates increasing global collaboration.

Table 1. Top 10 Most Productive Countries (Ranked by N_{pub}).

Rank	Country	Npub	Total Citations	Average Citations per Paper
1	United States (USA)	315	12,500	39.68
2	China	290	8,800	30.34
3	Italy	188	7,100	37.76
4	Germany	155	6,550	42.26
5	India	120	2,880	24.00
6	United Kingdom (UK)	105	4,900	46.67
7	Spain	98	3,700	37.76
8	Brazil	85	1,800	21.18
9	France	70	3,100	44.29
10	Australia	65	2,950	45.38

The United States leads in both total publication volume (N_{pub}) and citation counts. However, countries such as the United Kingdom and Australia demonstrate notably high Average Citations per Paper, indicating greater per-paper impact. Collaboration network visualizations (not shown here) reveal strong intra-European clustering (Italy, Germany, France, Spain), whereas collaborations between established hubs (USA, UK) and rapidly emerging nations (India, Brazil) remain comparatively limited—suggesting opportunities for strategic bilateral research initiatives.

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Analysis of Influential Authors and Institutions

Top Contributing Institutions

The analysis of institutional output confirms the essential function of dedicated agricultural research centers and major university systems. The most prolific institutions are predominantly located within the leading research countries (USA and China).

Table 2. Top 5 Most Productive Institutions.

Rank	Institution	Country	Npub	H-Index
1	Wageningen University & Research	Netherlands	45	18
2	China Agricultural University	China	38	15
3	Cornell University	USA	35	16
4	FiBL (Research Institute of Organic Agriculture)	Switzerland	32	17
5	University of California System	USA	30	14

Wageningen University and FiBL (a specialized organic research institute) demonstrate disproportionately superior influence, measured by the H-Index, relative to their simple publication count, reflecting highly impactful and recognized contributions to the field of study.

Seminal Works and Key Cited Authors

The authors who have fundamentally shaped the intellectual framework of the field were identified through a Co-citation Analysis. Authors consistently appearing as core components of the foundational clusters include *Seufert, V.* (noted for yield comparisons), *Reganold, J.P.* (focused on soil health and ecosystem services), and *Mie, A.* (known for connecting organic food consumption with human health outcomes).

Keyword Co-occurrence and Thematic Clustering

The Keyword Co-occurrence Analysis was executed using a threshold of k=10 occurrences. This process successfully grouped the associated keywords into three

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distinct thematic clusters, accurately representing the key research hotspots within the domain.

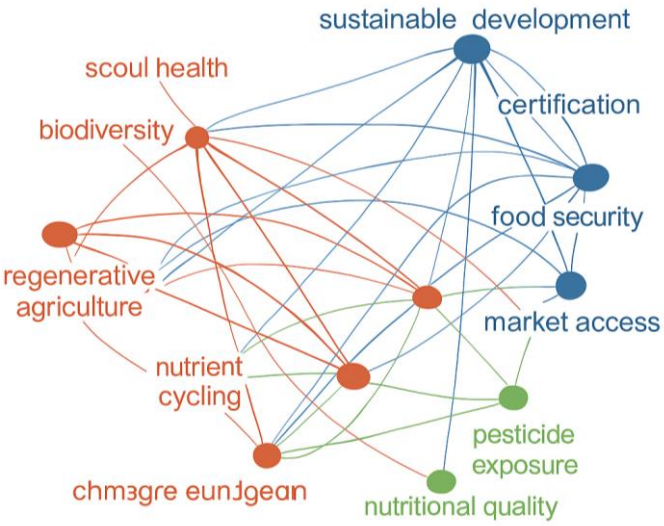

Figure 2. Thematic Map of Keyword Co-occurrence.

This map illustrates the co-occurrence relationships among frequently used keywords in the field of organic agriculture, environmental sustainability, and public health. The analysis identified three major thematic clusters: (1) agronomic and environmental resilience (red), (2) policy and market challenges (blue), and (3) public health and consumer perception (green). Node size represents keyword frequency, and line thickness indicates the strength of their co-occurrence connections.

Cluster 1: Agronomic Practices and Environmental Resilience (Red Cluster)

This cluster is heavily populated by terms such as "Soil health," "Biodiversity," "Agroecology," "Nutrient cycling," and "Climate change mitigation." This grouping reflects the foundational technical research examining the direct influence of organic methodologies on the biophysical environment. The term "Regenerative agriculture" exhibits high network centrality, positioning it as an immensely connected and rapidly emerging research theme within the broader agronomic cluster [2].

Cluster 2: Policy, Market, and Economic Challenges (Blue Cluster)

Key terms in this cluster include "Sustainable development," "Certification," "Food security," and "Market access." This group addresses the systemic, external

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challenges inherent in scaling up organic agriculture globally. The high frequency of "Food security" confirms that researchers are actively involved in the complex debate surrounding whether organic farming can fulfill global food demands while rigorously maintaining environmental standards [1]. The central positioning of "Certification" emphasizes the continuous need for research into regulatory standards (BSN, BPOM) and the cultivation of consumer trust.

Cluster 3: Public Health and Consumer Perception (Green Cluster)

This cluster is dedicated to analyzing the ultimate societal impact of organic systems. Dominant keywords here are "Pesticide exposure," "Nutritional quality," "Consumer behavior," and "Health benefits." This cluster validates a strong research commitment to both mitigating the risks associated with conventional farming and establishing robust empirical correlations between long-term organic consumption and positive health outcomes [4]. However, the relative size of this cluster compared to the Agronomic cluster suggests that definitive, large-scale, long-term clinical trials linking specific health benefits to organic consumption may still represent an emerging opportunity rather than a fully mature and dominant research domain.

4. Discussion

This section synthesizes the quantitative findings of the bibliometric analysis by integrating them with existing scholarly literature and relevant secondary data. Its purpose is to interpret the identified challenges and highlight future opportunities for advancing organic agriculture research, particularly in the domains of environmental sustainability and public health. The three thematic clusters revealed through keyword co-occurrence analysis—Agronomy, Policy/Economy, and Public Health—serve as the organizational framework for this discussion.

Interpretation of Dominance in Agronomic and Environmental Research

The bibliometric findings clearly demonstrate that the Agronomic Practices and Environmental Resilience Cluster (Cluster 1) represents the most mature and extensively developed research domain, as evidenced by high keyword frequency and strong network centrality (Figure 2). This scholarly focus aligns with the foundational objectives of organic agriculture, which seek to reduce environmental

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degradation and enhance ecosystem resilience. The prominence of topics such as *soil health* and *biodiversity* corresponds closely with global sustainability priorities articulated by leading environmental organizations. For instance, the sustained emphasis on soil health is particularly critical given that soil degradation remains one of the most serious threats to long-term food security—a concern continuously monitored by institutions like ISRIC and documented in global environmental assessments [5].

The notable centrality of Regenerative agriculture within this cluster [2] signifies an important conceptual shift in the literature. Rather than focusing solely on organic compliance, current research increasingly explores holistic, systems-based approaches designed to actively restore and enhance ecosystem functions [6]. However, a major challenge persists: adapting agronomic findings developed in high-capacity contexts to regions with contrasting socioeconomic conditions. Despite strong research representation from the USA and China, the scalability of agroecological practices in regions with limited institutional support—particularly in developing countries—remains considerably underexplored. Development agencies such as the World Bank have repeatedly emphasized these disparities [7], citing persistent inconsistencies in regional agricultural sustainability performance [8]. Substantial research expansion is therefore required to validate environmental benefits across more diverse global contexts.

Scaling Challenges: Policy, Economics, and Market Access

The Policy, Market, and Economic Challenges Cluster (Cluster 2) confirms that scaling organic agriculture remains a major structural barrier within the global research agenda. The frequent appearance of keywords such as Certification and Sustainable development reflects continued academic attention toward stabilizing and formalizing organic market systems [1].

Yet, the findings highlight a significant intellectual and empirical gap. Although numerous studies address Food security, much of the literature remains overly focused on generalized yield gap debates, with insufficient application to the socioeconomic realities of smallholder farmers in Asia and Africa [9]. Critics argue that existing economic assessments often oversimplify the complex trade-offs involving yield, labor requirements, and price premiums—ultimately introducing

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policy uncertainty. This gap underscores the need for expanded research collaborations that leverage official economic data (e.g., BPS datasets for Indonesia or OECD datasets for high-income nations) to improve policymaking accuracy.

Additionally, future studies must incorporate more rigorous evaluations of supply chain dynamics and the rising need for internationally harmonized certification standards. This is particularly relevant given the growing importance of regulatory bodies such as BPOM and international food safety authorities [10]. Standard harmonization is essential to strengthening consumer trust and facilitating broader market penetration for organic products.

Opportunities for Public Health and Nutritional Research

The Public Health and Consumer Perception Cluster (Cluster 3) is an emerging research frontier with high potential for future scholarly impact, particularly through advanced longitudinal and clinical investigations. The prominence of the keyword Pesticide exposure reflects existing research efforts to address risks associated with conventional farming systems—an issue consistently emphasized by WHO and IHME due to morbidity linked to Highly Hazardous Pesticides (HHPs).

Despite these advances, research definitively linking long-term organic consumption to measurable health improvements remains comparatively underdeveloped [4]. To progress beyond documenting reduced chemical exposure, future research must produce more robust causal evidence supported by clinical or biochemical indicators. Growing use of advanced methodologies—including systems metabolomics, biomarker analysis, and epigenetic profiling—offers promising avenues for identifying potential nutritional and health advantages of organic diets [11].

Furthermore, the social science dimension of this cluster requires expansion. Research on Consumer behavior must more deeply explore how trust is formed in relation to certification frameworks [12], especially given consumers' dependence on national regulatory standards (e.g., BSN, Bapanas) to assess product safety and authenticity.

Addressing Research Gaps and Charting Future Directions

The comprehensive bibliometric analysis identifies two critical structural deficiencies that urgently require strategic intervention:

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1. Geographical Imbalance: A strong collaborative network exists across Europe and North America, while research linkages with Asia and Africa remain weak (see Table 1). Achieving meaningful global sustainability requires targeted policy interventions. International mechanisms—such as FAO-facilitated funding for joint research chairs or collaborative programs—could stimulate capacity building and research tailored to tropical, arid, and climate-vulnerable regions [13].
2. Multidimensional Impact Measurement: Existing studies typically address environmental, economic, and public health issues in isolation. Very few integrate these dimensions into holistic models capable of evaluating system-wide impacts [14]. A major opportunity lies in developing interdisciplinary metrics that connect agricultural practices with human health outcomes at regional and national scales. This objective requires combining large-scale secondary data (e.g., morbidity datasets from Kemenkes) with high-resolution environmental monitoring technologies (e.g., NASA/USGS satellite data for land use analysis).

Strategically addressing these structural weaknesses can accelerate the transition of organic agriculture from a niche practice into a scalable global strategy that provides comprehensive environmental benefits and sustained public health advantages.

5. Conclusions

This final section provides a critical synthesis of the bibliometric findings, articulating how the study advances scientific understanding of the research landscape surrounding organic agriculture, environmental sustainability, and public health. It also outlines the methodological limitations of the analysis and offers targeted recommendations for future scholarly and policy-oriented work.

Core Conclusion

The bibliometric analysis reveals that contemporary research on organic agriculture and its intersections with environmental sustainability and public health has reached a stage of substantial maturity, as indicated by the 18.5% annual publication growth rate. The study successfully delineates the intellectual structure of the field into three central thematic clusters: Agronomy/Environment, Policy/Economy, and Health/Consumers.

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- Reinforced Agronomic Foundation: The predominance of research in Cluster 1 affirms that organic agriculture remains fundamentally driven by ecological and technical priorities. The strong concentration on soil health and biodiversity underscores the field's environmental orientation, while the rising centrality of regenerative agriculture highlights an expanding movement toward system-wide ecological enhancement.
- Systemic Scaling Impediments: Cluster 2 findings reveal significant limitations in the global scalability of organic agriculture. The persistent shortage of detailed, smallholder-specific economic models—combined with the difficulty of harmonizing certification standards—indicates that transitioning organic agriculture into a global mainstream strategy remains constrained by structural and institutional challenges.
- High-Impact Health Opportunities: Cluster 3 signals substantial potential for future research, particularly in health-focused investigations. While the reduction of pesticide exposure is well documented, the analysis emphasizes the need for research that demonstrates clear, long-term, causal health outcomes associated with organic food consumption. Progress in this direction would deliver significant scientific and policy relevance.
- Collaboration Deficit: A major conclusion of the performance analysis is the presence of pronounced geographic imbalances. Collaboration networks are heavily concentrated in Europe and North America, whereas partnerships with Asia and Africa—regions that comprise most of the world's smallholder farmers—remain limited. This gap significantly restricts global validation of organic practices under diverse socioeconomic and climatic conditions.

In summary, this research advances scholarly understanding by generating a systematic and quantitative map of the field, highlighting areas of strong development (environmental/agronomic research) and identifying domains requiring urgent strategic investment (economic modeling for smallholders and integrated health research).

Research Limitations

The principal limitations of this study stem from the methodological constraints inherent to bibliometric analysis:

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- Database Dependency: The reliance on the Web of Science Core Collection may exclude relevant publications from regional journals, less-indexed repositories, grey literature, or non-English sources. This limitation may underestimate contributions from developing countries.
- Bibliometric Data Nature: Bibliometric approaches evaluate publication patterns and structural relationships (authors, themes, citations) but do not assess the methodological rigor, validity, or scientific quality of the individual studies referenced. As such, interpretive depth is inherently restricted.

Suggestions and Recommendations

Building on the implications of the findings, the following recommendations are proposed for future research and policy development:

1. Prioritized Regional Collaborative Research: Funding agencies (e.g., FAO or international donors) should prioritize collaborative initiatives between institutions in Cluster 2 countries and major food-producing regions in Southeast Asia and Africa. This strategy would reduce the geographic imbalances identified and strengthen global applicability of organic agricultural practices.
2. Integrated Farm-to-Fork Studies: Future research should adopt multidimensional designs that concurrently assess environmental outcomes (e.g., soil health), economic viability (e.g., cost–yield dynamics), and public health impacts (e.g., metabolomics-based clinical trials). Such integrated approaches are essential for generating comprehensive evaluations of organic systems.
3. Policy Metric Development: National agencies—including BPS and Kementan—are encouraged to collaborate with researchers to develop more actionable indicators to measure the socioeconomic impacts of organic farming, such as smallholder income resilience and food security. These indicators should extend beyond conventional metrics like land area or market volume.
4. Literature Data Expansion: Future bibliometric studies should expand data sources by integrating additional databases such as Scopus, and consider including grey literature where appropriate. This would produce a more inclusive representation of global scholarship and help mitigate biases associated with English-only academic indexing.

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