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RESEARCH ON GOOD AGRICULTURAL PRACTICES (GAP)

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ABSTRACT

This study presents a comprehensive bibliometric evaluation of research on Good Agricultural Practices (GAP), utilizing Scopus data to examine the temporal and thematic progression of the field from 1964 to 2024. GAP, developed to ensure food safety, environmental sustainability, and economic feasibility in agriculture, has gained global recognition. However, research in this domain remains fragmented across disciplines such as agronomy, environmental science, and food safety. The study of GAP is essential for addressing global challenges, including climate change and food security. It serves as a framework to enhance sustainable agricultural productivity, reduce environmental impacts, and strengthen the resilience of production systems against escalating global pressures.

By analyzing research trends, this study highlights the pivotal role of GAP in shaping a sustainable future for global agriculture. Bibliometric tools such as VOSviewer and Biblioshiny were employed to synthesize and visualize key contributions to GAP research. A total of 1,732 publications were analyzed to identify leading authors, major contributing countries, and significant thematic trends. The results reveal an increasing focus on sustainable crop management, food safety regulations, and the integration of advanced technologies such as precision agriculture into GAP.

The findings also indicate that most existing evidence on GAP's potential to minimize food processing waste is concentrated in developed regions. In contrast, developing regions face significant barriers, including limited financial resources, inadequate knowledge dissemination, and insufficient infrastructure, which hinder effective implementation. Addressing these socio-economic constraints is critical to achieving equitable and sustainable agricultural development worldwide.

A significant research gap persists in studies focusing on developing regions, where GAP could have the greatest impact. Additionally, socio-economic challenges—particularly those faced by smallholder farmers in adopting GAP—remain underexplored. The study emphasizes the need for further investigation into the long-term effects of GAP, especially in relation to climate change and global food security. This analysis identifies research gaps and emerging trends, providing a foundation for future studies and policy interventions aimed at promoting sustainable agricultural practices globally.

However, certain limitations exist, including reliance on the Scopus database, which excludes relevant studies indexed in other sources. Furthermore, the bias toward English-language publications may obscure valuable research conducted in non-English-speaking regions, potentially overlooking important global patterns.

KEYWORDS: Sustainable agriculture; economic sustainability; farmers; bibliometric analysis.

INTRODUCTION

The concept of Good Agricultural Practices (GAP) has evolved into a holistic strategy aimed at addressing major agricultural challenges, including food safety, environmental conservation, and rural development (Siebrecht, 2020a). Initially introduced by international organizations such as the Food and Agriculture Organization (FAO), GAP standards have been widely adopted to harmonize agricultural practices across both developed and developing regions (Amekawa et al., 2022). GAP seeks to establish a balanced agricultural system capable of responding to external pressures such as climate change and market volatility, based on four fundamental pillars: economic viability, environmental sustainability, social equity, and food safety.

The body of literature on GAP is extensive and multidisciplinary, encompassing agronomy, food safety, economics, and environmental sciences (Sparling et al., 2021). Consequently, researchers often encounter difficulties in integrating findings from diverse fields, resulting in fragmented knowledge and a limited understanding of GAP's overall influence on agricultural systems (Pervez et al., 2016). Bibliometric analysis offers a solution to this issue by providing a systematic assessment of existing research, tracking scholarly output, and mapping the evolution of GAP studies over time (Zhao et al., 2023).

Scopus, a comprehensive abstract and citation database, serves as an appropriate platform for bibliometric studies due to its extensive coverage of peer-reviewed journals, conference

proceedings, and other academic resources. This study employs Scopus data to systematically map research outputs on GAP, identify leading authors, institutions, and countries, and evaluate citation patterns to measure the impact of key publications. By examining significant keywords and thematic clusters, the study aims to uncover emerging trends and research gaps, thereby offering a roadmap for future investigations.

Given the global challenges facing agriculture—particularly climate change, resource scarcity, and population growth—understanding the evolution of GAP research is essential (Viana et al., 2022). This bibliometric analysis provides valuable insights into the development and application of GAP across various agricultural systems worldwide, supporting policymakers, practitioners, and researchers in advancing sustainable agricultural development. Ultimately, the study enhances understanding of GAP's role in promoting sustainability and addressing global food security concerns.

LITERATURE REVIEW

The concept of Good Agricultural Practices (GAP) has achieved widespread global acceptance as an approach to fostering agricultural sustainability, environmental protection, and food safety (Bertola et al., 2021). Numerous studies suggest that GAP frameworks provide structured guidelines that enable farmers to adopt practices that minimize environmental degradation while enhancing productivity. Key components of GAP include soil fertility management, efficient water utilization, and integrated pest management (IPM), all of which contribute to sustainable agricultural systems.

Existing literature indicates that while GAP has been successfully implemented in developed countries, its adoption in developing regions remains uneven (Eriksen et al., 2021). Factors such as inadequate infrastructure, financial constraints, and limited technical knowledge restrict farmers from fully embracing GAP. Research shows that overcoming these challenges could significantly improve agricultural productivity and livelihoods, particularly in regions dominated by subsistence farming (Khatam et al., 2013). Additionally, GAP plays a crucial role in improving food safety standards, which are increasingly important in international trade and export requirements.

The importance of certification systems associated with GAP is widely discussed in the literature. GAP certification provides farmers with competitive advantages, especially in accessing premium markets that demand strict quality standards (De Lima et al., 2023). However, smallholder farmers often face challenges in obtaining such certifications due to

high costs and complex administrative procedures, highlighting the need for government support to ensure equitable access to GAP benefits.

Recent studies have explored the integration of digital technologies and precision agriculture within GAP frameworks to enhance their effectiveness (Onyango et al., 2021). Digital tools facilitate real-time monitoring, data collection, and decision-making, enabling farmers to implement GAP more efficiently. The potential of these technologies to improve GAP adoption and outcomes represents a rapidly expanding area of research, particularly in the context of climate change and its impact on agriculture.

Overall, the literature emphasizes the critical role of GAP in promoting sustainable agriculture and ensuring food security (Chouhan et al., 2021). It also highlights the socio-economic barriers and technological gaps that must be addressed to enable broader and more equitable adoption of GAP, particularly in developing countries. Further research is required to examine the long-term impacts of GAP on smallholder farmers, environmental sustainability, and global food systems (Beck-O'Brien & Bringezu, 2021).

3. METHODOLOGY

Across various academic disciplines, researchers have employed comprehensive scientific mapping techniques to analyze scholarly literature. In addition to traditional statistical and graphical approaches, advanced tools are available; one notable open-source R package with an intuitive web interface is **Biblioshiny**. Furthermore, **VOSviewer**, a robust visualization software for constructing and mapping bibliometric networks, is utilized (Khanam et al., 2023).

For this study, the **Scopus database**, covering the period from 1964 to 2024, was selected as the primary data source. Scopus is widely acknowledged as a reliable bibliographic database among researchers (Kabir et al., 2024). In the initial stage, 1,755 publications were retrieved using the keyword *"Good Agricultural Practices."* After removing duplicate records, a total of 1,732 documents were retained for detailed bibliometric analysis, including full records and cited references. The data extraction process was conducted on September 21, 2024.

Figure 1 illustrates the comprehensive five-step research framework adopted in this study, outlining the systematic process of data collection, screening, analysis, and interpretation.

4. RESULTS AND DISCUSSION

4.1 Description of the Data

Table 1 summarizes the descriptive characteristics of the dataset, spanning the period from 1964 to 2024. The dataset comprises contributions from 867 sources, including academic journals and books, resulting in a total of 1,732 publications. Despite the extensive scope of the dataset, the annual growth rate is recorded at 0%, while the average age of the documents is 8.23 years.

On average, each publication has received 17.71 citations, contributing to a cumulative total of 71,684 references. The dataset includes 6,496 **Keywords Plus (ID)** and 4,605 **Author Keywords (DE)**, reflecting a broad range of thematic areas. A total of 6,079 authors have contributed to the dataset, among which 206 authors produced single-authored papers, accounting for 221 publications.

The average number of co-authors per document is 4.36, with 20.55% of publications involving international collaboration, indicating a significant level of global research partnership. The types of documents included in the dataset are diverse, consisting of 1,159 research articles, 195 book chapters, 196 conference papers, 154 review articles, along with smaller categories such as editorials, data papers, and short notes.

The selected timeframe of 1964–2024 was chosen to encompass six decades of scholarly work, providing a comprehensive perspective on the evolution of research related to Good Agricultural Practices (GAP). This period aligns with the early emergence and subsequent development of GAP concepts in response to global agricultural and environmental challenges. The year 1964 marks the earliest recorded publication in this domain, while 2024 represents the most recent endpoint, ensuring the inclusion of current research developments and ongoing advancements.

This extended time horizon facilitates the identification of long-term trends, key transitions, and emerging research patterns within GAP studies. Moreover, it enables a thorough evaluation of how GAP has evolved in response to changing priorities in sustainable agriculture and global food security.

Table 1. Descriptive statistics for the data

Description	Results
Main Information About Data	
Timespan	1964:2024
Sources (Journals, Books, etc.)	867
Documents	1732
Annual Growth Rate %	0
Document Average Age	8.23
Average citations per doc	17.71
References	71684
Document Contents	
Keywords Plus (ID)	6496
Author's Keywords (DE)	4605
Authors	
Authors	6079
Authors of single-authored docs	206
AUTHORS COLLABORATION	
Single-authored docs	221
Co-Authors per Doc	4.36
International co-authorships %	20.55
Document Types	
article	1159
book	8
book chapter	195
conference paper	196
conference review	2
data paper	2
editorial	5
letter	3
note	5
review	154
short survey	3

4.2 Publication Progression

Figure 2 presents a line graph illustrating the annual number of publications from 1964 to 2025. The y-axis represents the total number of articles, while the x-axis reflects the timeline across the selected years. The overall trend remains relatively stable during the early period, with minimal publications recorded from 1964 until the mid-1990s.

A noticeable upward trajectory emerges after this phase, with a steady increase in publications beginning around 2000. This growth becomes more pronounced after 2010, indicating a significant expansion in research activity related to Good Agricultural Practices (GAP). The number of publications reaches its peak in 2021, followed by a sharp decline by 2025.

Overall, the graph highlights a substantial rise in academic output over recent decades, accompanied by a notable drop in the most recent years, which may be attributed to incomplete indexing or ongoing publication processes.

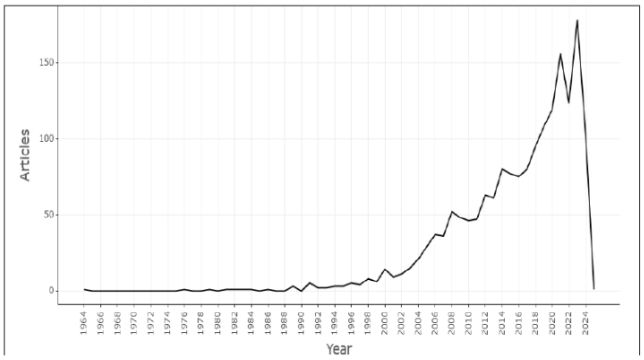

Fig. 2. Annual progression of publications (1964-2024)

4.3 Influential Journals

Figure no. 3 llustrates the cumulative publication trends of six major sources from 1964 to 2025. Among these, *Acta Horticulturae* (red) demonstrates the most significant growth, with a sharp increase beginning around 2000 and reaching nearly 100 total publications by 2025.

The *EFSA Journal* (yellow) begins to gain prominence around 2008, showing a steady upward trend and reaching approximately 50 publications. Similarly, *Food Control* (green) started contributing in 1996 and exhibits consistent growth, particularly after 2006, culminating in nearly 60 publications.

The *IOP Conference Series: Earth and Environmental Science* (blue) enters the dataset later, around 2010, and displays gradual growth, exceeding 40 publications by 2025. The *Journal of Food Protection* (cyan), which began contributing in 1996, follows a comparable growth pattern and reaches close to 40 publications.

Lastly, *Sustainability (Switzerland)* (purple) appears more recently, around 2016, and shows a slower rate of increase compared to the other journals, with relatively fewer publications by 2025.

Overall, the figure reflects varying publication patterns among journals, with *Acta Horticulturae* exhibiting the most substantial and consistent growth over time.

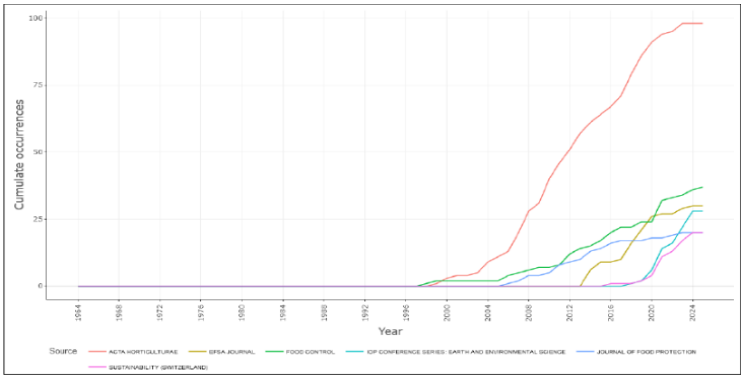

Fig. 3. Influential journals

4.4 Authors' Outputs

Figure 4 presents a horizontal bar chart highlighting the most prolific authors based on the number of published papers. The y-axis lists the authors, while the x-axis represents the total number of publications contributed by each researcher.

Among the leading contributors, Hu J ranks highest with 19 publications, followed by Santos M with 17 papers. A group of authors—including Greco L, Jarrah S, Leuschner R, Miron I, Pedersen R, Reich H, and Theobald A—each contributed 16 publications. Brancato A follows closely with a total of 15 papers.

The size of the circular markers at the end of each bar visually represents the volume of publications, where larger circles indicate a higher number of contributions.

Overall, the figure effectively identifies the key contributors within the dataset, with Hu J emerging as the most productive author in the field of Good Agricultural Practices (GAP).

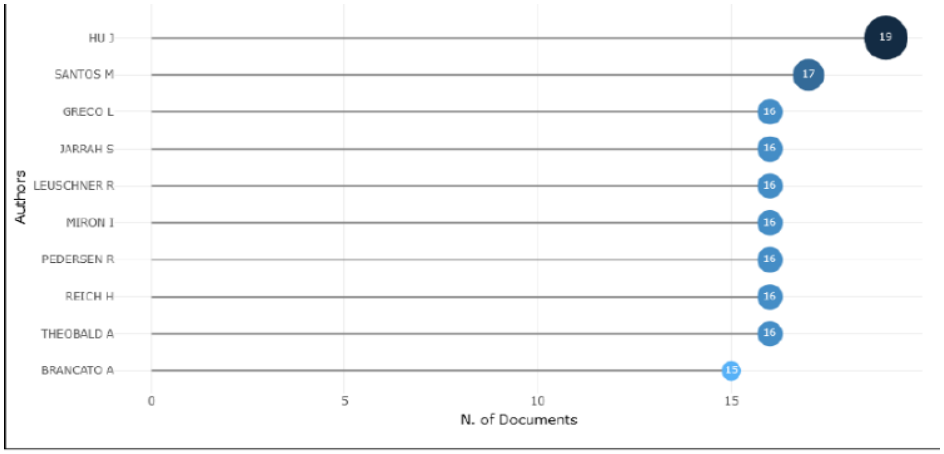

Fig. 4. Most relevant authors in good agricultural practice

4.5 Author Efficiency Using Lotka's Law

Presents a curve illustrating the distribution of authors based on the number of publications they have produced. The x-axis represents the number of documents authored, while the y-axis indicates the proportion of contributors.

Both the solid and dashed curves demonstrate a steep initial decline, indicating that the majority of authors have contributed only a small number of publications. Approximately 80% of the authors have produced between one and three papers. Beyond this point, the curve gradually levels off, suggesting that only a limited number of researchers have authored more than five publications.

This distribution aligns with Lotka's Law, revealing that a small group of highly productive authors accounts for a substantial share of the total output, whereas the majority of contributors have relatively low publication counts.

4.6 Countries of Corresponding Authors

Figure 6 illustrates the distribution of publications across countries, categorized by collaboration type: MCP (Multiple Country Publications) and SCP (Single Country Publications). China ranks highest in total publications, followed by the United States and India.

In the figure, blue bars represent SCPs, while red bars indicate MCPs. In most countries, SCPs dominate, suggesting that a large proportion of research is conducted domestically without international collaboration. However, countries such as the United States, India, and China exhibit a notable share of MCPs, reflecting strong global research partnerships.

Other countries, including Brazil, Thailand, and Indonesia, also contribute significantly, although their outputs are largely dominated by SCPs. Overall, the figure highlights the global distribution of research contributions, with China and the United States emerging as leading contributors in both domestic and collaborative research outputs.

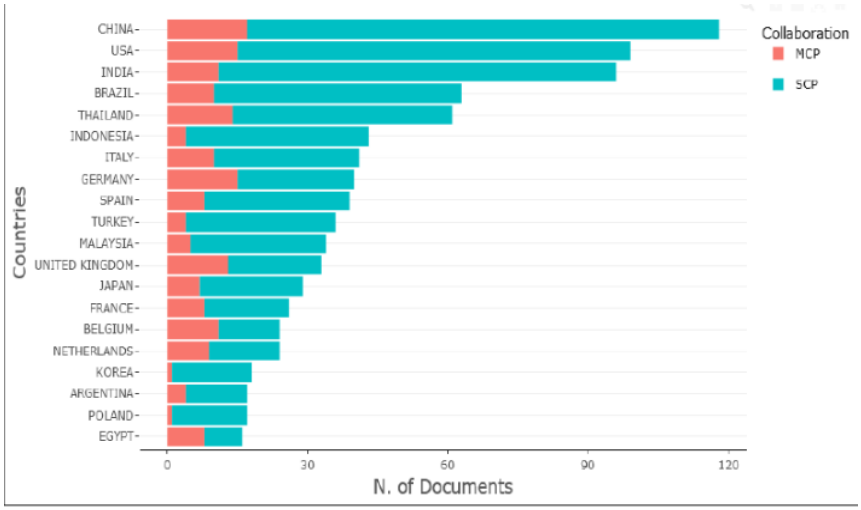

Fig. 6. Corresponding 'authors' countries

4.7 Scientific Production by Countries

The map illustrates the global distribution of scientific output, with countries color-coded based on their relative contribution. Darker shades of blue indicate higher research productivity, while lighter shades represent lower levels of output.

The visualization reveals that the United States and China are the leading contributors to scientific production, followed by countries such as India, Japan, Germany, the United Kingdom, France, South Korea, Canada, and Italy. Nations including Brazil, Russia, Australia, Spain, and Mexico also demonstrate considerable research activity.

In contrast, several regions—particularly in Africa and parts of Asia—exhibit relatively low levels of scientific output. This disparity highlights the uneven global distribution of research capacity and resources.

4.8 Country Collaboration

Figure 8 depicts a global network of research collaborations. The map features connecting lines between countries, representing the extent of collaborative research activities. The thickness of each line indicates the strength of these partnerships.

The United States, China, and several European countries emerge as central nodes within this network, maintaining extensive collaborative links with other nations. This visualization emphasizes the growing interconnectedness of global scientific research, with collaborations increasingly spanning multiple regions and continents.

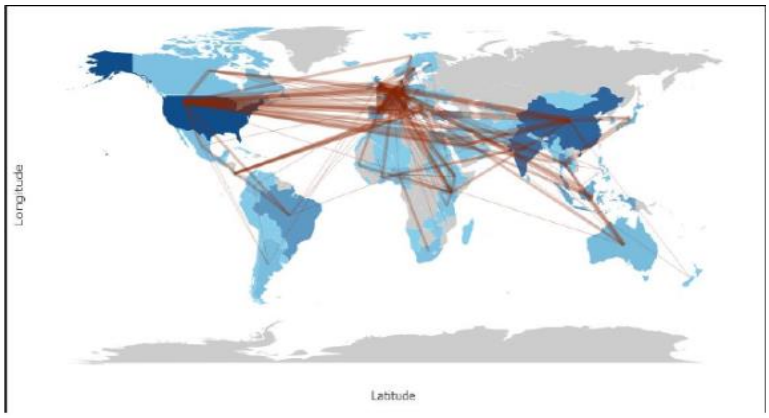

Fig. 8. Collaboration among the countries

4.9 Active Institutions

Presents a bar chart of the top ten institutions ranked by the number of published research articles. The horizontal axis indicates the number of publications, while the vertical axis lists the names of the institutions.

Ghent University leads with 67 publications, followed by the University of Science and Technology Beijing with 54 articles. Other prominent institutions within the top ten include Chiang Mai University, China Agricultural University, Anand Agricultural University,

Kasetsart University, the Agricultural Research Centre, Wageningen University, and the University of Nairobi.

The figure provides a comparative overview of institutional contributions, highlighting the leading organizations driving research output in the field of Good Agricultural Practices (GAP).

4.10 Network Analysis and Trend Word Analysis

4.10.1 Co-occurrence Network of Keywords

Figure 10 presents a network visualization of scholarly publications related to Sustainable Development Goal (SDG) 2: Zero Hunger. In this network, nodes represent keywords extracted from the literature, while the connecting edges indicate the co-occurrence of these keywords within the same documents.

The size of each node corresponds to the frequency of the respective keyword, whereas the color (hue) represents its thematic grouping or semantic classification. The central node, "agriculture," highlights the core focus of the research domain. Surrounding it are closely related terms such as "pesticide residue," "risk assessment," "chemistry," and "human," which form prominent thematic clusters.

The network further reveals a wide range of interconnected topics associated with SDG 2, including "food contamination," "non-human," "microbiology," and "food handling." Overall, this visualization provides a comprehensive representation of the knowledge structure within SDG 2 research, emphasizing key thematic areas and the interrelationships among various research domains.

4.10.2 Trend Topics

Figure 11 illustrates a word cloud depicting the most frequently occurring terms associated with emerging trend topics. The words are arranged according to their relative prominence, with larger terms indicating higher frequency within the dataset.

The word cloud is divided into multiple segments, each representing a distinct sub-theme within the broader research area. Prominent terms identified include "Germany," "Greece," "United Kingdom," "Triticum aestivum," "herbaceous agent," "Bos taurus," "World Health Organization," "drug contamination," "drug products," "drug quality," "Europe," "herbicides," "standard," "safety," "Netherlands," "Eastern Hemisphere," "Western Europe," and "manure."

This visualization provides an effective graphical summary of dominant themes and emerging research directions, offering insights into the evolving focus areas within the field.

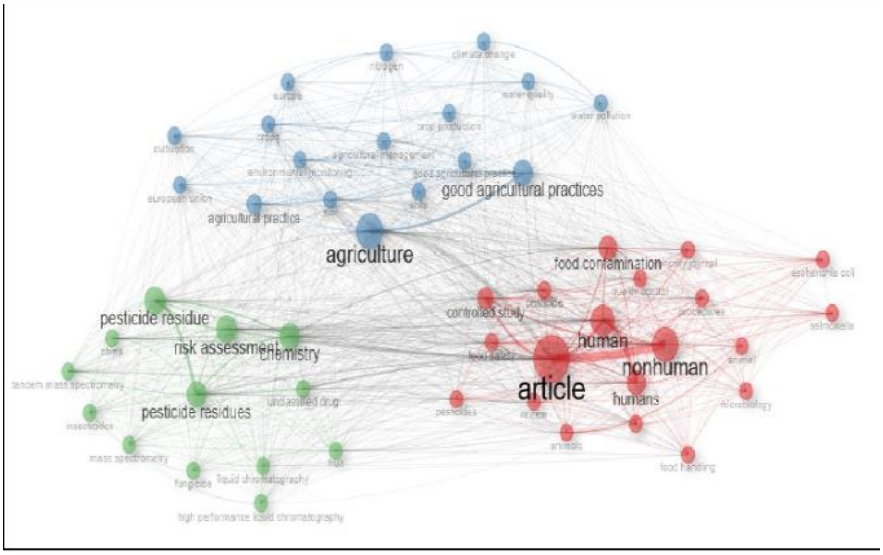

Fig. 10. Co-Occurance network of the keyword

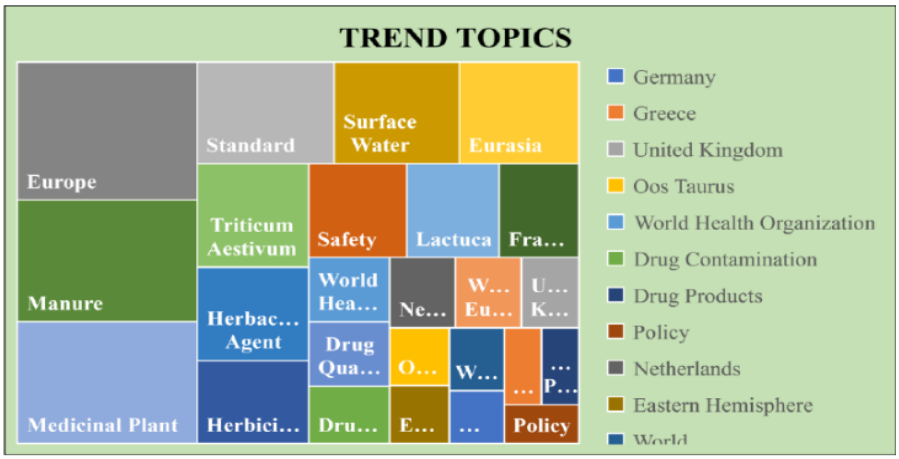

Fig. 11. Trend topic in good agricultural practices

5. RESEARCH GAPS AND FUTURE DIRECTIONS

Despite the considerable body of research on Good Agricultural Practices (GAP), several gaps persist in the literature that require further exploration to achieve a comprehensive understanding and more effective implementation of GAP (Siebrecht, 2020b). One major imbalance lies in the geographical distribution of research. While developed countries with advanced agricultural systems contribute a substantial volume of studies, research originating from developing regions—particularly in Africa, South Asia, and Latin America—remains limited, despite the critical role of agriculture in ensuring food security and livelihoods in these areas.

The lack of region-specific studies hinders the development of localized GAP strategies that can address the unique environmental, socio-economic, and cultural challenges faced by farmers in these regions (Mojid & Mainuddin, 2021). Furthermore, existing research predominantly focuses on the technical and environmental benefits of GAP, while comparatively less attention is given to the socio-economic barriers affecting its adoption, especially among smallholder farmers. These challenges include restricted market access, financial constraints, limited training and awareness, and the high costs associated with GAP certification.

Understanding the socio-economic determinants influencing GAP adoption is essential for improving its accessibility and long-term sustainability among small-scale farmers. Another important area for future research is the long-term impact of GAP on agricultural productivity, environmental conservation, and rural livelihoods. While many studies highlight short-term benefits, there is a notable lack of evidence regarding its sustained effects, particularly in the context of climate resilience and economic viability.

In addition, the role of emerging technologies in enhancing the efficiency and effectiveness of GAP remains insufficiently explored. Digital tools such as precision agriculture, data analytics, and mobile-based advisory systems have the potential to significantly improve the implementation and monitoring of GAP. However, their integration with traditional farming practices is still at an early stage.

Future studies should also focus on policy frameworks and institutional mechanisms that support GAP adoption (Kanger et al., 2020). There is a need for research evaluating the effectiveness of government policies, subsidy programs, and international initiatives in promoting GAP. Moreover, examining the role of public–private partnerships in facilitating GAP adoption—particularly in resource-constrained settings—can provide valuable insights into scalable and sustainable solutions.

6. CONCLUSION

The bibliometric analysis of Good Agricultural Practices (GAP) literature, based on Scopus data, provides a comprehensive overview of research trends, key focus areas, and existing gaps within the field. The findings indicate a growing academic interest in GAP, particularly in response to increasing concerns related to environmental sustainability and economic viability in agriculture.

However, the analysis also reveals notable deficiencies in the current body of literature. Research addressing socio-economic barriers to GAP adoption—particularly among

smallholder farmers—remains limited. Additionally, there is a need for more in-depth studies examining the long-term impacts of GAP on agricultural productivity, climate change adaptation, and rural livelihoods (Pervez et al., 2024). The uneven geographical representation of research further indicates that many regions where GAP adoption is most critical are underrepresented in academic discourse.

Future research should therefore prioritize these underexplored areas by integrating technological innovations, addressing socio-economic challenges, and developing supportive policy frameworks that facilitate wider adoption of GAP. By doing so, researchers can contribute to the development of more effective, context-specific GAP strategies that enhance agricultural productivity while promoting environmental sustainability and socio-economic well-being.

In conclusion, bibliometric analysis serves as a valuable tool for understanding the evolution and current state of GAP research. It provides important insights that can guide future investigations toward the most impactful areas, ultimately supporting the advancement of sustainable agriculture and global food security.

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