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Global research dynamics in organic farming: Emerging trends and scientometric insights

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ABSTRACT

Amid growing global concerns over environmental degradation, food security, and climate change, organic farming has emerged as a key pillar of sustainable agriculture. This scientometric analysis of global research from 2003 to 2023 examined trends across 11,561 publications, revealed an annual growth rate of 8.8 % and an average of 24.27 citations per document, emphasizing the growing significance of organic farming in both academic and practical spheres. Scientific collaborations across 33,576 authors, with an average of 4.4 co-authors per paper, underscore the interdisciplinary and international scope of organic farming research. The USA, Germany, and Italy played a major role in advancing the field of organic farming through publications in high-impact journals, facilitating the rapid and effective communication of research findings. The Scientometric analysis further revealed that the key research areas of organic farming include soil fertility, biological pest control, climate-resilient practices, and socioeconomic aspects. Emerging interest in precision agriculture and digital tools suggests a shift towards technologically enhanced organic farming. However, the concerns relating to the scalability and economic viability of organic farming practices, particularly for smallholders, remain critical challenges. This analysis offers strategic insights to inform future research directions, policy development, and sustainable agricultural transformation.

1. Introduction

Organic farming is an environmentally focused agricultural approach that has gained attraction due to the increasing demand for sustainable food production practices (Eyhorn et al., 2019). This system prioritizes the avoidance of synthetic chemicals such as fertilizers, pesticides, growth regulators, and additives in animal feed, while focusing on promoting ecological balance, social responsibility, and economic viability (Stockdale et al., 2001). The key principles of organic farming include maintaining soil fertility through the use of organic matter (OM), fostering biological activity, recycling organic materials, and managing pests and diseases using methods such as crop rotations, natural predators, and resistant varieties (Chhonkar, 2002). Historically, organic farming emerged as an alternative to conventional agricultural practices prior to the 1940s, addressing issues such as soil degradation, chemical pollution, and biodiversity loss (Youngberg and DeMuth, 2013). This approach gained momentum in the 1980s, largely driven by the USDA's report on Recommendations for Organic Farming and the

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passage of the Organic Foods Production Act of 1990, which established the foundation for organic certification in the United States. Similarly, the European Union developed its regulatory framework through Regulation 2092/91, which played a significant role in shaping organic farming across the region.

Organic farming makes a significant contribution to the achievement of multiple Sustainable Development Goals (SDGs). The FAO identified eight SDGs particularly relevant to organic agriculture, with five of them benefiting directly from its practices *viz.,* SDG 2 (Organic farming supports food security by producing nutritious, safe and diverse food, while promoting sustainable agricultural practices that ensure long-term availability of food), SDG 6 (by minimizing the use of chemical fertilizers and pesticides, organic farming helps reduce water pollution and conserve water resources, leading to improved water quality), SDG 13 (practices like crop rotation, agroforestry in organic farming aid in climate change mitigation by capturing carbon in the soil and lowering the greenhouse gas emissions), SDG 14 (organic farming minimizes chemical runoff, helping to protect aquatic life and maintain the health of oceans, seas and marine ecosystems) and SDG 15 (organic agriculture promotes biodiversity, restores degraded lands, and prevents deforestation and soil erosion, contributing to conserving terrestrial ecosystems). In addition, organic farming also contributes to SDG-3 by providing healthier food, SDG-8 through labour-intensive practices, and SDG-12 by encouraging environmentally responsible farming methods and ethical consumption (Batra et al., 2024).

In numerous regions, modern agriculture has led to substantial productivity gains through input-intensive methods, often at the expense of environmental sustainability. As concerns over the exploitation of natural resources and the decline in biodiversity grew, organic farming began to regain focus. The shift towards organic practices is part of a broader global movement aimed at sustainability. In the Indian context, this transition is represented by traditional and alternative systems such as *Rishi Krishi*, Natural Farming, Eco-Farming, Homa Farming, *Panchagavya Krishi*, and Biodynamic agriculture (Chaitanya et al., 2024). In countries such as India, organic farming has deep historical roots. Indian states like Sikkim and Uttarakhand have been officially declared as “organic states”, while other regions actively promote organic practices. This growing trend reflects the global shift towards organic farming as a sustainable and practical alternative to traditional chemical-intensive farming. The growth of organic farming is closely tied to the rising demand for healthier and more sustainable food systems, driven by growing consumer awareness and concerns about environmental degradation (Pandiselvi et al., 2017). Organic farming has become a crucial approach to achieving sustainable agricultural goals. It addresses several modern challenges, including soil erosion, water scarcity, and the harmful effects of chemical-intensive farming. Organic farming promotes ecological balance and sustainability, enhancing ecosystems while providing healthier food that is free from pesticide residues and additives (Sahoo et al., 2021; Hammed et al., 2019). Organic products are typically richer in nutrients, and their production supports biodiversity while minimizing environmental harm (Seufert and Ramankutty, 2017).

The term scientometrics was coined in the 1960s by Nikolay Vasileyvich Punikel in the Soviet Union, although the field gained significant momentum and recognition after the 1970s. Scientometric techniques, which involve the quantitative analysis of research output, citations, and collaborations, provide a systematic approach to assessing intellectual contributions and understanding the dynamics of knowledge creation in scientific fields (Martinez et al., 2020). These methods have gained significant importance as scientific and technical knowledge advances rapidly, posing challenges for researchers and scholars. The increasing volume of research has led to the widespread use of scientometric techniques to evaluate research performance at different levels, including individual researchers, research groups, institutions, and journals. This trend is evident across various fields such as construction (Martinez et al., 2022), agriculture (Kamali et al., 2020), artificial intelligence (Li et al., 2022), and medicine (Guo et al., 2023), where scientometric techniques are used to track research trends, identify influential authors, institutions, uncover emerging topics and map collaboration networks (Baca et al., 2023). It also helps highlight promising areas for further exploration by analysing subfields within organic farming and identifying leading universities, research centres and countries contributing to the field, based on publication and citation data. Additionally, these techniques enable the mapping of global collaboration networks, providing insights into the international nature of organic farming research and uncovering key trends and emerging topics. Such insights are crucial for guiding research priorities, shaping policy decisions and directing future strategic initiatives. With the global shift towards SDGs, the role of organic farming in mitigating climate change, promoting biodiversity, and enhancing food security is more critical than ever. As interest in organic agriculture continues to rise, there is a growing need for comprehensive insights into the global research landscape to identify key trends, hotspots and research gaps. Many studies focus on isolated aspects of organic farming, such as specific techniques or region-specific practices, but a more holistic understanding of the global research landscape is needed. Furthermore, there is a lack of an integrated analysis that systematically maps the intellectual structure of organic farming research, the relationship between key research areas, and the geographic and institutional contributions to this field. This study aims to bridge these gaps by applying Scientometric analysis to map the global research landscape of organic farming.

Topic modeling is a method used to reveal and uncover underlying themes or topics within large text collections by analyzing how words are distributed across documents. It works by categorizing text based on the underlying topic structure, where each topic is represented by a set of words that frequently occur together. This process helps to identify cluster words that share common themes, making it easier to analyze extensive amounts of unstructured data. Latent Dirichlet Allocation (LDA) is a widely adopted probabilistic technique for topic modeling that estimates the proportion of each topic in a document and the likelihood of words appearing within those topics (Donthu et al., 2021). In the present study, LDA was implemented using R studio to systematically analyze a collection of research articles, identifying and grouping relevant topics by calculating the probability distribution of words across topics and the contribution of each topic within individual documents. The primary objectives of this study were to analyze global research trends in organic farming between 2003 and 2023 through scientometric and topic modeling methods. Specifically, the study aimed to (i) identify influential authors, institutions, and countries contributing to the field; (ii) uncover prevailing and emerging thematic areas within organic farming research; and (iii) highlight research gaps to inform future investigations.

Unlike earlier studies, this work combines scientometric and topic modeling (LDA) approaches to provide an integrated, data-driven understanding of organic farming research over two decades. This study employs an integrated analytical framework combining scientometric mapping and Latent Dirichlet Allocation (LDA) topic modeling to deliver a comprehensive, multi-dimensional assessment of global organic farming research from 2003 to 2023. Drawing on an unprecedented dataset of 11,561 publications and 33,576 authors spanning more than 100 countries, it represents the most extensive scientometric exploration of organic farming to date. The analysis identifies five key emerging research frontiers—soil health, sustainability, crop productivity, socio-economic transitions, and climate resilience—revealing evolving thematic priorities and remaining knowledge gaps. Additionally, global collaboration patterns highlight the USA, Germany, and Italy as major hubs, while exposing underrepresented regions such as South Asia and Sub-Saharan Africa. The findings provide strategic insights to strengthen international research cooperation, align research agendas with the UN Sustainable Development Goals (SDGs), and guide policy formulation for climate-resilient and sustainable agricultural development.

2. Materials and methods

A scientometric analysis was performed to evaluate the research output in the field of organic farming. Data were collected from the Scopus database in December 2024, selected for its esteemed status as a comprehensive and widely recognized bibliographic resource, offering an extensive collection of scholarly articles (Baas et al., 2020).

2.1. Data retrieval

The data for this scientometric analysis were retrieved from Scopus using a structured search strategy to ensure relevance and precision. The search was conducted using the query: TITLE-ABS-KEY ("Organic farming" OR "Organic agriculture" OR "Organic food production"), which results in publications where these terms appear in the title, abstract, or keywords. The publication period was limited to 2003–2023 to focus on recent and pertinent studies. To maintain quality and consistency, only English-language documents were considered. Furthermore, the document types were refined to include journals and conference proceedings from both Agricultural and Biological Sciences and environmental sciences, aligning the dataset with the core thematic domains of organic farming research.

2.2. Data filtering and extraction

After data retrieval, a comprehensive review was performed to filter out irrelevant publications, ensuring that only articles directly related to organic farming were retained, resulting in a refined dataset of 11,561 publications. The final dataset, which included full records and cited references, was then exported from Scopus in CSV format for further analysis.

2.3. Data analysis

The bibliometric analysis was conducted using established analytical tools within the R Studio environment. Specifically, the Bibliometrix package was employed in R Studio, and its web-based interface, biblioshiny (Aria and Cuccurullo, 2017), was utilized to facilitate an interactive and user-friendly analysis workflow. The bibliographic data, extracted in CSV format from Scopus, were imported into Biblioshiny to perform a comprehensive analysis of the organic farming research landscape. The analysis yielded critical insights into research output, including productive authors, collaborations between authors, countries, institutions, the most cited articles, and the most relevant institutions. This methodological approach provided a robust and systematic bibliometric analysis of organic farming research, leveraging advanced bibliometric techniques to map the intellectual and collaborative structure of global research on organic farming.

2.4. Topic modeling

Latent Dirichlet Allocation (LDA) topic modeling was used to identify key topics within the text data. LDA is a widely known method for uncovering latent structures in document collections and has been shown to efficiently generate descriptive topics (Stevens et al., 2012). The analysis focused on the Scopus dataset, specifically examining titles, abstracts, and keywords to uncover the underlying topics or themes. *Topic modeling* using LDA was conducted in R Studio with the relevant packages for analysis. The model was carefully evaluated to ensure that the generated topics were relevant and aligned with the research objectives. For each identified topic, the top ten terms were extracted and visualized through word clouds, providing an intuitive view of the primary themes associated with each topic. During the process, challenges such as text pre-processing, parameter selection, and model evaluation were addressed to ensure that the resulting topics were both reliable and interpretable. This methodology highlights the utility of LDA in topic modeling, enabling researchers to expose hidden patterns within large datasets and derive valuable insights from complex datasets (Asmussen and Moller, 2019).

3. Results

The distribution of research publications on organic farming from 2003 to 2023 is presented in Table 1. A total of 11,561 documents were published over these two decades, showing a consistent increase in academic output. The field demonstrated a notable annual growth rate of 8.88 %, reflecting rising global interest and ongoing research activity in organic farming. The average age of the documents was 9.19 years, with each document receiving an average of 24.27 citations. The total number of references across all documents was 436,125. Regarding authorship, there were 33,576 authors, with 901 contributing to sole-authored works. Collaboration was frequent, with an average of 4.4 co-authors per document and 20.74 % of documents featuring international co-authorships. Most publications were articles (10,392), followed by conference papers (1169).

3.1. Annual scientific production and citation impact

The yearly publication trends from 2003 to 2023 are depicted in Table 2. Starting with 177 documents in 2003, the number gradually increased, showing a significant rise from 2006 to more than 800 by 2019, and reaching a peak of 1025 in 2021. Following this, there was a slight drop in 2022 (914 documents), but with a small rebound in 2023 (970 documents). The data reflect a continuous growth in academic publishing over the years. However, citation impact, measured by the mean total citations (TC) per article, showed a significant decline over time. In 2005, the mean TC peaked at 74.02 but decreased steadily to 3.67 by 2023. Similarly, the mean total citations per year decreased, indicating a decline in citation visibility with the age of the article. Additionally, the number of years during which articles remain citable, that is, continue to receive citations, has diminished over time, reaching only 3 years in 2023. This suggests that while publication volume continues to grow, both citation impact and the lasting influence of the articles have decreased over time.

3.2. Most relevant sources and their production over time

The number of articles published in most relevant sources related to agriculture and environmental sciences is shown in Fig. 1. The journal Acta Horticulturae leads with 377 articles, followed by Sustainability

Table 1
Details of publications and authorship.

S.No.	Description	Results
1	Timespan	2003:2023
2	Sources (Journals, Books and others)	2271
4	Documents	11,561
5	Annual Growth Rate (%)	8.88
6	Document Average Age	9.19
7	Average Citations Per Document	24.27
8	References	436,125
9	*Document Contents*	
a	Keywords plus (ID)	22,769
10	Author's Keywords (DE)	23,231
11	*Authors*	
a	Authors	33,576
b	Authors of single-authored documents	901
12	*Authors Collaboration*	
a	Single-authored documents	1023
b	Co-authors per documents	4.4
13	International Co-authorships (%)	20.74
14	*Document Types*	
a	Articles	10,392
b	Conference papers	1169

Table 2
Trends in number of articles and citation impact from 2003 to 2023.

Year	No. of articles published	Mean Total Citations per article	Mean Total Citations per year	Citable years
2003	177	56.72	2.47	23
2004	180	45.23	2.06	22
2005	178	74.02	3.52	21
2006	223	44.59	2.23	20
2007	290	47.81	2.52	19
2008	347	37.46	2.08	18
2009	395	34.92	2.05	17
2010	427	41.73	2.61	16
2011	538	31.06	2.07	15
2012	545	32.09	2.29	14
2013	564	28.09	2.16	13
2014	556	26.42	2.2	12
2015	587	31.86	2.9	11
2016	607	22.71	2.27	10
2017	645	27.45	3.05	9
2018	690	19.95	2.49	8
2019	801	19.58	2.8	7
2020	902	14.89	2.48	6
2021	1025	12.22	2.44	5
2022	914	7.61	1.9	4
2023	970	3.67	1.22	3

Annual Growth Rate: 8.88 %.

(Switzerland) with 336 articles. Other prominent sources include Agriculture, Ecosystems and Environment (280 articles) and Renewable Agriculture and Food Systems (217 articles), Agronomy (180 articles). The data highlights key journals that have contributed extensively to the research in agricultural and environmental sciences, reflecting active academic engagement in these areas. The production of articles in scientific journals from 2003 to 2023 is depicted in Fig. 1. Acta Horticulturae consistently increased its publications over the years, reaching 377 articles in 2023, the highest among the sources listed. Sustainability (Switzerland) saw significant growth, with production rising from 0 in 2003 to 337 articles in 2023, reflecting a steady rise in its contribution. Agriculture, Ecosystems and Environment followed a similar upward trajectory, reaching 280 articles by 2023. Renewable Agriculture and Food Systems also showed a continuous increase, peaking at 217 articles in 2023. Agronomy, although it began with no publications before 2006, experienced steady growth and reached 180 articles by 2023. The data indicates a clear trend of growing academic output across these sources, with Sustainability (Switzerland) showing the most significant increase in recent years. The overall pattern reflects a rise in research output in the fields of agricultural and environmental sciences.

3.3. Most relevant authors

The most relevant authors in the field, based on their article contributions, are shown in Fig. 2a. Mader P leads with 58 articles, followed closely by Tscharntke T with 43 articles. Other significant contributors include Leifert C and Olesen JE, each with 41 articles. Authors like Canali S (35 articles) and Campanelli G (32 articles) also made substantial contributions, indicating their collaboration intensity. It also highlights the notable contributions of Zanoli R, Entz MH, Li Y, and Kumar A, all of whom have made significant article contributions, demonstrating their involvement in a broad spectrum of research. This data emphasises the impact of these authors and their collaborative work in the field of organic farming.

3.4. Authors production over time

Trends in individual contributions and the influence of authors in organic farming research over time are visually depicted in Fig. 2b. Bubbles in the figure indicate the number of articles published each year. The size of the bubble relates to the volume of articles published. Tscharnkte T and Leifert C have shown consistent and impactful contributions over many years. Authors like Mader P and Tscharntke T showed prominent activity from 2010 to 2015. Other authors, like Entz MH and Li Y, have limited or occasional contributions. The color intensity (brightness) of the bubbles corresponds to the average number of citations received per year, where brighter bubbles indicate authors with higher citation impact and research influence. Accordingly, authors

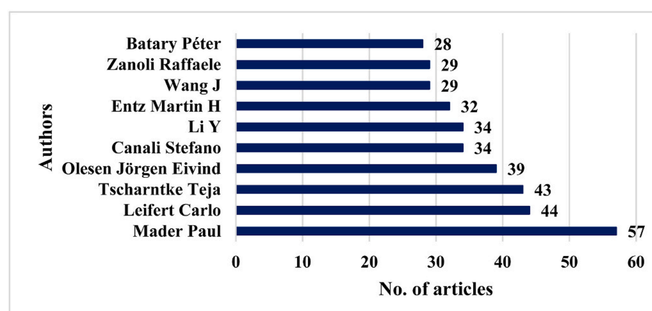

Fig. 2a. *Most relevant* authors and their article contributions.

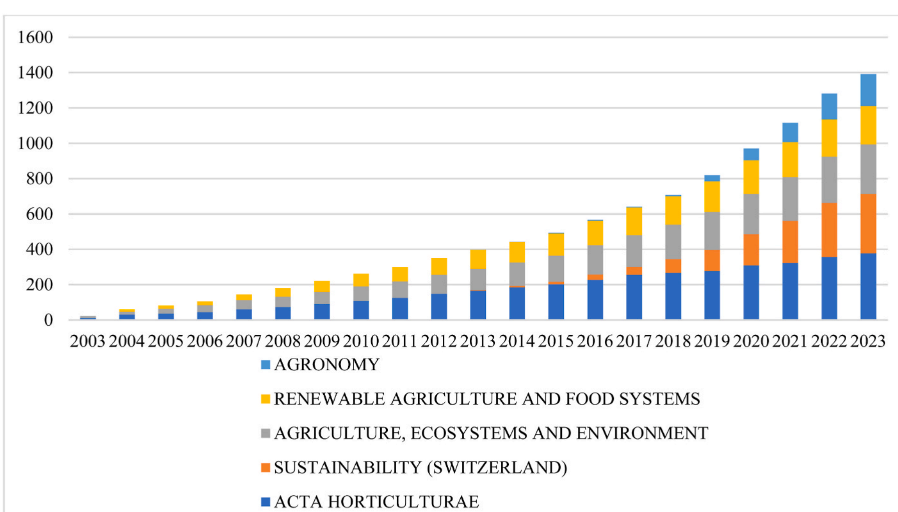

Fig. 1. Production trends of the most relevant journals based on the number of articles published between 2003 and 2023.

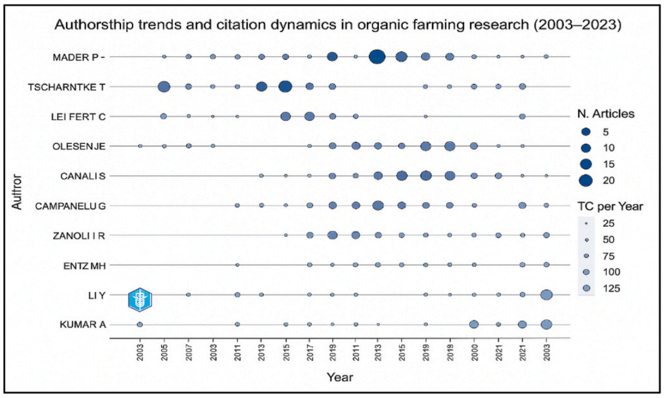

Fig. 2b. Production of research articles by different authors over time.

such as Tscharnkte T and Kumar An achieved higher citation impacts during their most productive phases.

3.5. Author impact metrics and scholarly contributions

Table 3 presents key bibliometric indicators for leading authors in the field, including the h-index, g-index, m-index, total citations (TC), number of publications (NP), and the year of first publication (PY_start). The h-index reflects an author's productivity and citation impact, representing the number of papers (h) that have received at least h citations each (Hirsch, 2005). Mader P has the highest h-index (37), indicating significant academic impact with 6982 total citations and 58 publications starting in 2004. Tscharntke T followed closely with a h-index of 35 contributing to 6481 citations since 2005. Other authors, such as Olesen JE (h-index 30, 2435 citations) and Leifert C (h-index 24, 1681 citations), also made notable contributions. Batary P and Sans FX started their publishing careers in 2010, showing strong citation counts (2855 and 939, respectively). Authors such as Birkhofer K, Moller K, and Hallmann E also demonstrated a good citation impact, with m-index values indicating their average rate of citation over time. The data underscores the scholarly influence and productivity of these authors, with most beginning their work in the 2000s and early 2010s.

3.6. Most global cited document

The details of research papers, including their DOI, total citations (TC), citations per year (TC per Year), and normalized total citations (Normalized TC) are given in Table 4. For instance, the paper by Bengtsson et al. (2005) in the Journal of Applied Ecology has received 1252 total citations, with a high citation rate of 59.62 per year, and a normalized TC of 16.91, indicating a strong long-term impact. Similarly, Hole et al. (2005) in Biological Conservation had 1139 total citations, averaging 54.24 per year with a normalized TC of 15.39, reflecting significant but slightly lower impact over time. Geiger et al. (2010) stand out with a normalized TC of 25.69, demonstrating a strong research influence over a shorter period. The Hartmann et al. (2015) paper in the ISME Journal had the highest TC per year (92.36) and normalized TC (31.89), indicating a highly influential recent publication. The data suggest a mixture of older foundational studies and newer influential research, with papers from Banerjee et al. (2019) and Kennedy et al. (2013) exhibiting high normalized TC, indicating growing interest and citation impact in recent years.

Table 3
Key metrics for authors.

Author	Country	h_index	TC	NP	PY_start
Mader Paul	Switzerland	37	6982	58	2004
Tscharntke Teja	Germany	35	6481	43	2005
Olesen Jörgen Eivind	Denmark	30	2435	41	2003
Leifert Carlo	Norway	24	1681	41	2005
Batary Péter	Hungary	20	2855	28	2010
Sans Francisco Xavier	Spain	20	939	23	2008
Armengot Laura	Spain	19	880	22	2010
Birkhofer Klaus	Sweden	18	1454	23	2008
Moller Kurt	Germany	18	1255	22	2006
Hallmann Ewelina	Poland	17	1066	24	2010

TC: Total Citations, NP: Number of Publications, PY_start: Publication Year Start.

Table 4
Most globally cited documents.

Paper	DOI	Total citations	TC per year	Normalized TC
Bengtsson et al., 2005, J Appl Ecol	10.1111/j.1365–2664.2005.01005.x	1252	59.62	16.91
Hole et al., 2005, Biol Conserv	10.1016/j.biocon.2004.07.018	1139	54.24	15.39
Geiger et al., 2010, Basic Appl Ecol	10.1016/j.baae.2009.12.001	1072	67.00	25.69
Steiner et al., 2007, Plant Soil	10.1007/s11104-007-9193-9	1049	55.21	21.94
Hartmann et al., 2015, ISME J	10.1038/ismej.2014.210	1016	92.36	31.89
Kennedy et al., 2013, Ecol Lett	10.1111/ele.12,082	868	66.77	30.90
Asami et al., 2003, J Agric Food Chem	10.1021/jf020635c	829	36.04	14.61
Banerjee et al., 2019, ISME J	10.1038/s41396-019-0383-2	783	111.86	40.00
DE Ponti T, 2012, Agric Syst	10.1016/j.agsy.2011.12.004	778	55.57	24.24
Batary et al., 2015, Conserv Biol	10.1111/cobi.12,536	736	66.91	23.10

3.7. Most relevant affiliations and production over time

The top institutions based on the number of articles published in the field of organic farming are shown in Fig. 2c. The Swedish University of Agricultural Sciences leads with 375 articles, closely followed by Aarhus

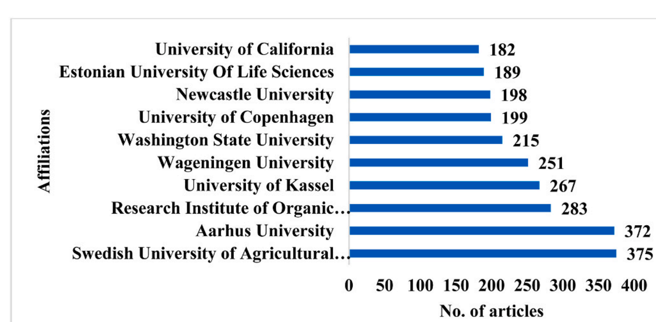

Fig. 2c. *Most relevant* affiliations or institutions.

University with 372 articles. Other notable institutions included the Research Institute of Organic Agriculture (FIBL), with 283 articles, and the University of Kassel, with 267 articles. Wageningen University and Washington State University also contributed significantly, publishing 251 and 215 articles, respectively. University of Copenhagen and University of California followed with 199 and 198 articles, respectively. Moreover, the Estonian University of Life Sciences (with 189 articles) and the University of Pisa (with 182 articles) have emerged as key contributors to organic farming research. This highlights the important role of leading academic institutions in advancing the field and emphasises the growing relevance of organic farming studies.

The cumulative publication data from 2003 to 2023 highlights the growth and scholarly output of leading institutions in organic farming research (Fig. 2d) University of Kassel demonstrates a steady and substantial increase in publications, starting with 2 publications in 2003 and reaching 260 by 2023, indicating consistent research productivity over two decades (Fig. 6). Similarly, the Swedish University of Agricultural Sciences (SLU) shows a pronounced upward trend, with publications rising from 0 in 2003 to 369 in 2023, reflecting rapid growth and strong international research influence. The Research Institute of Organic Agriculture (FiBL) exhibits slower initial output, with virtually no publications until 2006, but experienced accelerated growth afterwards, reaching 266 publications by 2023. This indicates its increasing prominence and expanding contribution to organic farming literature over the past decade and a half. Aarhus University exhibits late but significant productivity, with no publications until 2008, followed by a steep increase, resulting in 353 publications by 2023. These patterns highlight a growing focus on agricultural and organic research with notable expansion. This data may also suggest increasing investments in research initiatives, international partnerships, and a growing focus on sustainable agricultural practices. Overall, all organizations exhibited collective research contributions over time, with considerable growth observed from 2010 onwards, signifying a growing global interest in organic farming research. The data highlights the increasing importance of these institutions, particularly in recent years, and underscores their growing role in advancing knowledge of organic farming.

3.8. *Scientific production of countries*

The number of documents published by researchers from different countries/territories has been depicted in Fig. 3. The United States leads with 1538 documents, followed by Germany (1,093) and Italy (1,042). India ranked fourth with 925 documents, followed by Spain with 680. Other notable countries include France (573), United Kingdom (566), and China (507). Brazil (466) and Denmark (422). The data highlights the significant contribution of these countries to the academic field, with the United States, Germany, and Italy being the top three contributors.

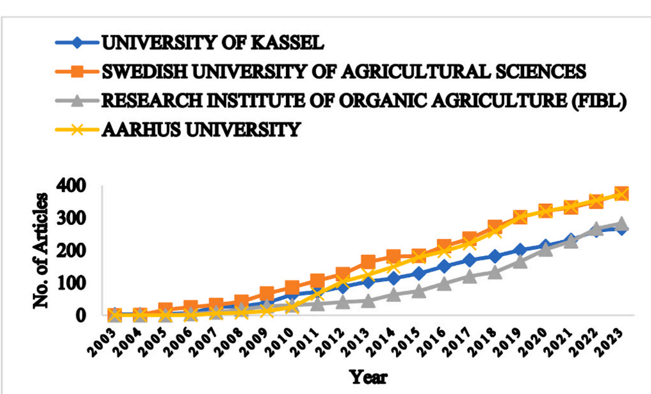

Fig. 2d. Trends in the research output of four key institutions in the field of organic farming.

The overall global research activity in the field is substantial, with multiple countries showcasing robust academic output. While these bibliometric indicators reveal *how* research communities are connected, they do not yet explain *what thematic domains* these collaborations have produced. Therefore, the subsequent section focuses on the conceptual and thematic evolution of the field, mapping how research priorities within organic agriculture have transitioned over time from production-oriented studies to sustainability, ecosystem services, and climate resilience.

3.9. *Collaboration networks*

3.9.1. *Collaboration network among authors*

Table 5 and Fig. S1 illustrates the collaboration network among prominent authors in organic farming research, revealing distinct clusters that signify thematic and institutional linkages. Cluster 1, the largest, comprises leading European researchers such as Mäder, Bàrberi, and Gattinger, who focus on soil health, crop diversification, and long-term organic trials, indicating strong multidisciplinary collaboration within Europe. Cluster 2, featuring Tscharntke and Batáry, emphasises landscape ecology and biodiversity conservation in organic systems. Cluster 3 represents international collaboration, notably between European and Chinese researchers, addressing yield performance and quality of organic produce. Cluster 4 highlights Italian and Central European researchers working on composting, soil fertility, and organic amendments. Smaller clusters (5–8) represent region-specific or thematic collaborations, such as market development (Zanoli), agronomic practices in India (Kumar), and sustainable cereal production (Konvalina). Overall, the network underscores global yet regionally concentrated collaborations shaping organic farming research.

3.9.2. *Collaboration network among institutions*

The collaboration network among institutions (Table 6 and Fig. S2) reveals extensive global linkages in organic farming research, led by a few highly connected academic hubs. European institutions, particularly Wageningen University and Research, the Swedish University of Agricultural Sciences, Aarhus University, the Research Institute of Organic Agriculture (FiBL), and the University of Kassel, exhibit strong centrality, reflecting their pivotal role in advancing sustainable agriculture and organic production systems. North American universities, including Washington State University, Cornell University, and the University of Minnesota, form a robust cluster driving research on organic production, soil health, and ecological management. Emerging participation from Asia, particularly China Agricultural University and Tamil Nadu Agricultural University, signals the growing global diversification of research efforts. Collaborative linkages among Southern and Eastern European universities further enhance regional integration. Overall, the network underscores the importance of international research partnerships in addressing sustainability, food security, and climate resilience through organic farming.

3.9.3. *Collaboration network among countries*

The network visualization of international collaborations in organic farming research underscores the diverse levels of engagement and centrality across different countries (Fig. 4). The USA stood out with the highest centrality, signifying its dominant role in global organic farming research. Other key contributors include Italy and Germany, both of which demonstrated strong centrality, reflecting their substantial impact on advancements in organic farming. Additionally, Spain, the United Kingdom, and France enhanced the European presence within the network. Emerging economies, such as Brazil, India, and Australia, are becoming increasingly engaged in organic farming research, although their position in the global research network remains relatively peripheral. Argentina and Canada play key roles in regional research, while countries such as Mexico, Pakistan, and Nigeria are positioned on the fringes. Eastern European nations, including Poland, Hungary and

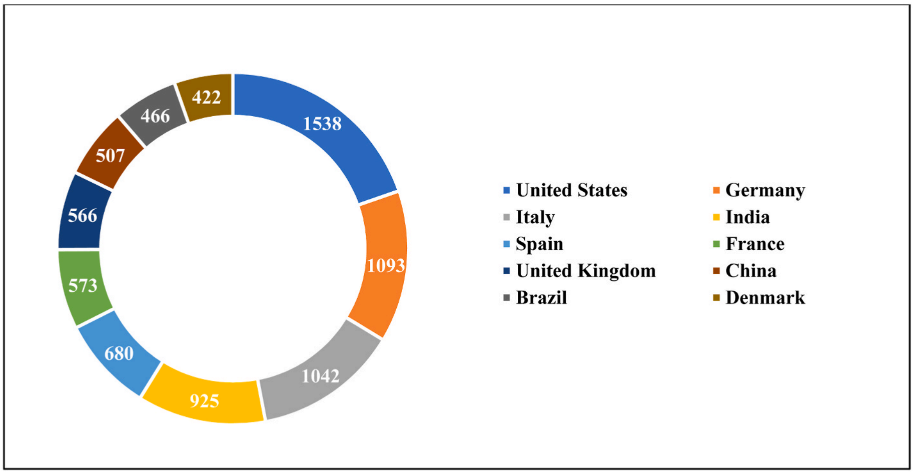

Fig. 3. Scientific production by leading countries.

Table 5
Collaboration network of authors.

Cluster	Authors
1	Mäder P, David C, Luik A, Van Der Heijden Mga, Sans FX, Armengot L, Möller K, Heβ J, Hülsbergen K-J, Bàrberi P, Finckh Mr, Friedel JK, Gattinger A, Eremeev V
2	Tscharntke T, Batáry P
3	Leifert C, Olesen Je, Li Y, Wang J, Hallmann E, Li J, Zhang J, Dorais M, Wang X, Wang Y, Li X
4	Canali S, Campanelli G, Montemurro F, Tittarelli F, Ciaccia C, Diacono M, Bavec M, Leteo F
5	Zanoli R, Solfanelli F
6	Kumar A, Singh R, Kumar S, Das A
7	Konvalina P, JR, Moudrý J
8	Birkhofer K, Smith HG

Table 6
Collaboration network among the institutions.

Cluster	Institutions
1	Washington State University, University of California, Cornell University, University of Minnesota, Michigan State University, University of Florida, University of Georgia, Montana State University, University of Maryland, Pennsylvania State University
2	Aristotle University of Thessaloniki, University of Novi Sad, University of Belgrade, University of Zagreb
3	Aarhus University, Research Institute of Organic Agriculture (FiBL), University of Kassel, University of Copenhagen, Estonian University of Life Sciences, University of Hohenheim, Newcastle University, China Agricultural University, University of Natural Resources and Life Sciences, Warsaw University of Life Sciences, Wageningen University and Research, Ghent University, Germany, University of Maribor, Université de Toulouse, University of Barcelona
4	Nanjing Agricultural University, North Carolina State University
5	University of Pisa, University of Bologna, University of Florence
6	Swedish University of Agricultural Sciences, Wageningen University, Research Institute of Organic Agriculture, Lund University, Wageningen University and Research Centre
7	Agricultural University of Athens
8	University of Bonn
9	University of Perugia
10	Universitat Politècnica de València
11	Northwest A&F University
12	University of Naples Federico II
13	Tamil Nadu Agricultural University

Romania, are also involved, but they hold less central positions compared to Western Europe and North America. Asian countries, such as Japan, South Korea, and Indonesia, exhibited lower levels of connectivity, reflecting their emerging role in organic farming research. The network visualization shows that North America and Europe remain dominant research hubs, while regions such as Africa, Southeast Asia and Latin America are gradually increasing their participation.

Cluster 1, comprising North America and major Asian economies (the USA, China, India, Brazil, and Canada), represents the most prolific contributors, with high publication volumes and extensive international collaborations. Cluster 2 includes Europe (Italy, Germany, the United Kingdom, France, and Spain), known for its strong research infrastructure and policy-driven support for organic agriculture. Cluster 3 comprises Northern and Western Europe (Sweden, Denmark, the Netherlands, and Austria), which exhibit concentrated efforts in high-impact, niche research areas within organic farming. Cluster 4 encompasses South Asia and Southeast Asia (Pakistan, Indonesia, Malaysia, Thailand), reflecting growing regional engagement with organic practices, often driven by sustainability challenges and agrarian policy reforms. Cluster 5, representing Africa and the Middle East (Egypt, South Africa, Iran), indicates emerging interest in organic farming in the context of food security and environmental resilience. Cluster 6 comprises smaller European and Mediterranean countries (Greece, Portugal, Hungary, Croatia), which contribute modestly yet consistently to the field. Cluster 7 includes Latin America (Argentina, Mexico), which is increasingly integrating organic methods into traditional farming systems. Finally, Cluster 8 highlighted other emerging Players (New Zealand, Israel, Philippines, Nigeria), signalling expanding research activity and potential for future growth in organic farming scholarship within these regions. This cluster-based analysis highlights that the most influential research on organic farming is concentrated in North America and Europe, while Asia and Latin America are increasing their involvement. Countries within each cluster tend to collaborate more intensively within their respective regions, although cross-regional partnerships are slowly growing. This trend reflects the expanding global interest in sustainable agriculture and the increasing interconnectedness of research efforts across regions.

3.10. Most relevant words

Fig. 5a and b presents most frequently occurring keywords in organic farming research from 2003 to 2023. The size of each word corresponds to its frequency in the dataset, highlighting the dominant research themes and areas of focus. Keywords such as organic farming, organic agriculture, organic, sustainability, agroecology, sustainable agriculture, etc., appear prominently, indicating the central topics explored in recent literature. The data reflect a clear academic focus on organic and sustainable agricultural practices. The frequency of these terms reveals that the literature emphasises both the practices and outcomes of organic farming, with a clear focus on productivity, sustainability, and

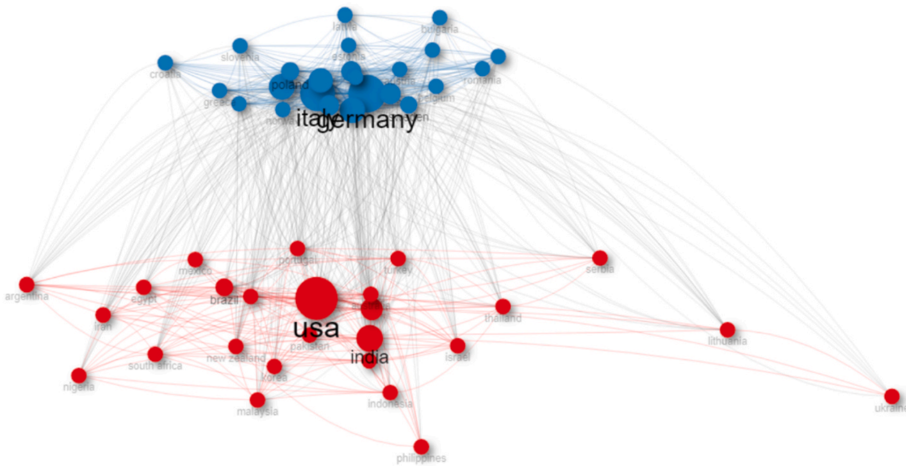

Fig. 4. Collaboration network between the countries.

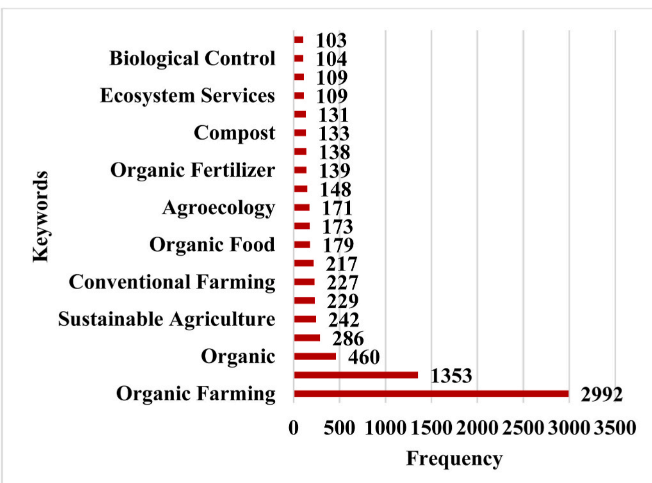

Fig. 5a. *Most relevant* words in global organic farming research.

Fig. 5b. Word cloud of global organic farming research.

agricultural systems. The prevalence of these terms indicates ongoing research efforts to address key challenges in organic and sustainable agriculture. Overall, the data suggests a strong focus on organic and sustainable farming practices to improve agricultural outcomes.

3.11. *Trending topics*

Fig. 6 outlines the key terms in agricultural research, highlighting trends over time and their increasing relevance. In the early 2000s, terms such as organic animal husbandry and organic livestock production gained prevalence, emphasizing the foundations of organic farming practices. Between 2004 and 2008, soil solarisation, soil structure, and microbial activity became key topics, reflecting an increasing understanding of soil health and the biological processes that support sustainable agriculture. The data revealed notable trends in organic farming research, with a clear shift toward sustainability and organic practices over time. Key terms like "organic farming" and "organic agriculture" dominate the field, indicating a growing interest in environmentally friendly farming methods. The rising focus on soil health, reflected in terms such as "soil quality" and "microbial biomass," underscores a broader emphasis on ecosystem vitality. Additionally, the increasing prominence of sustainable agriculture and development points to an evolving recognition of long-term environmental responsibility. Recent research also emphasises climate-related issues with terms like "climate change" and agro ecology" gaining traction. The growing attention to innovative practices, such as bio-stimulants and the circular economy, highlights the sector's commitment to sustainability-driven solutions. Furthermore, the continued focus on topics such as biodiversity, yield, and nitrogen demonstrates a strong commitment to resource management and crop productivity. The rise of discussion surrounding organic production and animal welfare reflects the growing intersection of ethical concerns and organic principles. Together, these trends signal a wider recognition of the need for sustainable, climate-resilient and ethically responsible agricultural practices. In the topic-trend map, the terms "organic farming" and "organic agriculture" appear predominantly after 2010 due to keyword normalisation and minimum-frequency filtering applied in *Biblioshiny*. Earlier publications used narrower thematic descriptors (e.g., soil fertility, pest control, sustainability), which were grouped into separate clusters. Hence, the observed trend reflects the period of increased keyword standardisation rather than the actual inception of research in organic farming.

3.12. *Topic modeling analysis*

3.12.1. *Topic distribution*

Table 7 and Fig. 7a to b, 8 indicates the distribution of documents across five thematic topics generated through Latent Dirichlet Allocation (LDA), a topic modeling technique used to uncover latent patterns in textual data.

Collectively, these five topics offer a comprehensive overview of the dominant research themes within the field of organic farming, ranging

Fig. 6. Trends in organic farming research, key terms and their evolution over time.

from fundamental agronomic practices to systemic sustainability assessments. The top terms for each topic (e.g., "organic," "farming," "soil") reveal the primary subjects or keywords associated with these themes, helping to label and understand the topics. This distribution helps identify dominant areas of research or discussion, guiding further analysis or exploration. The dataset primarily focuses on organic farming and related agricultural practices. Themes such as sustainable farming, soil health, crop yield management, and the role of farmers are central. There is a focus on both environmental and production aspects of agriculture, highlighting discussions on organic methods, crop management, and sustainability.

3.12.2. Topic trends over time

Fig. 7b shows the frequency of five topics from 2003 to 2023. Topic 2 demonstrated consistent growth, peaking around 2020, which indicates an increasing relevance over time. Topic 1 and Topic 4 also showed steady growth, with Topic 1 closely following Topic 2 in later years. Topic 3 had a moderate and stable trend, without significant spikes. Topic 5 remained relatively low in frequency throughout the period, indicating its lower prominence compared to other topics. The trends highlight evolving research interests, with Topics 1 and 2 becoming dominant in recent years.

4. Discussion

The most globally cited document in organic farming research is Bengtsson et al. (2005), which presents a meta-analysis demonstrating that organic farming has a positive influence on biodiversity and species abundance. This aligns with findings from Hole et al. (2005), who emphasized the conservation potential of organic farming systems. Geiger et al. (2010) further highlighted the negative impact of pesticides on biodiversity, underscoring the role of sustainable practices such as organic agriculture in preserving ecological balance. Recent studies continue to affirm the ecological benefits of organic farming. For example, Bathaei and Streimikiene (2023) highlight the role of sustainable agriculture in supporting biodiversity by providing habitats for pollinators and beneficial insects, while also promoting animal welfare. Similarly, Amorim et al. (2023) discuss how organic practices contribute to producing safe, nutritious food while enhancing biodiversity conservation. These collective insights reinforce the potential of organic farming as a sustainable and ecologically sound alternative to conventional agriculture.

The integration of scientometric analysis with Latent Dirichlet Allocation (LDA)-based topic modeling represents a methodological advancement in understanding research landscapes. This combined approach enabled both a quantitative evaluation of publication and citation patterns and a qualitative exploration of thematic evolution within the field. Unlike conventional bibliometric studies that focus solely on citation metrics or co-authorship patterns, this dual framework provides a multi-dimensional and temporally dynamic understanding of how organic farming research has evolved globally. It also enhances interpretability by linking collaboration structures with emerging scientific themes, thereby offering richer insights into the intellectual and institutional architecture of the field.

Table 7
Summary of thematic topics identified through LDA topic modeling.

Topic	Theme/Focus Area	Key Terms	Brief Description
Topic 1	Core Aspects of Organic Farming	organic, plant, farming, control, study, fruit, growth, content	Focuses on fundamental organic farming practices, plant-based studies, and crop management within the organic sector.
Topic 2	Sustainable Agriculture and Development	organic, farming, food, development, sustainable	Explores sustainability and development within agriculture, highlighting the role of farmers and farming systems that prioritize long-term viability.
Topic 3	Soil Health and Environmental Sustainability	soil, organic, farming, microbial, diversity, carbon	Examines soil management and microbial diversity as foundations for sustainable farming and ecological health.
Topic 4	Crop Management and Productivity	yield, crop, weed, fertilizer, soil management, farming	Discusses techniques for maximizing crop yield, weed and fertilizer management, and improving production efficiency.
Topic 5	Alternative Farming Systems and Environmental Impact	organic, farming, conventional, production, energy, systems, farms, environmental	Compares organic and conventional farming systems, emphasizing energy use, sustainability, and environmental outcomes.

Key researchers, such as Tscharnke, T., Mäder, P., and Leifert, C., have made significant contributions in areas like soil fertility, pest control, crop rotation, and environmental sustainability, all of which are core principles of organic agriculture. These contributions have shaped the scientific discourse around the ecological foundations of organic systems. Countries like the USA, Italy, and Germany, alongside broader regions such as Europe and Asia, have emerged as major hubs of organic farming research. Strengthening international collaborations remains crucial for expanding the impact and applicability of research findings, particularly in diverse agroecological contexts. Cross-border cooperation enables the exchange of best practices and enhances the global relevance of research outcomes.

Leading journals in this field include Acta Horticulturae, Sustainability (Switzerland), Agriculture, Ecosystems & Environment, and Renewable Agriculture and Food Systems, which serve as key platforms for disseminating advances in organic farming. Targeted publication in such journals ensures visibility among both academic audiences and policymakers. Keyword analysis reveals consistent themes, including soil fertility, biological pest control, and climate-resilient farming practices. Socio-economic challenges associated with transitioning to organic systems also emerge as a critical research area. Notably, technological integration is gaining traction. Digital tools, including precision agriculture, remote sensing, and agricultural robotics, offer promising avenues to improve efficiency in organic systems. These innovations, when adapted to local contexts, hold significant potential, especially for developing countries like India. Here, the fusion of traditional farming knowledge with modern technologies can foster climate-resilient agricultural systems (Singha et al., 2024; Aich et al., 2022).

Advances such as Agriculture 4.0, leveraging real-time data analytics, precision input management, and automation, may play a transformative role in enhancing productivity, reducing waste, and increasing the resilience of organic systems (Javaid et al., 2022). However, it is critical to ensure that the integration of such technologies aligns with organic principles and remains accessible to small and marginal farmers. The analysis of global collaboration networks suggests existing gaps in international research integration. Addressing these gaps through strategic partnerships can significantly advance the global organic farming agenda and facilitate the co-development of context-specific solutions to agricultural challenges. Despite notable progress, several challenges remain. These include the economic viability of smallholders, difficulties in scaling up organic practices, and limited incorporation of organic principles into mainstream agricultural policies. Overcoming these barriers demands interdisciplinary approaches that integrate technological innovation with the core ecological values of organic farming.

Key areas for future development include breeding cultivars suited for organic systems, developing eco-friendly seed treatment methods, enhancing integrated organic farming approaches, and combining agroforestry with organic practices (Sharma et al., 2023a, 2023b). Additional focus is needed on effective crop residue management, establishing ecological buffer zones, and addressing policy and

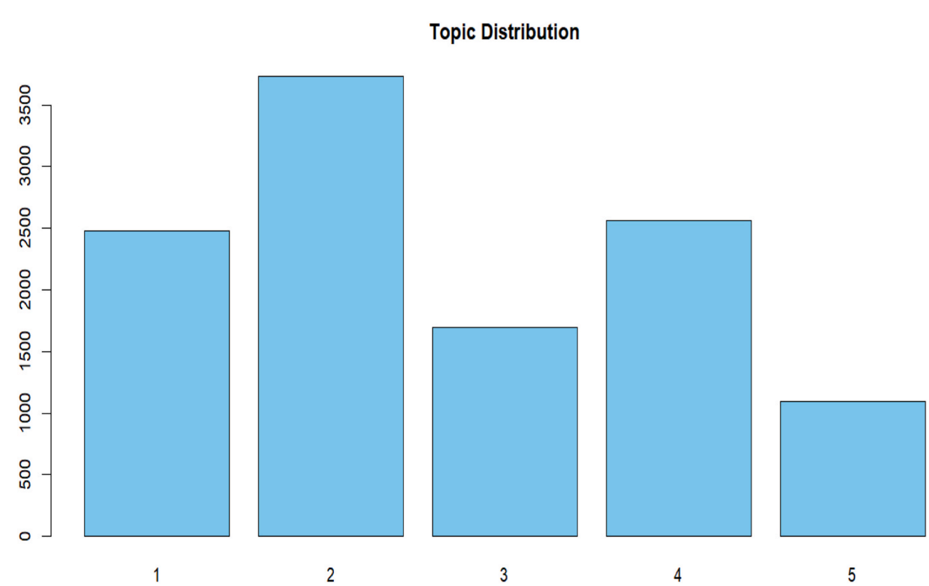

Fig. 7a. Topic distribution.

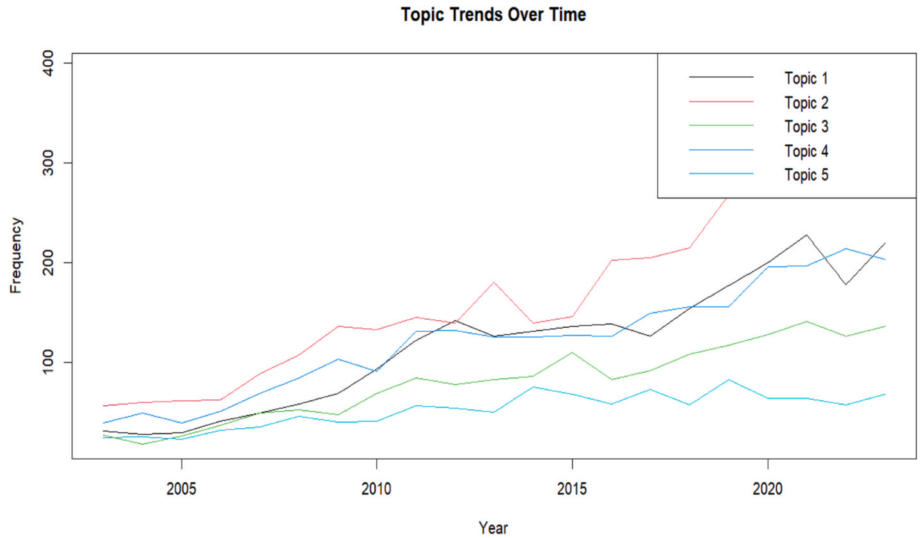

Fig. 7b. Topic trends over time.

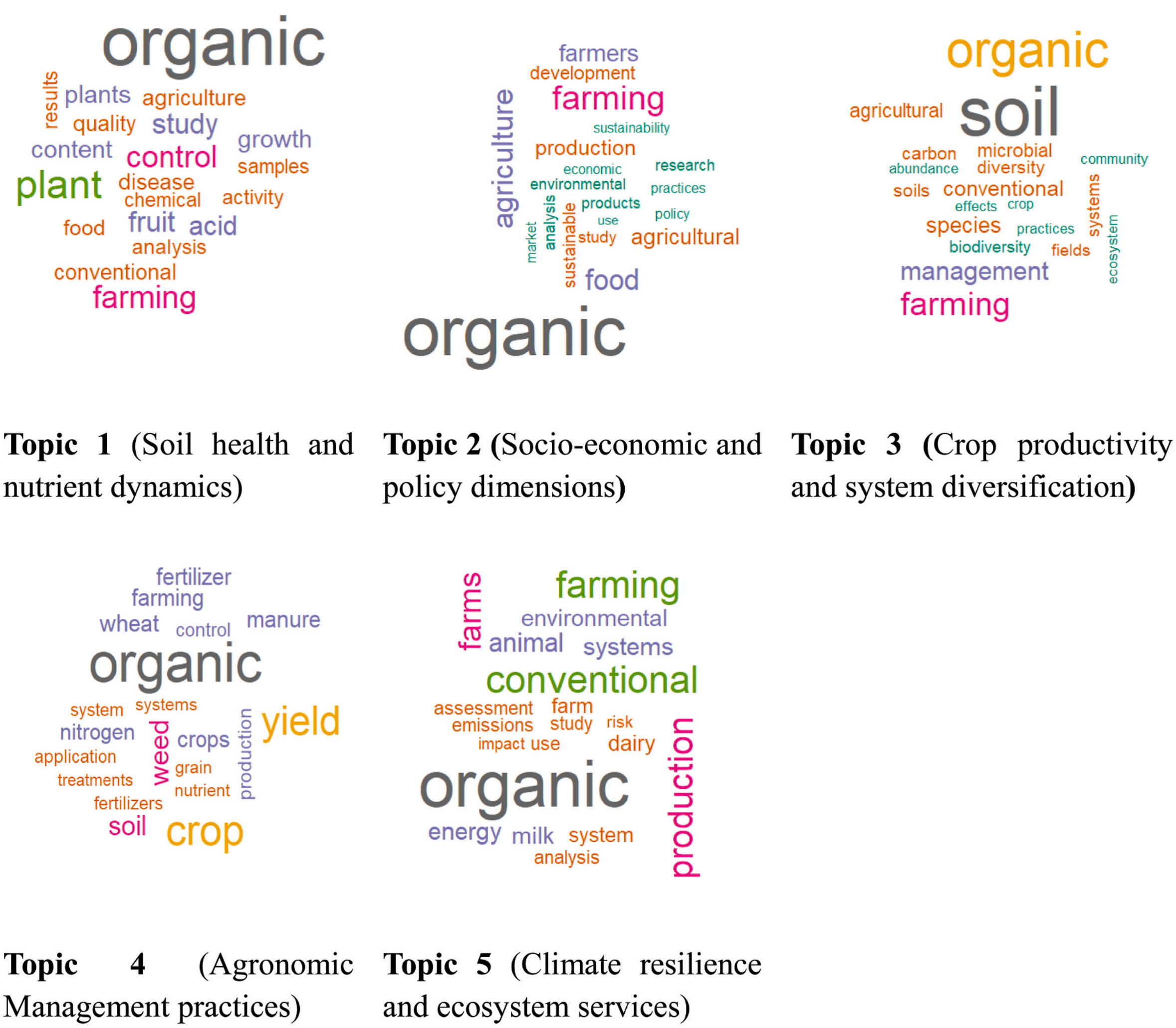

Fig. 8. Conceptual structure map showing five topic clusters in organic farming research (2003–2023).

regulatory bottlenecks (Ramanjaneyulu et al., 2025). Finally, topic modeling analysis revealed five main thematic areas, with strong emphasis on organic practices, sustainability, and soil management. Topics ranged from practical farming techniques and comparisons between organic and conventional methods to concerns with soil health, yield optimization, and long-term sustainability. These findings underscore the centrality of sustainability in current organic farming research and highlight the ongoing integration of ecological, technological, and socio-economic considerations.

4.1. Research gaps and future directions

Despite the significant growth of organic farming research worldwide, several critical gaps remain. First, there is limited emphasis on the economic feasibility and scalability of organic systems specific to regions, especially in developing countries. Second, the integration of digital and precision technologies into organic farming is still underexplored, with most studies continuing to focus on traditional practices. Third, long-term impact assessments of organic systems on soil carbon, biodiversity, and ecosystem services are insufficiently addressed. Fourth, policy-oriented and socio-economic studies relating to market access, certification, and consumer behaviour are relatively scarce. Lastly, there is a methodological gap in cross-disciplinary frameworks that combine scientometric, econometric, and sustainability assessment tools. Future research should aim to close these gaps through promoting multi-country collaborations, longitudinal research, and the adoption of advanced analytical techniques such as machine learning (ML) and AI-driven bibliometrics.

5. Conclusion

Scientometric analysis of organic farming research offers valuable insights into the field's development, scholarly impact, and future potential on a global scale. Over the last two decades, organic farming research has seen notable advancements, fuelled by a strong global network of research and institutions. The high volume of publications and citation metrics reflects the field's relevance in tackling critical agricultural issues, addressing pressing global challenges related to food security, environmental sustainability, and climate change mitigation. Key thematic areas identified include soil fertility, pest management, and climate resilience, as well as the recognition of leading authors and countries driving innovations. The strong presence of international collaborations highlights the collective effort to advance organic farming practices worldwide. Furthermore, integrating innovation technologies, policy support, and interdisciplinary research will be essential to overcoming current challenges and expanding sustainability. Consequently, organic farming research is poised to play a key role in shaping more sustainable and resilient agricultural systems worldwide, contributing to broader goals of environmental conservation and sustainable development. By identifying underexplored areas and emerging priorities, this study provides a roadmap for future investigations that can strengthen the scientific and policy foundations of organic farming.

CRediT authorship contribution statement

M. Ramesh Naik: Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation, Conceptualization. **R. Ravi Teja:** Visualization, Software, Project administration, Methodology, Formal analysis, Data curation. **A.V. Ramanjaneyulu:** Software, Resources, Methodology, Investigation. **D. Damodar Reddy:** Validation, Supervision, Software, Resources, Methodology, Conceptualization. **K.A. Gopinath:** Visualization, Validation, Supervision, Software, Resources, Project administration. **V. Ramasubramanian:** Validation, Supervision, Software, Investigation. **M.A. Sarath Chandran:** Visualization, Supervision, Software, Resources, Formal analysis, Data curation. **Sonaka Ghosh:** Project administration, Methodology, Formal analysis, Data curation. **K. Viswanatha Reddy:** Supervision, Software, Resources, Investigation. **Venkatesh Paramesha:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Methodology, Investigation, Data curation, Conceptualization. **Rupesh Kumar:** Writing – review & editing, Writing – original draft, Data curation, Conceptualization. **Amit Kumar:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources.

Declaration of competing interest

Authors declare no potential conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pce.2025.104223.

Data availability

The data will be made available upon request.

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