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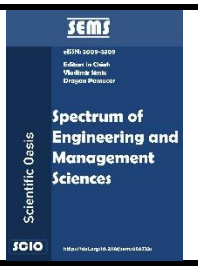

Multi-Criteria Decision-Making Applications in Agro-based Industries for Economic Development: An Overview of Global Trends, Collaborative Patterns, and Research Gaps

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ABSTRACT

Agro-based industries (ABI) play a significant role in stimulating economic growth by boosting agricultural output, minimizing post-harvest losses, and promoting sustainability. Despite its significance, decision-making in ABI remains hard due to the need to balance economic, environmental, and social objectives. This paper tackles this gap with a bibliometric analysis of multi-criteria decision-making (MCDM) applications in ABI, concentrating on global trends, collaborative patterns, and research gaps. Data were obtained from 407 publications published between 2015 and 2024 and examined using programs such as VOSviewer. The results indicate strong growth in MCDM research, with a peak in production reached in 2022. Key findings include the domination of contributions from nations like India, China, and the UK, and the identification of major writers and organizations impacting the subject. However, difficulties such as limited interdisciplinary collaboration and poor integration of emerging technology like artificial intelligence remain prominent. This study concludes that MCDM techniques are essential in optimizing supply chains, resource allocation, and sustainability assessments in ABI. By connecting theoretical frameworks with practical applications, the research gives actionable insights for better decision-making processes in agro-industrial environments, particularly in emerging economies.

1. Introduction

Agro-Based Industries (ABI) are vital catalysts for economic expansion and rural advancement [1]. They offer substantial employment opportunities, improve agricultural productivity, and augment national GDP through several industries, including food processing, textile manufacturing, and bio-based products [2]. These industries not only generate cash but also mitigate post-harvest losses and enhance the value of agricultural products, establishing them as a cornerstone of socio-economic advancement.

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India, as an agricultural economy, obtains significant economic value from ABI. Comprising more than 15% of the nation's industrial production, these industries cater to both rural and urban market needs. The dairy business employs millions, is vital for sustaining rural livelihoods, and notably contributes to GDP [3]. The emergence of agro-industrial clusters and value-added goods illustrates their capacity to bridge the economic gap between rural and urban areas [4]. Due to their significance, decision-making in agro-industries necessitates managing intricate trade-offs among economic efficiency, environmental sustainability, and social equality [5]. Multi-criteria decision-making (MCDM) approaches provide an organized approach to tackling these difficulties. MCDM approaches enable optimization of supply chains, resource allocation, and sustainability assessments. They are crucial in tackling challenges including environmental impact reduction, cost-effectiveness, and aligning operations with global sustainability goals [6-7].

1.1 *Significance of the Study*

i. *Practical importance* – MCDM techniques enable ABI to enhance environmental sustainability by facilitating decisions that limit resource wasting, reduce environmental deterioration, and promote renewable energy use [8-9]. For instance, MCDM methods can examine trade-offs between economic gains and environmental consequences, assuring long-term survival. These methodologies also play a vital role in supply chain optimization by integrating sustainability measurements with financial performance, particularly in resource-constrained contexts where effective allocation of inputs is critical [10].
ii. *Theoretical importance* – This study intends to contribute to the theoretical knowledge of MCDM applications in agro-industries, bringing new perspectives to researchers and practitioners [11-12]. It explores the connection between quantitative and qualitative decision-making frameworks, thereby expanding the existing knowledge base [13-14]. Also, it bridges the gap between theoretical models and their practical implementation by addressing challenges like scalability, adaptability, and the integration of emerging technologies such as artificial intelligence and machine learning in MCDM applications, fostering interdisciplinary insights [15-16].

1.2 Past Literature on Bibliometric Analysis of MCDM in ABI

Bibliometric analysis has gained popularity in understanding the uses of MCDM in ABI. Past research highlights its importance in evaluating tools and approaches that maximize decision-making for agricultural supply chains, sustainability, and resource allocation. Table 1 outlines major studies, highlighting prominent authors, research titles, tools applied, and their findings. These studies underline the growing significance of MCDM approaches in solving complex agro-industrial concerns successfully.

1.3 Research Gap

Gaps persist in MCDM applications for agro-industries, including limited interdisciplinary collaboration, regional research bias, weak integration of novel innovations, lack of holistic frameworks, insufficient policy linkages, underexplored social impacts, and inadequate longitudinal research and global studies.

Table 1
Summary of past literature on bibliometric analysis in ABI

Authors	Year	Tools	Findings
Francik et al. [17]	2017	VOSviewer	The study analyzed development trends in scientific research on MCDM methods in agriculture, highlighting an intensive development in recent years.
Yu and Mu [18]	2022	VOSviewer and CiteSpace	The findings indicated weak collaboration between authors and institutions, a wide coverage of disciplines, and a concentration of authors from Asian and European countries.
Wijesing [19]	2024	Bibliometric analysis,	The findings reveal increasing research trends emphasizing spatial decision support tools for sustainable agriculture, highlighting key factors like environmental impact, resource optimization, and regional land.
Sohail et al. [20]	2023	VOSviewer and graphical analysis	MCDM-based waste management research highlights increasing trends, sustainability focus, emerging methods, and collaboration among diverse academic disciplines globally.
Alnoor et al. [21]	2024	Citespace	MCDM methods enhance decision-making in agriculture by optimizing resource use, boosting sustainability, and driving digital transformation in agro-industries.
Khulud et al. [22]	2023	R-based Biblioshiny and VOS viewer	The analysis highlights key trends, influential authors, and gaps in decision-making frameworks for sustainable supplier selection using MCDM methods.
Murali et al. [23]	2022	Mendeley reference management software	The analysis highlights India's advancements in agri-tech adoption, identifying research gaps in innovation, sustainability, and policy integration for future studies
Bortoluzzi et al. [24]	2021	VOSviewer and CiteSpace	Key findings reveal trends in performance indicators and decision models for renewable energy evaluation, highlighting sustainability, efficiency, and optimization priorities.
Riahai et al. [25]	2021	VOSviewer	The study highlights key trends, technological advancements, and research gaps in AI adoption for optimizing supply chain operations.
Zhu et al. [26]	2005	VOSviewer	The study finds that China faces significant pressures for green supply chain practices, improving environmental performance and fostering sustainability.
This review paper		*VOSviewer*	*Highlights global trends, identifies research gaps, and provides actionable insights for economic development and sustainability.*

1.4 Novelty of the Study

This work distinguishes out as the first complete bibliometric examination of MCDM applications in ABI. Unlike earlier research, which generally focuses on discrete applications or specific case studies, this work comprehensively investigates the global landscape of MCDM research in ABI. It detects significant trends, emphasizes research gaps, and examines novel applications in areas including sustainability, supply chain management, and economic efficiency.

Moreover, this approach lays a major emphasis on the junction of MCDM, sustainability, and agro-industrial development in emerging nations. By applying advanced bibliometric techniques such as VOSviewer. The study offers a deep analysis of collaboration networks, theme progressions, and important contributors in the field. This approach not only gives a macro-level understanding of the research topic but also uncovers actionable insights for bridging gaps between theory and practice, particularly in the context of underdeveloped nations where these businesses hold great revolutionary potential.

1.5 Objectives of the Study

i. To explore and document global trends in the application of MCDM methods within agro-based industries, using advanced bibliometric tools like VOSviewer.
ii. To identify research gaps, including limited interdisciplinary collaboration, regional disparities, weak integration of innovations, and insufficient policy linkages in the current body of MCDM literature for agro-industries.
iii. To investigate how MCDM methods contribute to environmental sustainability, resource optimization, and economic efficiency in agro-industrial contexts, particularly focusing on emerging economies.
iv. To provide actionable insights by bridging the gap between theoretical models of MCDM and their practical implementation, fostering advancements in sustainability and decision-making frameworks in agro-industries.

The study is organized into five sections. Each section systematically addresses the research objectives.

2. Methodology

This study presents a bibliometric analysis of the applications of MCDM in ABI for economic development, based on data from Dimensions.AI (Figure 1).

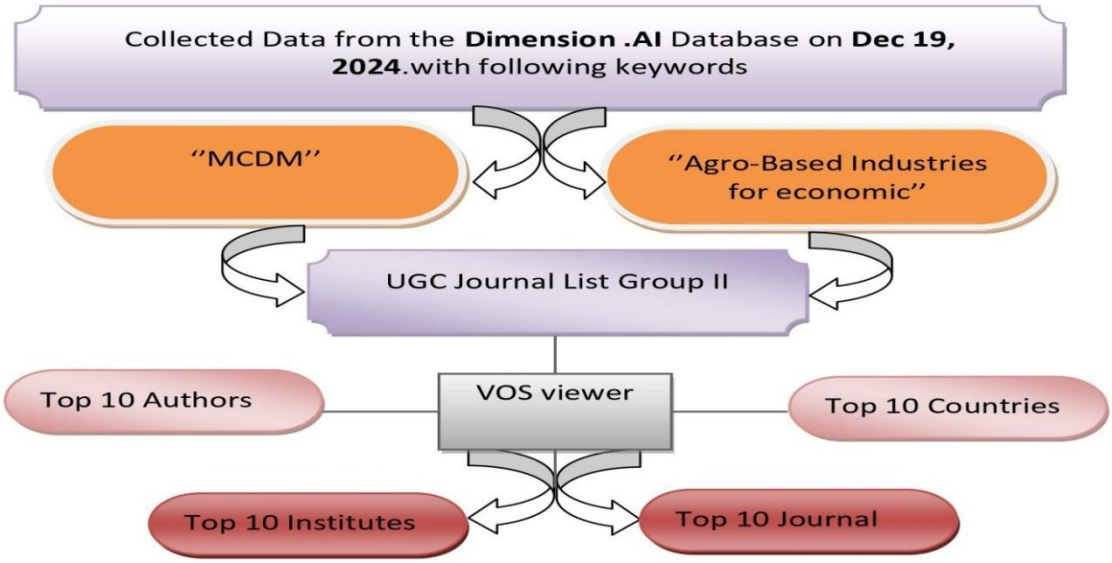

Fig. 1. Flowchart of bibliometric analysis of MCDM

Using the keywords "MCDM" AND "Agro-Based Industries for Economic Development", 407 articles published (Figure 2) between 2015 and 2024 in UGC Group II journals under Commerce, Management, Tourism, and Services were analyzed. The study employed VOSviewer software to visualize trends, collaborations, and thematic patterns, providing insights into the field's academic landscape and its role in economic growth.

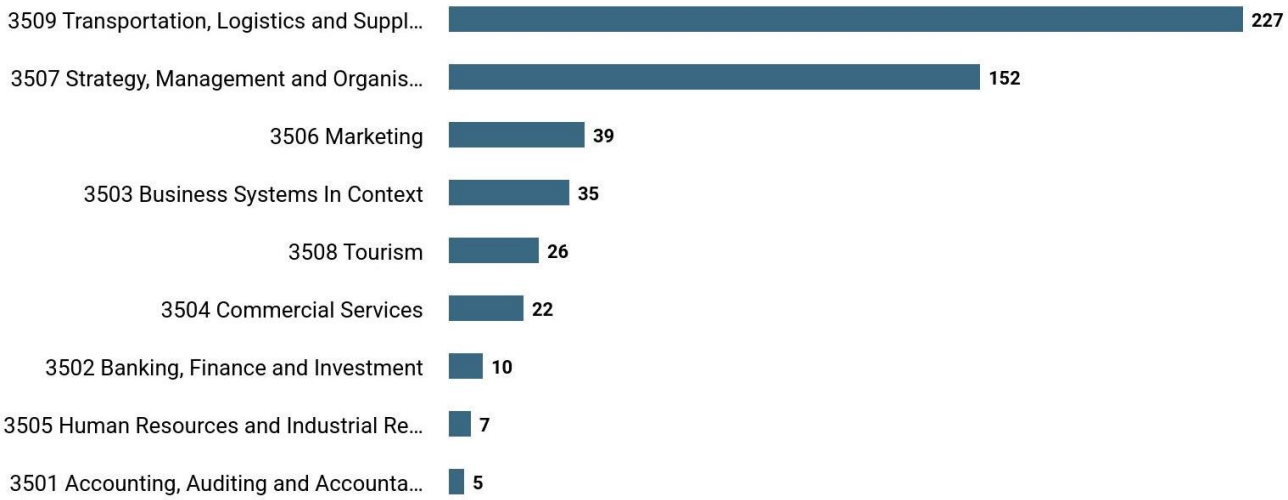

Fig. 2. Flowchart of fields of research in commerce, management, tourism, and services

3. Results and Discussion

3.1 Trend Analysis of Publication

The publication data (Table 2) from 2015 to 2024 demonstrates a strong increasing trend in research productivity, culminating in 2022. Initially, from 2015 to 2017, the number of publications remained quite low and constant, averaging approximately 5 articles each year. A strong growth phase began in 2018, with publications jumping from 7 in 2017 to 27 in 2018, followed by regular rises. The high was reached in 2022, with 86 publications, indicating the most productive year in this period. However, a fall is noticed in 2023, with publications dropping to 69 and stabilizing at the same figure in 2024. Despite this, the overall average number of publications during the ten years is 40.7 per year. This graph implies initial growth, a productive peak, and a minor drop, warranting investigation to sustain productivity (Figure 3).

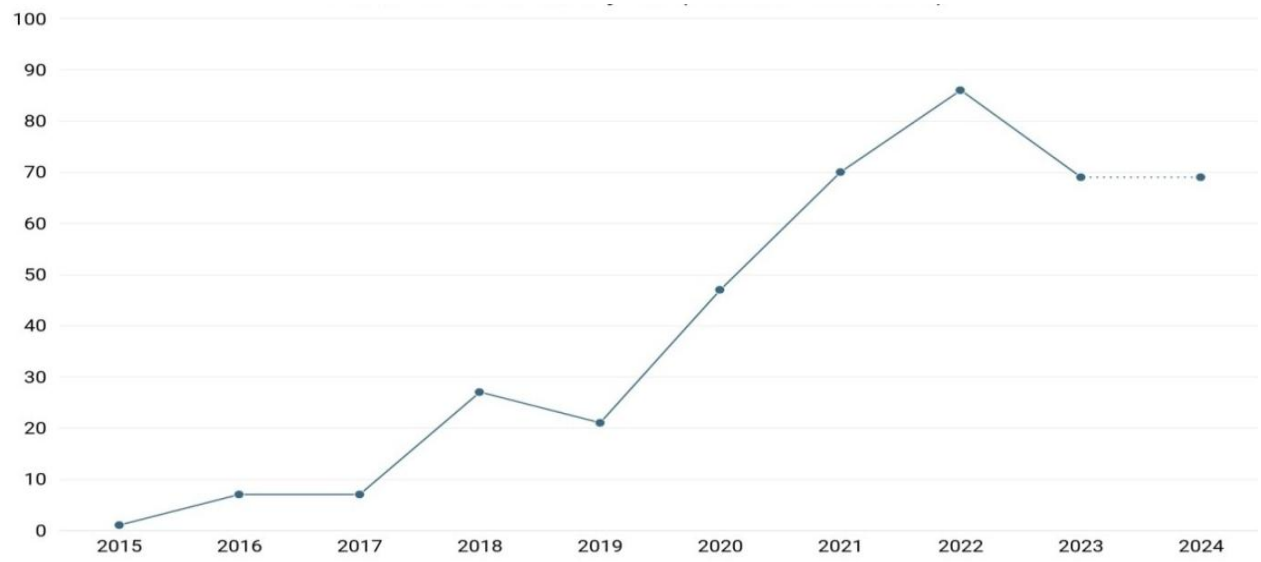

Fig. 3. Number of publications in each year

Table 2
Publications trend analysis (2015–2024)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Publications (total)	1	7	7	27	21	47	70	86	69	69
Average publications (up to a year)	1.0	4.0	5.0	10.5	12.6	18.3	25.7	33.2	37.0	40.7

3.2 Trend Analysis of Citations

The citation data (Table 3) from 2015 to 2024 demonstrates an exponential growth pattern, demonstrating the increasing impact of the study throughout the years.

Table 3
Citations trend analysis (2015–2024)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Citations (total)	13	16	64	120	311	665	1377	2127	3179	3784
Average citations (up to a year)	13.0	14.5	31.0	53.3	104.8	198.2	366.6	586.1	964.0	1192.5

From 2015 to 2017, citations remained very low, averaging less than 50 annually, indicative of the initial phase of citation accumulation. However, a noteworthy spike occurred in 2018, with citations climbing from 64 in 2017 to 120 in 2018 and further accelerating in consecutive years. By 2023, citations had reached 3,179, and the trend is predicted to peak at 3,784 in 2024. This steady boost in citations implies a growing reputation and importance of the works, particularly after 2020 (Figure 4).

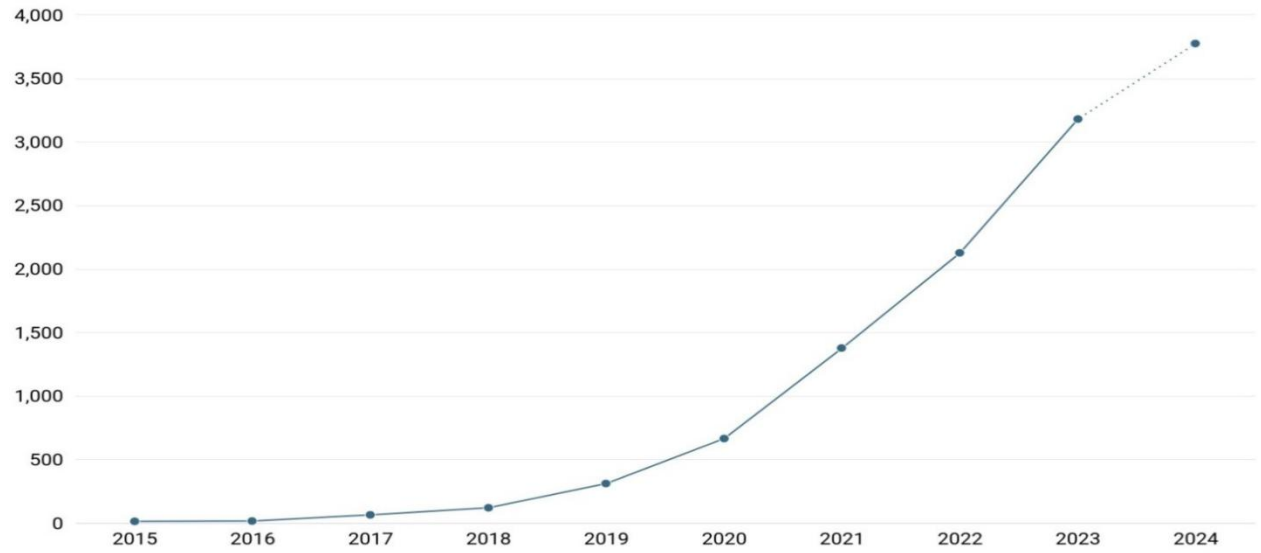

Fig. 4. Number of citations in each year

3.3 Trend Analysis of Publications with Citations

The data displays (Table 4) the percentage of publications earning at least one citation from 2015 to 2024.

Table 4
Publications with citations trend analysis (2015–2024)

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Publications with citations (% ≥1)	100.0	100.0	100.0	100.00	95.24	97.87	98.57	96.51	89.86	56.52
Average publications with citations (up to a year)	100.0	100.0	100.0	100.0	99.05	98.35	98.32	97.90	96.31	89.43

The trend indicates a high initial consistency of 100% from 2015 to 2018, meaning that all publications during this period were mentioned at least once. However, a modest fall begins in 2019, with the proportion reducing to 95.24%. From 2020 to 2022, the proportion stayed constant, averaging around 97%, but a substantial reduction is noticed in 2023 (89.86%) and further lowers significantly in 2024 (56.52%). The overall average percentage of publications with citations over all years is 89.43%, demonstrating a robust but continuously diminishing trend (Figure 5).

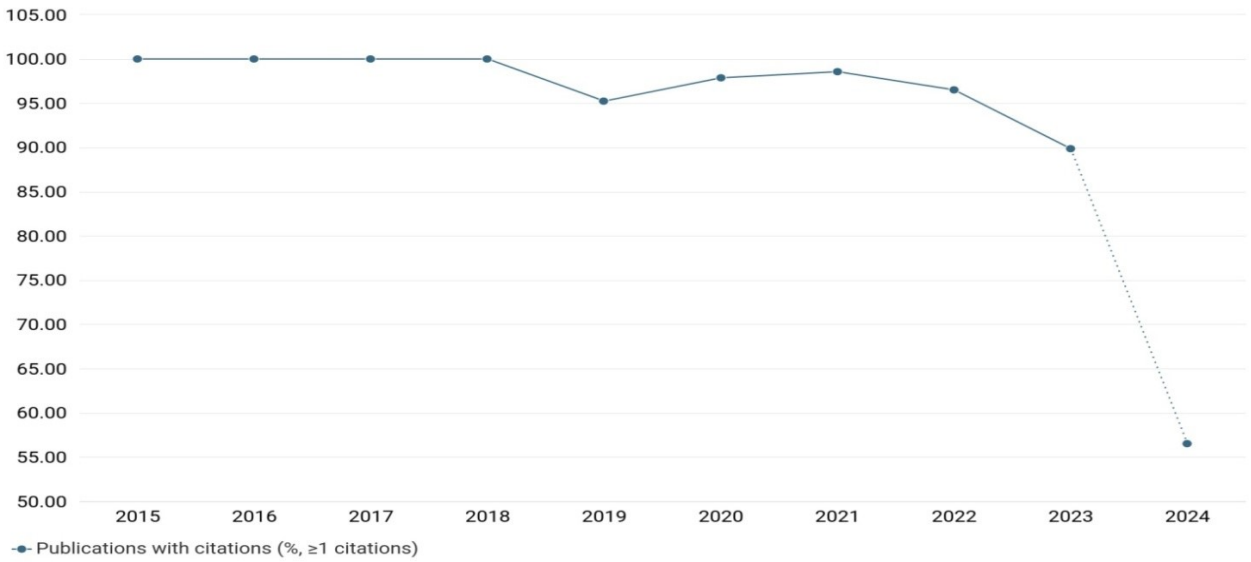

Fig. 5. Number of publications with citations (% ≥1)

3.4 Co-authorship Analysis

Co-author analysis examines the collaborative efforts among researchers by analyzing co-authored publications. Using tools like VOSviewer, such analyses generate visual networks where nodes represent authors, and edges signify their collaborative relationships. This approach highlights prominent researchers, patterns of collaboration, and clusters of academic partnerships. Additionally, it can assess collaboration at various levels, such as between countries or institutions, offering valuable insights into research dynamics and fostering stronger academic connections [27].

3.4.1 Authors

This investigation identifies 1267 authors after removing texts with a maximum of 25 authors apiece (Figure 6). Out of these, only 49 authors match the criteria of having at least 3 documents and a minimum of 3 citations. Figure 6 demonstrates that among the 49 authors, 40 researchers had the highest number of linked works.

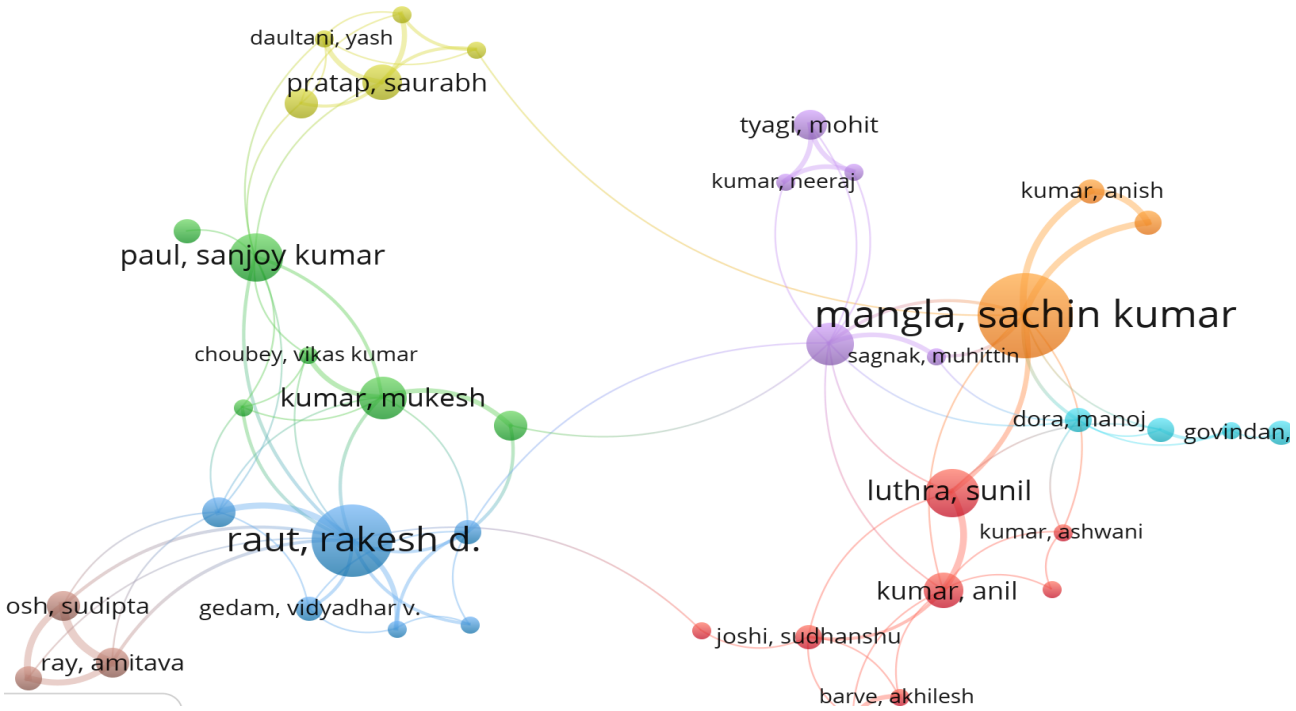

Fig. 6. Bibliometric map on co-authorship with network visualization mode

The top 10 authors in this analysis indicate significant contributions to the area, with measures such as publications, citations, and average citations per article serving as major markers of their research influence (Table 5). Sachin Kumar Mangla takes the lead with an unparalleled 14 publications and 1039 citations, indicating his strong impact on the academic community. Sachin S. Kamble ranks second with fewer publications (i.e. three) but an astounding 997 citations, indicating the exceptional quality and relevance of his research. Sunil Luthra secures the third position with eight publications and 655 citations, indicating a healthy blend of output and impact. Rakesh D. Raut exhibits consistency with 12 publications and 483 citations, demonstrating his strong contribution to research output. Anil Kumar and Pradeep Kumar follow closely, with both authors earning high citation counts relative to their publication numbers, showing their work's strong influence. Notably, Kirti Nayal and Yigit Kazancoglu display significant academic visibility through a mix of impactful publications and high average citations per article. Saurabh Pratap blends regular productivity with commendable citations, while Mukesh Kumar stands out for his seven publications, despite his citation total reflecting a specific research emphasis.

Table 5
Top 10 authors regarding publications, citations, and average citation per article

Rank	Author name	Publications	Citations	Average citations per article
1	Sachin Kumar Mangla	14	1039	21
2	Sachin S. Kamble	3	997	332
3	Sunil Luthra	8	655	82
4	Rakesh D. Raut	12	483	40
5	Anil Kumar	6	285	47.5
6	Pradeep Kumar	4	393	98.25
7	Kirti Nayal	4	252	63
8	Yigit Kazancoglu	7	244	35
9	Saurabh Pratap	6	168	28
10	Mukesh Kumar	7	56	8

3.4.2 Organizations (Affiliations)

VOSviewer also enables the analysis of organizations or affiliations that authors are associated with, in addition to examining individual authors [28]. By restricting the analysis to a maximum of 25 organizations per document, a total of 678 organizations were found. After removing documents, only 26 organizations, each having at least five articles and citations fit the criteria. Figure 7 demonstrates that out of these 26 organizations, 22 have the maximum number of linked works.

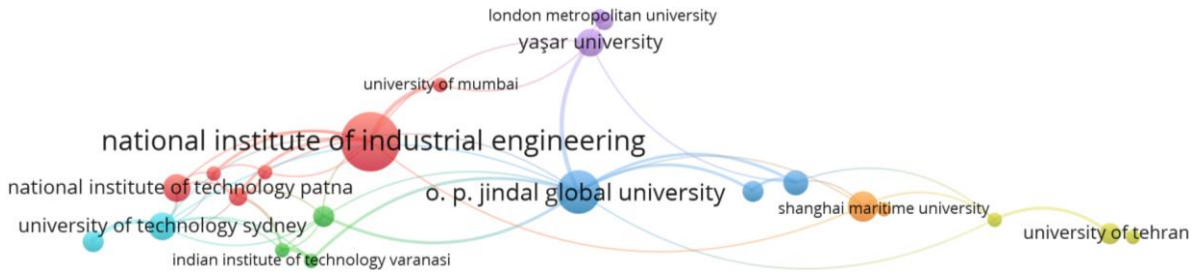

Fig. 7. Bibliometric map on organizations with network visualization mode

The top 10 ranked organizations in research output display strong academic influence based on their publications, citations, and average citations per article (Table 6). The National Institute of Industrial Engineering (NITIE) ranks 1 with 19 publications and an astounding 1623 citations, showing its prominent influence in significant research. O.P. Jindal Global University follows with 14 publications and 382 citations, indicating its productivity and considerable average citations per piece. The University of Plymouth and the University of Technology Sydney gained notable places with high citation counts compared to their output, demonstrating their global research importance. Indian universities such as IIT Roorkee, IIT Delhi, and IIM Lucknow display balanced contributions, combining consistent output with good citation metrics. Coventry University and the University of Defence also stand out for their influential research, despite smaller publication counts. Collectively, these universities establish milestones for academic output and excellent research contributions.

Table 6
Top 10 organizations regarding publications, citations, and average citation per article

Rank	Organization	Publications	Citations	Average citations per article
1	National Institute of Industrial Engineering	19	1623	85.42
2	O.P. Jindal Global University	14	382	27.29
3	University of Plymouth	8	777	97.13
4	University of Technology Sydney	9	238	26.44
5	Indian Institute of Technology Roorkee	7	411	58.71
6	Indian Institute of Technology Delhi	7	226	32.29
7	Indian Institute of Management Lucknow	5	180	36.00
8	University of Defence	5	285	57.00
9	Coventry University	5	267	53.40
10	Yaşar University	9	264	29.33

3.4.3 Countries

VOSviewer supports the analysis of nations inside co-authorship networks, enabling a full understanding of collaborative patterns. This study identified 65 nations by eliminating articles that involved a maximum of 25 countries each. As indicated in Figure 8, only 33 organizations match the necessary criteria, which include having a minimum of 4 published papers and significant country-level citations.

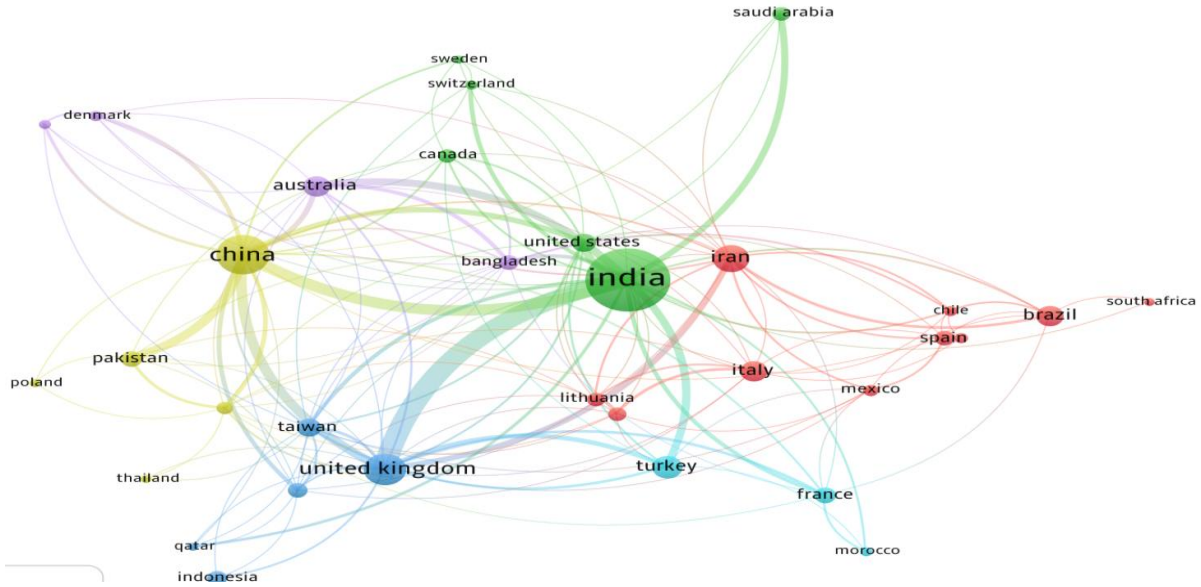

Fig. 8. Bibliometric map of countries with network visualization mode

The top 10 ranked countries based on research contributions have a great academic impact globally (Table 7). India leads with 149 publications and 4961 citations, demonstrating its significant role in research productivity and influence. China follows with 64 publications and 2083 citations, displaying significant scholarly contributions and excellent total link strength. The United Kingdom earns the third position, achieving 43 articles and 2314 citations, suggesting strong research production and involvement. The United States ranks fourth, with 16 publications and 1630 citations, underlining its high average citation per article. Italy and Turkey show balanced productivity and influence, whereas Taiwan shines with a good citation count relative to its 16 publications. Australia and France display a blend of consistent productivity and meaningful research. Iran closes out the top 10, displaying solid scholarly contributions and international engagement.

Table 7
Top 10 countries regarding publications, citations, and average citation per article

Rank	Country	Publications	Citations	Average citations per article
1	India	149	4961	33.29
2	China	64	2083	32.55
3	United Kingdom	43	2314	53.81
4	United States	16	1630	101.88
5	Italy	21	690	32.86
6	Turkey	24	894	37.25
7	Taiwan	16	748	46.75
8	Australia	20	408	20.4
9	France	13	551	42.38
10	Iran	34	591	17.38

3.5 Citation Analysis

VOSviewer is a popular tool for bibliometric analysis, allowing researchers to look into citation relationships across various units, including documents and sources [29]. Each aspect plays a different purpose in enriching citation analysis, offering precise insights into intellectual linkages and research trends. Here is an outline of how these modules contribute to the statistical features of VOSviewer:

i. *Documents* – The study of citations primarily focuses on specific academic publications, including journal articles, conference papers, books, and patents. Using VOSviewer, researchers can analyze citation links among these papers, find influential publications, track the history of ideas, and discover the intellectual framework of a certain field of study [30]. There are 407 documents found in this analysis. Merely 295 documents satisfy the criterion with a minimum of four citations each. Figure 9 illustrates that of the 295 documents 129 papers had the greatest number of related things.

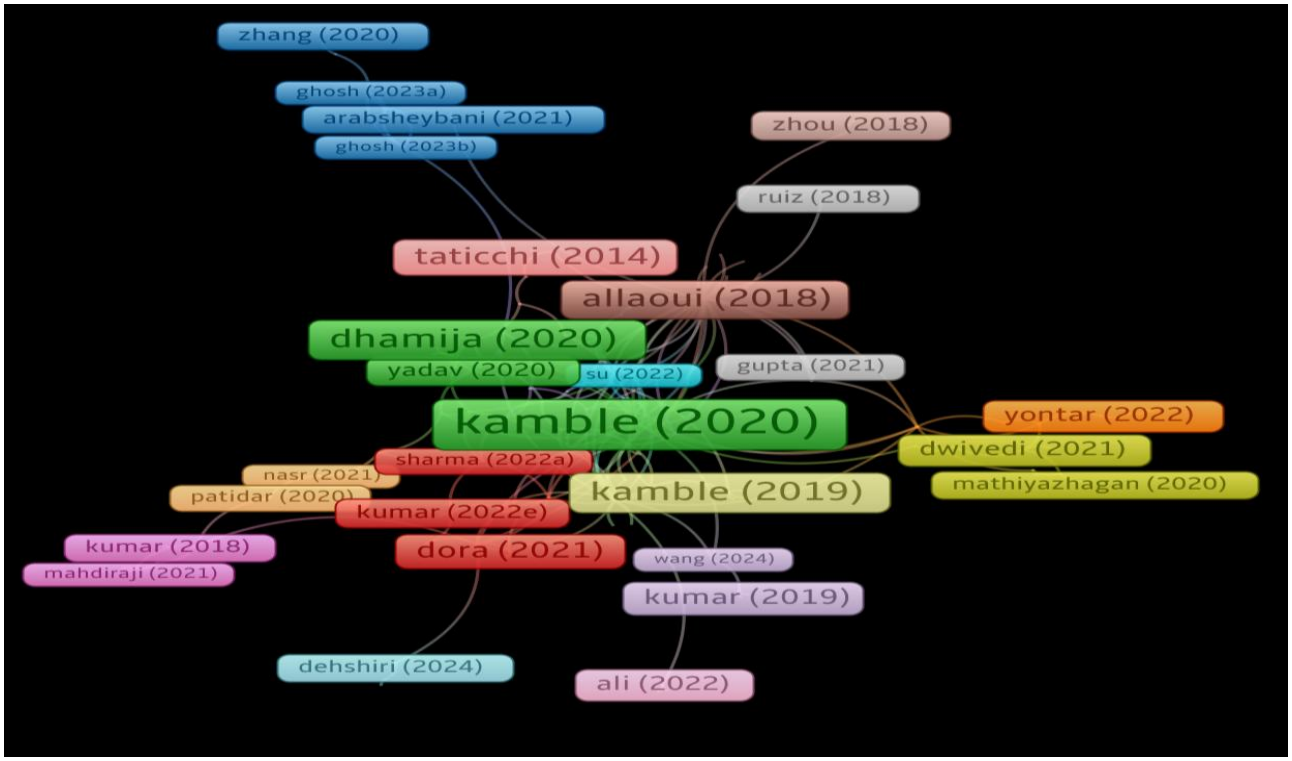

Fig. 9. Bibliometric map on documents with network visualization mode

ii. *Sources* – Journals and proceedings of conferences are significant examples of sources in academic publishing [31]. With VOSviewer, scholars may assess trends in citations across different sources, uncovering often co-cited articles and comprehending their contribution to the knowledge base of a given topic or study area. There are 130 sources in this analysis. Merely 27 sources satisfy the required minimum of 4 documents and source citations. Figure 10 illustrates that of the 27 sources, 26 have the greatest collection of related items.

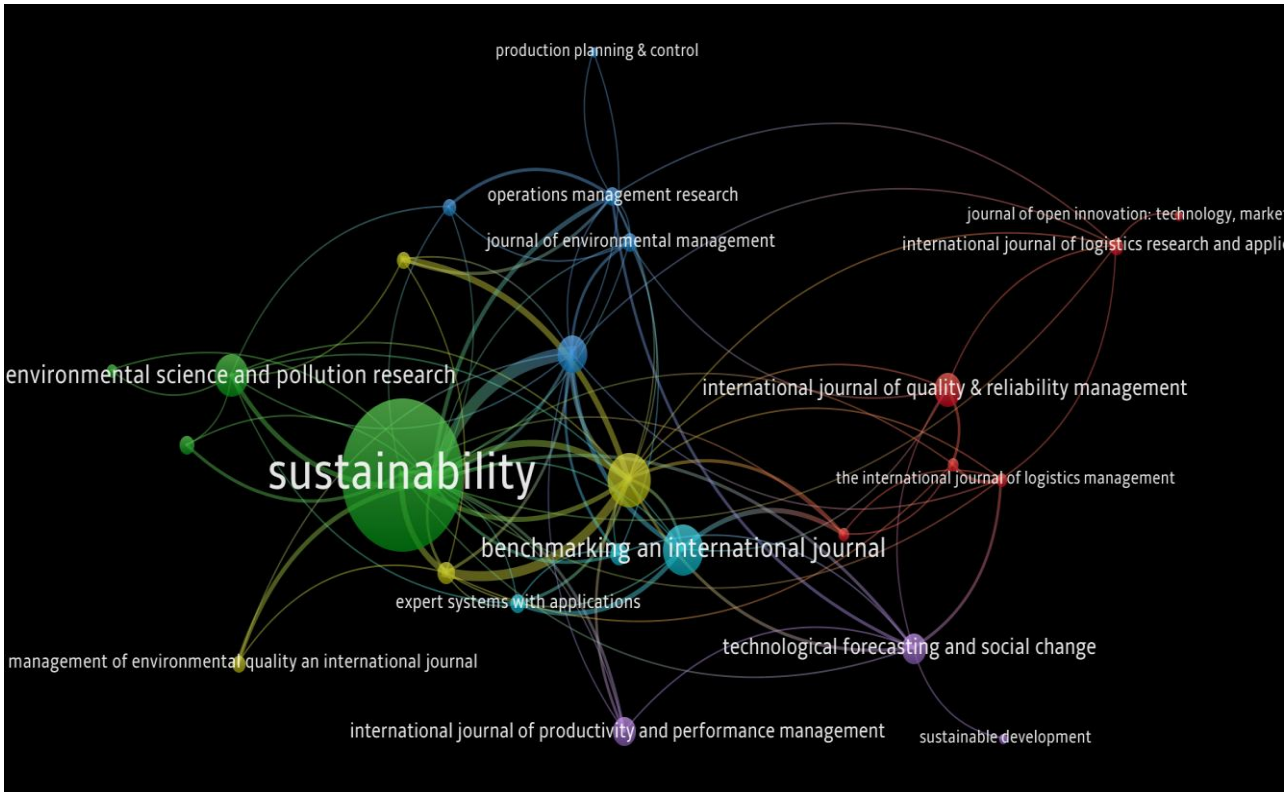

Fig. 10. Bibliometric map on sources with network visualization mode

The examination of Table 8 illustrates some noteworthy trends and insights about the most productive sources in the field. Sustainability appears as the leading journal, with 53 documents and 1021 citations, showing its popularity in research addressing sustainability challenges. Similarly, the International Journal of Production Economics, with the greatest citation count (1052) for only nine papers, highlights the strong influence and quality of its publications. Journals like Technological Forecasting and Social Change and Journal of Environmental Management display strong performance through measures such as CiteScore, Impact Factor, and SNIP, suggesting their importance and influence in their respective disciplines.

Diverse subject areas are visible across the journals, with issues spanning from environmental management and sustainability to operations research and benchmarking. High total link strength levels in publications such as the International Journal of Production Economics and Annals of Operations Research demonstrate their widespread academic collaboration and network visibility, making them desirable platforms for significant research. Emerging specialist topics like benchmarking and quality management, represented by Benchmarking: An International Journal and The TQM Journal are receiving scholarly interest and offer opportunities for researchers to address applied and practical difficulties.

Overall, the data demonstrates an increasing emphasis on environmental sustainability, technological innovation, and operational efficiency as significant study areas. Researchers striving for increased visibility and citation impact are urged to choose publications with strong metrics and collaboration potential, such as Sustainability, International Journal of Production Economics, and Technological Forecasting and Social Change. By matching their research with these high-impact areas, researchers can optimize their contributions to the academic community and solve important global concerns effectively.

Table 8
The topmost productive sources with the most cited articles

Rank	Source	Documents	Citations	Total link strength	Cite score	Impact factor	SNIP	SJR	H-index
1	Sustainability	53	1021	18	7.9	3.1	0.960	0.63	38
2	International Journal of Production Economics	9	1052	40	12.0	3.074	1.46	3.074	231
3	Annals of Operations Research	19	647	37	6.0	2.0	1.0	1.5	100
4	Technological Forecasting and Social Change	11	554	13	9.18	3.219	1.5	3.219	289
5	Business Strategy and the Environment	13	525	30	8.0	2.5	1.2	2.0	150
6	Environmental Science and Pollution Research	15	479	11	7.5	2.0	0.9	1.0	120
7	Journal of Environmental Management	7	483	8	11.4	5 - 10	1.91	Q1	150
8	International Journal of Production Research	8	506	19	9.74	2.668	1.2	2.668	186
9	Benchmarking: An International Journal	18	313	15	4.4	3.0	1.153	Q2	50
10	The TQM Journal	5	300	7	3.0	1.5	0.8	1.0	60

4. Discussions

The study's findings reveal a substantial growth trajectory in MCDM research, notably after 2018, driven by the rising complexity of decision-making in agro-industries. One of the most remarkable conclusions of the investigation is the dominance of a few prominent individuals, notably Sachin Kumar Mangla, and institutes like the National Institute of Industrial Engineering, which have greatly improved the discipline. The geographical analysis suggests that countries like India, China, and the United Kingdom are leaders in this subject, demonstrating substantial academic collaboration and resource investments. However, the study also identifies geographical discrepancies and inadequate representation from undeveloped regions, which could restrict the worldwide applicability and adaptability of MCDM frameworks.

The co-authorship and cooperation analysis suggest a fairly connected research network, with some noteworthy clusters of academics and institutions. Strengthening such partnerships can promote knowledge exchange and contribute to addressing complex, varied difficulties in ABI.

From a methodological standpoint, the study underlines the revolutionary potential of integrating MCDM with future technologies such as artificial intelligence and machine learning [32]. These technologies can enhance the scalability and adaptability of MCDM frameworks, enabling more effective decision-making in dynamic and uncertain contexts. However, the analysis also identifies shortcomings in the integration of these technologies into current frameworks, as well as little attention to policy implications and longitudinal studies, which are crucial for bridging the gap between theoretical research and practical applications.

The examination of publication and citation trends suggests robust academic interest in MCDM applications, notably in domains like supply chain management, sustainability, and digital transformation. Journals such as Sustainability and the International Journal of Production Economics are key platforms for communicating influential research, indicating their critical role in developing the debate on MCDM in ABI.

5. Conclusion

This bibliometric research shows the growing importance of MCDM applications in ABI, notably its contributions to economic development and sustainability. The research trends suggest a considerable increase in progress, with a notable peak in productivity in 2022. Prominent authors, significant institutions, and countries such as India, China, and the UK have played a crucial role in defining this field.

The findings emphasize the usefulness of MCDM in tackling crucial difficulties in supply chain management, resource optimization, and sustainable practices. The report also illustrates the contributions of significant academic venues, including journals like Sustainability and the International Journal of Production Economics, which serve as essential centers for developing research on this topic. The study confirms MCDM's effectiveness as a robust method for optimizing decision-making processes in agro-industrial environments, adding to sustainability and operational efficiency.

Acknowledgment

We like to convey our deepest gratitude to all who contributed to the successful completion of this research initiative. Our heartfelt thanks go to our friends and coworkers for their constant support, wise advice, and generous assistance during our journey. Their guidance, encouragement, and shared expertise have been important in determining the path and outcome of this project, and we remain sincerely thankful for their contributions.

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Conflicts of Interest

The author declares no conflicts of interest.

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