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How Is Research Connecting Artificial Intelligence, Sustainability Governance, and Agri-Food Supply Chains Evolving? A Bibliometric Analysis

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Abstract

This study examines the development of research situated at the intersection of artificial intelligence, sustainability governance, and agri-food supply chains through a comprehensive bibliometric analysis of 988 Scopus-indexed articles published between 2017 and 2025. This time range was selected because scholarly attention to artificial intelligence in sustainability and agri-food systems began to intensify after 2017, alongside the emergence of Industry 4.0, data-driven governance frameworks, and circular economy agendas, allowing the analysis to capture both the formative and consolidation phases of this research domain. A structured search, screening, and eligibility process was applied to ensure thematic relevance and methodological rigor, followed by performance analysis and science-mapping techniques using VOSviewer, CiteSpace, and complementary normalization procedures. The findings reveal accelerating publication growth, concentrated collaboration networks, and thematic convergence around digital sustainability, circularity, and data-driven supply-chain optimization. Keyword and citation structures indicate that the field increasingly integrates technological and environmental perspectives, although research contributions remain unevenly distributed across authors, institutions, and countries. The study highlights the emergence of a more coherent knowledge base while underscoring the need for broader participation and deeper conceptual synthesis. These insights provide a consolidated foundation for guiding future work toward stronger theoretical development and more impactful applications in sustainable agri-food systems.

1. Introduction

The growing relevance of artificial intelligence in sustainability-oriented supply chains has reshaped how organizations and governments approach resource management, environmental performance, and operational governance [1–3]. In agri-food systems, which are characterized by high uncertainty, sensitivity to environmental shocks, and complex logistical flows, digital technologies are increasingly viewed as essential for supporting transparency and resilience [4–6]. Many studies emphasize that the integration of intelligent analytical tools has become central to improving efficiency and strengthening environmental accountability within food production and distribution networks [7–9]. These developments reflect a wider transformation in which sustainability objectives are no longer addressed solely through policy interventions or operational adjustments, but through the adoption of advanced digital capabilities that enhance decision-making across the entire value chain [10–12].

Although interest in digital sustainability has expanded considerably, existing research in this domain remains highly fragmented [13–15]. Studies addressing AI governance often focus on ethical considerations or oversight mechanisms, while literature on circular agriculture tends to examine resource recovery and waste reduction in isolation from digital transformation [16, 17]. At the same time, research on sustainable supply chain management frequently highlights operational optimization but provides limited connection to broader questions regarding circularity, digital intelligence, and long-term ecological outcomes [18–20]. This separation across thematic areas makes it difficult to understand how technological, operational, and environmental dimensions interact [21, 22]. Several authors have noted that progress in this field depends on the ability to bridge silos and develop more integrated perspectives on sustainability in agri-food systems.

These conditions create a clear need to map how the scientific community has developed knowledge at the intersection of artificial intelligence, sustainability governance, circular economy strategies, and agri-food supply chain management. A systematic examination of publication patterns, collaboration structures, thematic clusters, and intellectual foundations provides a way to understand how different streams of research have evolved and how they relate to one another [23–26]. Bibliometric analysis is particularly relevant in fast-growing fields because it allows researchers to identify conceptual concentrations, emerging topics, and underlying theoretical influences that shape the overall trajectory of a domain [27–29]. By examining these structural patterns, it becomes possible to trace how thinking on AI-enabled sustainability has progressed and where important gaps continue to exist.

This study responds to those needs by examining the development of knowledge across authors, institutions, countries, thematic keywords, and foundational references. The analytical focus captures not only the growth of scientific interest but also the ways in which scholars organize themselves into networks that reflect methodological preferences, thematic priorities, and regional research capacities. The presence of strong communities working on artificial intelligence, circular economy, environmental efficiency, Industry 4.0 applications, and sustainable operations indicates an emerging consolidation of ideas. At the same time, the distribution of influential contributions across Asia, Europe, and other regions highlights the increasingly global nature of the conversation surrounding digital sustainability in agri-food systems. This interconnected structure suggests that the transformation toward data-driven sustainability practices is advancing through both conceptual developments and expanding collaborative relationships.

This research, therefore, positions itself within a broader effort to understand how digital technologies shape sustainable transitions in food-related value chains. By offering a comprehensive synthesis of publication trends, collaboration networks, thematic landscapes, and theoretical foundations, the study provides insight into how artificial intelligence and circular economy principles are being integrated into the management and governance of agri-food systems. It also reveals areas where further inquiry is needed, such as the empirical evaluation of digital interventions, the incorporation of ethical and governance considerations, and the inclusion of underrepresented regions in global research activity. Through this perspective, the study contributes to ongoing discussions on how digital intelligence, organizational capabilities, and sustainability imperatives intersect to support the development of more resilient and environmentally responsible food supply chains [30, 31].

While several review and bibliometric studies have examined artificial intelligence applications in sustainability, circular economy, or supply chain management independently, existing literature rarely provides an integrated perspective that simultaneously connects artificial intelligence, sustainability governance, and agri-food supply chains. Many prior reviews focus on specific technologies, sectors, or operational outcomes, without systematically examining how governance structures, collaborative networks, and intellectual foundations co-evolve within this research domain. This study addresses this gap by offering a comprehensive bibliometric synthesis that maps publication trends, collaboration structures, thematic clusters, and co-citation patterns across these intersecting fields. By doing so, the study advances existing reviews by clarifying the

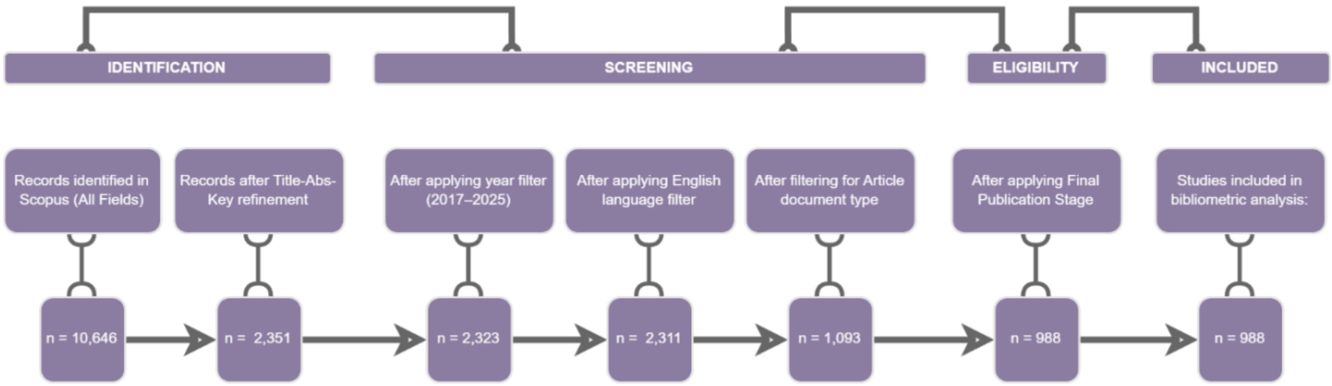

Figure 1. PRISMA flow diagram of the screening process.

distinctive knowledge structure of this domain and highlighting its emerging integration pathways rather than examining isolated research streams.

2. Materials and Methods

2.1. Data Source

This study employed the Scopus database as the primary source of bibliographic data. Scopus was selected due to its extensive coverage of peer-reviewed journals across management, sustainability, engineering, and environmental sciences, which are all relevant to the intersection of artificial intelligence, circular economy, and agri-food supply chain research. Only documents indexed in Scopus were considered, ensuring consistency in metadata structure and citation metrics. The use of a single, reputable database also enhances replicability and transparency in the data collection process.

Scopus was selected as the sole data source due to its broad coverage of peer-reviewed journals across interdisciplinary fields relevant to artificial intelligence, sustainability governance, and agri-food supply chains, as well as the consistency of its bibliographic metadata required for reliable bibliometric analysis. While other databases, such as Web of Science, are also widely used, differences in indexing scope and metadata structure may introduce inconsistencies when combining datasets, and therefore, a single database approach was adopted to ensure methodological coherence and reproducibility.

2.2. Search Strategy

The search process followed a systematic approach that combined thematic keywords related to artificial intelligence, sustainability governance, circular economy, and agri-food supply chains. The final query applied in Scopus was: ("AI governance" OR "artificial intelligence" OR "machine learning" OR "digital governance") AND ("sustainab*" OR "green" OR "responsible") AND ("supply chain" OR "value chain" OR "production network") AND ("circular economy" OR "resource efficiency" OR "waste valorization") AND (agricultur* OR "agri food" OR "food system" OR "farm" OR "agribusiness"). The query was first tested in the All Fields category and subsequently refined using the Title, Abstract, and Keywords fields to ensure thematic relevance. The year filter was set to capture all records published between 2017 and 2025, representing the full time window in which results were retrieved for this query.

2.3. Screening and PRISMA Flow

The retrieved documents underwent a structured screening process summarized in Figure 1, which presents a PRISMA flow diagram describing the stages of identification, screening, eligibility, and inclusion. Initial search results were filtered by publication year, language, document type, and publication stage. Only documents written in English, categorized as Articles, and marked as Final in the Scopus publication stage were retained. Duplicates were automatically removed by the Scopus export function. After all filters and eligibility steps were applied, a total of 988 documents were included in the final dataset and exported for bibliometric analysis.

2.4. Inclusion and Exclusion Criteria

The inclusion criteria were established to ensure the relevance and quality of the dataset. Eligible documents: (i) addressed at least one dimension of artificial intelligence, machine learning, or digital governance, (ii) related to sustainability, environmental performance, or circular economy practices, and (iii) focused on supply chains, value chains, or agri-food production networks. Articles that did not meet these thematic intersections were excluded. Non-English documents, conference papers, book chapters, editorials, and articles still in press were also removed. This approach ensured that the final dataset reflected peer-reviewed contributions most aligned with the research focus.

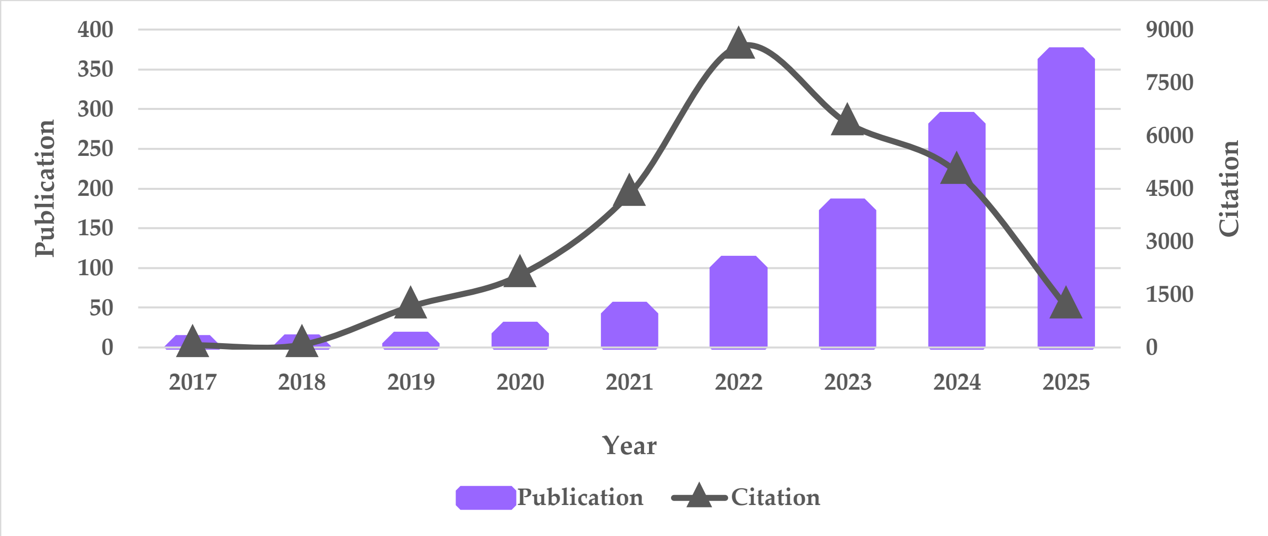

Figure 2. Trends of publications and citations in the field of artificial intelligence governance, sustainable agri-food supply chains, and circular economy practices.

2.5. Data Extraction and Preprocessing

The 988 selected documents were exported from Scopus in CSV format, including full bibliographic information such as authors, affiliations, titles, abstracts, keywords, references, and citation counts. The data were inspected to ensure consistency in field formatting before being processed. Preprocessing steps involved standardizing author names, consolidating institutional variants, harmonizing keyword spellings, and ensuring compatibility with the software tools. Excel was used to organize the data, compute normalized indicators, and prepare files for input into visualization software.

2.6. Bibliometric Techniques

The analysis combined performance analysis, science mapping, and network analysis. Performance analysis was used to examine publication trends, citation structures, and productivity indicators. Science mapping techniques included co-authorship analysis at the author, organization, and country levels, keyword co-occurrence analysis, and reference co-citation analysis. These methods allowed the study to identify collaboration patterns, thematic concentrations, and intellectual foundations within the field. Burst keyword analysis was conducted to identify emerging topics and shifts in scholarly attention over time.

2.7. Visualization and Normalization Procedures

VOSviewer was used to construct and visualize co-authorship, co-occurrence, and co-citation networks through its association strength and clustering algorithms. CiteSpace was employed to generate burst keyword detection, capturing periods of intensified citation activity associated with specific terms. Excel was used to develop annual publication trend graphs and to calculate normalized indicators such as normalized publications, normalized citations, total link strength, and overall score. These normalization procedures ensured comparability across authors, institutions, and countries, allowing for clearer interpretation of influence and research concentration.

2.8. Methodological Considerations

The methodological choices in this study were guided by the need for transparency, replicability, and analytical depth. Limiting the search to Scopus ensures consistency but may omit relevant studies indexed in other databases. The reliance on English-language documents introduces potential linguistic bias. Although bibliometric techniques offer powerful tools for mapping scientific landscapes, they focus on structural relationships rather than semantic meaning, which requires careful interpretation. Despite these considerations, the combined use of multiple analytical tools and clearly defined screening procedures ensures a robust methodological foundation for the findings presented in this study.

3. Results

3.1. Trends in Publications and Citations

The temporal distribution of publications demonstrates a consistent and accelerating rise in research relating to AI governance, sustainable agri-food supply chains, and circular economy transitions. As shown in Figure 2, publication activity began to grow noticeably after 2020 and reached its highest point in 2025, indicating a substantial surge in scholarly interest. Citation patterns display a more concentrated peak in 2022, reflecting the

Table 1. The top five years by publications and citations in the field of AI governance, sustainable agri-food supply chains, and circular economy research.

Year	Pub.	Cit.	N-Pub	N-Cit	OS
2024	282	4963	0.776	0.579	0.678
2022	101	8522	0.276	1.000	0.638
2023	173	6347	0.475	0.743	0.609
2025	363	1160	1.000	0.130	0.565
2021	43	4342	0.116	0.506	0.311
2020	18	2050	0.047	0.235	0.141

Note: Pub = publications; Cit = citations; TLS = total link strength; N-Pub/Cit/TLS = normalized values (max = 1.000); OS = Overall Score (composite index).

Table 2. Leading authors by publications, citations, and total link strength.

Author	Pub.	Cit.	TLS	N-Pub	N-Cit	N-TLS	OS	Cluster
Haleem, Abid	9	1912	26	0.667	1.000	0.619	0.762	84
Javaid, Mohd	9	1912	26	0.667	1.000	0.619	0.762	84
Kumar Mangla, Sachin Kumar	10	463	17	0.750	0.242	0.405	0.466	1
Kumar, Anil	13	943	42	1.000	0.493	1.000	0.831	2
Leal Filho, Walter D.S.	2	212	25	0.083	0.111	0.595	0.263	4

Note: Pub = publications; Cit = citations; TLS = total link strength; N-Pub/Cit/TLS = normalized values (max = 1.000); OS = Overall Score (composite index).

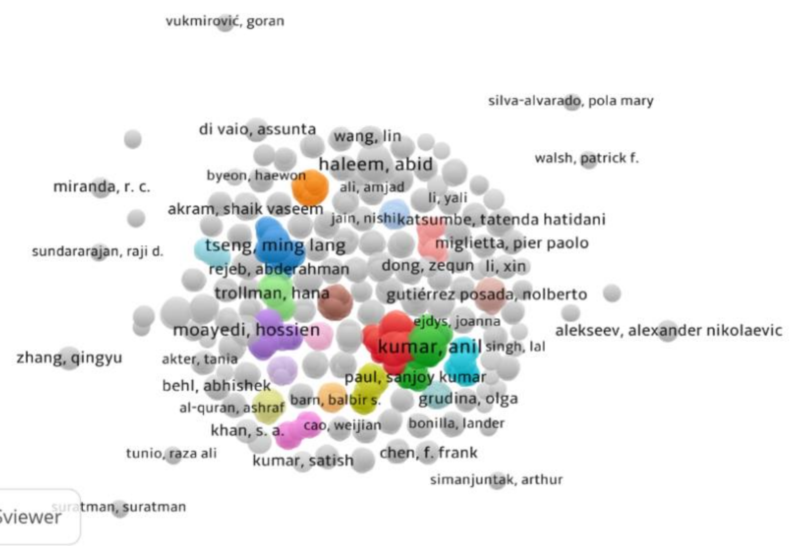

Figure 3. Authors co-authorship network in the field of AI governance, sustainable agri-food supply chains, and circular economy studies (Items: 1000, clusters: 145, links: 3730, TLS: 4046).

enduring influence of studies published in the preceding period. The quantitative patterns in Table 1 reinforce this narrative: the year 2025 exhibits the highest normalized publication score (N-Pub = 1.000), whereas 2022 achieves the highest citation performance (N-Cit = 1.000), accompanied by a strong Overall Score (OS = 0.638). Taken together, these results indicate that the field has expanded both in productivity and impact, with a notable shift toward increasingly influential scholarship in the early to mid-2020s.

3.2. Author Collaboration Network

The author collaboration structure is both extensive and multidimensional, reflecting the interdisciplinary nature of the field. As illustrated in Figure 3, the co-authorship network consists of 1,000 authors distributed across 145 clusters, supported by a cumulative total link strength (TLS) of 4,046. This configuration highlights the presence of numerous active research communities that contribute to the intellectual development of AI-enabled sustainable supply chains. According to Table 2, Kumar, Anil emerges as the most influential contributor, recording the highest OS value (0.831), which reflects his strong integration of productivity, citation impact, and collaborative connectivity. Haleem, Abid and Javaid, Mohd also demonstrate prominent influence through their identical citation records and OS values (0.762), indicating high-impact contributions embedded within

Figure 4. Organizations co-authorship network in the field of AI governance, sustainable agri-food supply chains, and circular economy studies (items: 412, clusters: 27, links: 1488, TLS: 1593).

Table 3. Top contributing organizations by publications, citations, and collaboration strength.

Organization	Pub.	Cit.	TLS	N-Pub	N-Cit	N-TLS	OS	Cluster
London Metropolitan University	12	657	43	1.000	0.344	1.000	0.781	5
Department of Mechanical Engineering, Jamia Millia Islamia	9	1912	15	0.727	1.000	0.349	0.692	13
IICE Asia University	8	749	41	0.636	0.392	0.953	0.661	4
O.P. Jindal Global University	10	577	32	0.818	0.302	0.744	0.621	5
The Department of Industrial & Production Engineering, Dr. BR Ambedkar NIT	7	1431	12	0.545	0.748	0.279	0.524	13

Note: Pub = publications; Cit = citations; TLS = total link strength; N-Pub/Cit/TLS = normalized values (max = 1.000); OS = Overall Score (composite index).

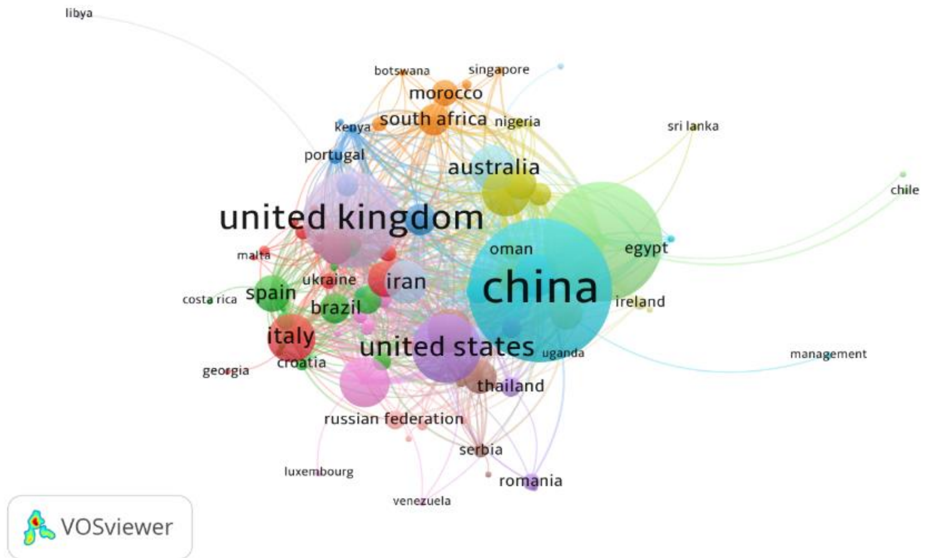

Figure 5. International co-authorship network of countries in the field of AI governance, sustainable agri-food supply chains, and circular economy studies (items: 104, cluster: 15, links: 823, TLS: 1694).

actively connected research clusters. Overall, the author-level analysis reveals that scholarly influence in this domain is shaped by balanced contributions across output, impact, and collaboration.

3.3. Organizations Collaboration Network

The organizational landscape reflects a similarly robust pattern of collaboration. As depicted in Figure 4, the network comprises 412 organizations grouped into 27 clusters, indicating diverse institutional participation and notable cross-institutional partnerships, with a combined TLS of 1,593. The performance indicators in Table 3 show that London Metropolitan University holds the most central institutional role, leading in publication output (12 publications), collaboration strength (TLS = 43), and achieving the highest OS value (0.781). The Department of Mechanical Engineering at Jamia Millia Islamia records the highest citation count (1,912 citations) and a strong OS value of 0.692, reflecting its association with several high-impact authors. Institutions such as IICE Asia University and O.P. Jindal Global University also demonstrate competitive OS values, indicating balanced performance across productivity, collaboration, and scholarly influence. Collectively, these findings suggest that institutional leadership in the field is distributed across multiple regions, with particularly strong representation from Asia and Europe.

3.4. International Collaboration by Country

International collaboration patterns reveal a wide and interconnected research network. As shown in Figure 5, the country-level map includes 104 nations organized

Table 4. Top countries by publications, citations, and total link strength.

Country	Pub.	Cit.	TLS	N-Pub	N-Cit	N-TLS	OS	Cluster
India	182	8526	257	0.774	1.000	0.911	0.895	11
United Kingdom	136	7798	282	0.577	0.915	1.000	0.831	14
China	235	4817	252	1.000	0.565	0.894	0.820	6
United States	85	2191	136	0.359	0.257	0.482	0.366	5
Australia	47	3252	115	0.197	0.381	0.408	0.329	15

Note: Pub = publications; Cit = citations; TLS = total link strength; N-Pub/Cit/TLS = normalized values (max = 1.000); OS = Overall Score (composite index).

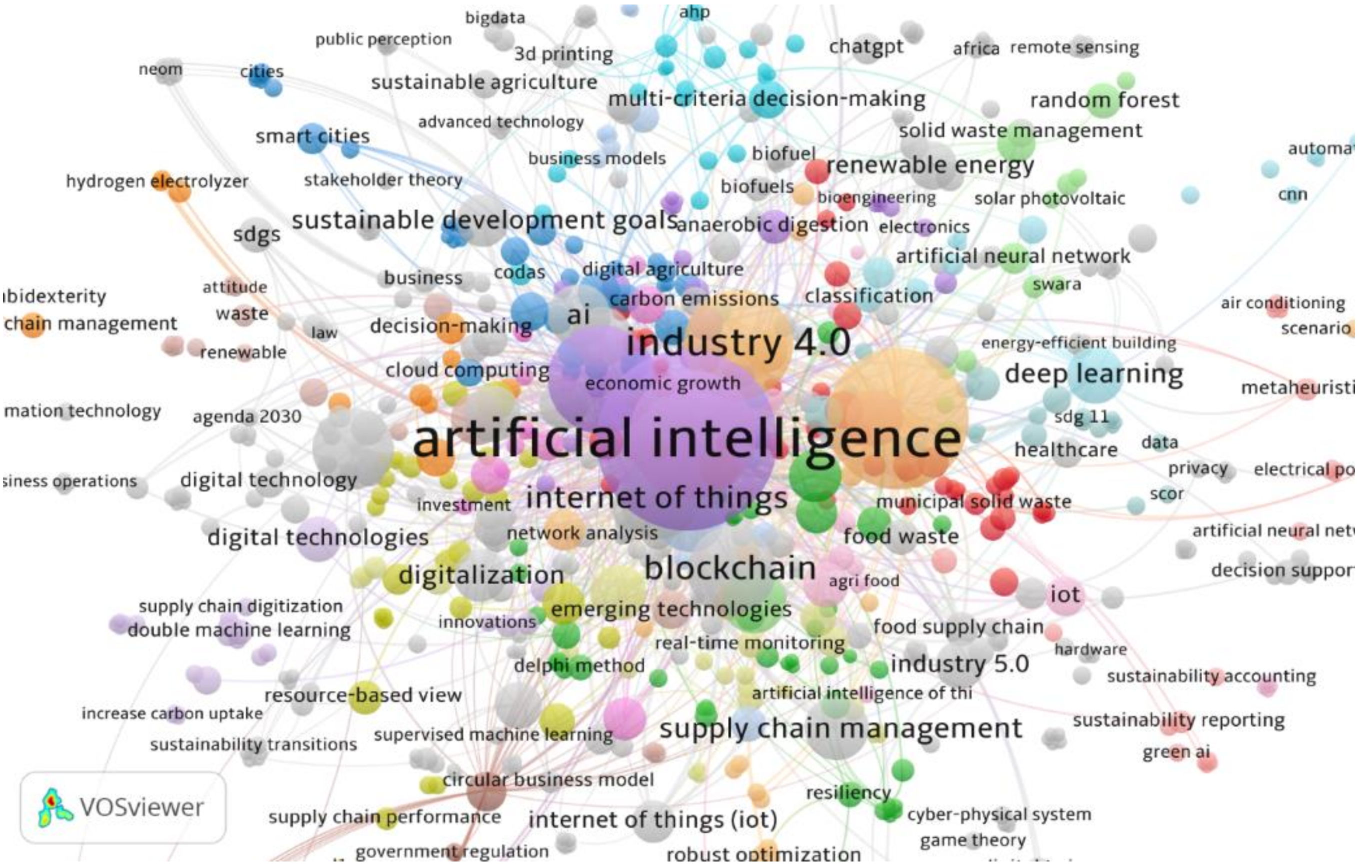

Figure 6. Author keyword co-occurrence network in the field of AI governance, sustainable agri-food supply chains, and circular economy studies (items: 963, cluster: 49, links: 6180, TLS: 7357).

into 15 clusters, with a total link strength of 1,694. The data in Table 4 illustrate distinct national research profiles. China leads in publication volume (235 documents; N-Pub = 1.000), while India dominates in citation performance (8,526 citations; N-Cit = 1.000) and achieves the highest integrated influence, reflected in its OS value of 0.895. The United Kingdom exhibits the strongest collaboration intensity (TLS = 282; N-TLS = 1.000), underscoring its central position in global research interactions. Additional contributions from the United States and Australia further enhance the field's international breadth. Overall, the country-level results confirm that the development of AI-driven sustainability and circularity research is supported by geographically diverse collaborations, with Asia-Pacific and European countries playing especially prominent roles.

3.5. Author Keyword Co-Occurrence Analysis

The thematic structure of the field is both rich and highly interconnected. As visualized in Figure 6, the keyword co-occurrence network comprises 963 keywords distributed into 49 clusters and supported by a substantial total link strength (TLS = 7,357). Table 5 identifies Artificial Intelligence as the most dominant thematic anchor, achieving the highest occurrence, connectivity, and OS value (1.000). Other influential themes include Machine Learning, Sustainability, Industry 4.0, and Circular Economy, which collectively reflect the convergence of digital transformation and sustainability priorities in contemporary agri-food supply chain research. The temporal dynamics presented in Table 6 reveal several keywords with significant citation bursts, such as Industry 4.0, Environmental Economics, Digitalization, and

Table 5. Top 5 author keywords**.**

Author Keyword	Occ.	TLS	N-Occ	N-TLS	OS	Cluster
Artificial Intelligence	280	909	1.000	1.000	1.000	5
Machine Learning	162	462	0.577	0.508	0.543	16
Sustainability	129	444	0.459	0.488	0.474	18
Industry 4.0	92	340	0.326	0.374	0.350	16
Circular Economy	90	322	0.319	0.354	0.337	5

Note: Occ = occurrence; TLS = total link strength; N-Occ/TLS = normalized values (max = 1.000); OS = Overall Score (composite index).

Table 6. Top 10 author keywords with the strongest citation bursts.

Keywords	Year	Strength	Begin	End	2017 – 2025
Industry 4.0	2020	9.42	2020	2022	
Anaerobic Digestion	2019	3.74	2019	2022	
Environmental Economics	2022	3.63	2022	2023	
Technology	2022	3.59	2022	2022	
Digitalization	2023	3.49	2023	2023	
Greenhouse Gases	2023	3.49	2023	2023	
Gas Emissions	2023	3.49	2023	2023	
Fuzzy Sets	2023	3.49	2023	2023	
Industrial Research	2022	3.21	2022	2023	
Decision Support Systems	2017	3.15	2017	2023	

Note: The red segments indicate periods of strong citation bursts, representing years in which the keyword received significantly increased scholarly attention. The blue segments represent periods of relatively lower citation activity within the observed time range.

Decision Support Systems, indicating shifts toward more technologically intensive and environmentally oriented research foci in recent years. These patterns demonstrate the field's movement toward increasingly data-driven sustainability practices and circularity-oriented innovations.

3.6. Reference Co-Citation Analysis

The intellectual foundation of the field is shaped by an interconnected body of high-impact literature. The co-citation structure shown in Figure 7, consisting of 727 referenced works distributed into 35 clusters, indicates a well-established yet increasingly multidimensional knowledge base. As summarized in Table 7, the most influential works include contributions by Bag (2021), Ahmad (2021), Barney (1991), Benzidia (2021), and Baryannis (2019). These foundational texts integrate topics spanning AI governance, sustainable manufacturing, green supply chain management, risk assessment, and the Resource-Based View (RBV), collectively forming the conceptual scaffolding for current research trajectories. The presence of both classic and contemporary contributions highlights a balanced intellectual structure in which modern advancements in digital and sustainable technologies are grounded in established management theories. This alignment indicates that the field maintains strong theoretical coherence while expanding into increasingly complex and technology-oriented research domains.

4. Discussion

The evolution of research in AI-enabled sustainability and circular agri-food systems indicates a rapid consolidation of knowledge driven by the convergence of digital innovation and environmental governance [32]. The upward trajectory of publications and citations demonstrates that scholars increasingly recognize the strategic importance of artificial intelligence in reshaping food production, distribution, and resource management. Many studies emphasize that the integration of AI-driven analytics has become central to modern sustainability governance in agri-food supply chains, and the observed growth pattern strongly aligns with this statement [33–36]. The surge in scientific attention after 2020 suggests that global disruptions, technological progress, and policy shifts have collectively accelerated the urgency to examine how digital technologies transform sustainability outcomes [37–41].

The author collaboration network further reinforces the multidimensional character of this field. The presence of large clusters with distinct thematic orientations demonstrates that researchers approach AI-enabled sustainability from diverse methodological and disciplinary angles. Influential authors such as Kumar, Haleem, and Javaid represent research communities that systematically build connections between artificial intelligence, operational efficiency, and environmental performance. Their recurrent arguments often highlight that sustainable operations are increasingly dependent

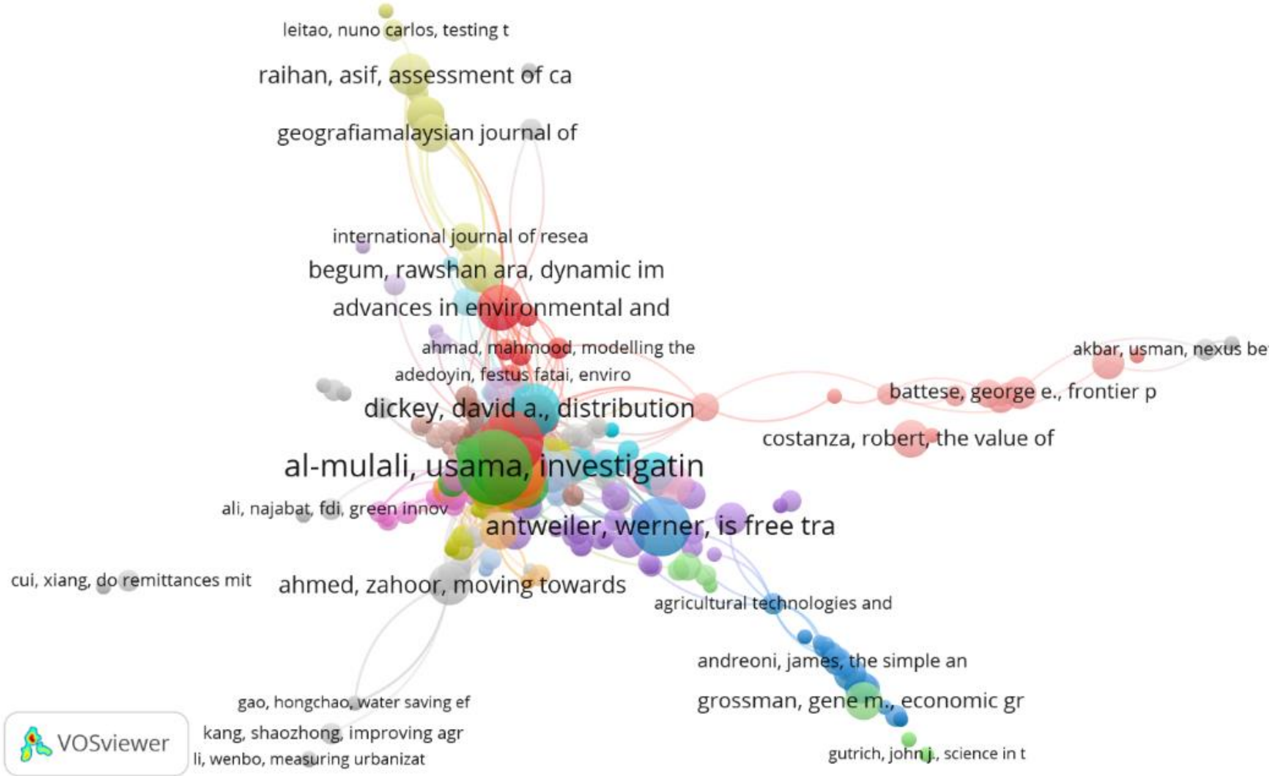

Figure 7. Reference co-citation network in the field of AI governance, sustainable agri-food supply chains, and circular economy studies (items: 727, cluster: 35, links: 2480, TLS: 2639).

Table 7. The top five most co-cited references.

Author	Title	Year	Citations	Cluster
Bag, Surajit	Role of Institutional Pressures and Resources in the Adoption of Big Data Analytics-Powered Artificial Intelligence, Sustainable Manufacturing Practices, and Circular Economy Capabilities, Technological Forecasting and Social Change	2021	20	17
Ahmad, Tanveer	Artificial Intelligence in Sustainable Energy Industry: Status Quo, Challenges and Opportunities	2021	16	5
Barney, Jay Bryan	Firm Resources and Sustained Competitive Advantage	1991	15	5
Benzidia, Smail	The Impact of Big Data Analytics and Artificial Intelligence on Green Supply Chain Process Integration and Hospital Environmental Performance, Technological Forecasting and Social Change	2021	13	19
Baryannis, George	Supply Chain Risk Management and Artificial Intelligence: State of the Art and Future Research Directions	2019	11	26

on the joint development of analytical capabilities, circular economy strategies, and collaborative governance structures, a perspective that is fully reflected in the network patterns described in the Results [42–46]. The dominance of certain authors is not merely a function of publication quantity but also their embeddedness within intellectually cohesive research clusters.

Institutional collaboration reveals a similarly structured landscape, where universities in Europe and Asia serve as focal points for advancing discussions on digital sustainability. Institutions such as London Metropolitan University and Jamia Millia Islamia appear to function as hubs that coordinate multi-actor research efforts around AI governance, green operations, and Industry 4.0-enabled supply chain transformation. Universities increasingly act as knowledge brokers that translate technological capabilities into sustainability transitions, a statement that is consistent with the organizational clusters identified in this study [47, 48]. The strong representation of Asian institutions, combined with European academic leadership, suggests a global research architecture informed by both technological advancement and sustainability imperatives.

At the country level, the distribution of influence points to a structured but highly internationalized research system. China dominates in publication output, India leads in citation impact, and the United Kingdom occupies a central role in global collaboration networks. This triadic configuration reflects asymmetries in research resources, policy priorities, and technological penetration, while also illustrating the interconnectedness of sustainability research across regions. Global sustainability transitions depend on cross-border knowledge integration supported by advanced digital infrastructures and the patterns identified here demonstrate that agri-food sustainability research is inherently global rather than nationally confined [49, 50].

The keyword co-occurrence patterns reveal a coherent thematic landscape that revolves around artificial intelligence, machine learning, sustainability, Industry 4.0, and circular economy principles. These themes emphasize a paradigm shift where digital tools are viewed not simply as operational enhancers but as foundational mechanisms for achieving circularity and resource efficiency. The clustering of keywords such as waste valorization, green logistics, digitalization, and environmental efficiency indicates that scholars increasingly examine the transformative potential of data-driven decision systems. A growing number of papers assert that "digital intelligence is emerging as a core enabler of circularity in agri-food supply chains," a claim that is consistent with the burst keyword analysis [51, 52]. The prominence of terms like environmental economics and decision support systems suggests a movement toward more analytical and quantitatively grounded research approaches.

A deeper examination of the identified clusters reveals that each thematic group represents a distinct yet interconnected research orientation within the field. Clusters centered on artificial intelligence and machine learning predominantly emphasize data-driven decision making, predictive analytics, and optimization of agri-food supply chain processes, which aligns with prior studies highlighting the role of advanced analytics in enhancing sustainability performance and operational resilience [53]. Other clusters related to circular economy and environmental efficiency focus on waste valorization, resource optimization, and emissions reduction, reflecting established discussions on circular supply chain transitions and green operations management. The presence of clusters associated with Industry 4.0 and digitalization further indicates that scholars increasingly frame sustainability challenges through the lens of cyber-physical systems, automation, and intelligent governance, reinforcing arguments that digital transformation serves as an enabling infrastructure for sustainable and circular agri-food systems [54]. Together, these clusters illustrate a layered knowledge structure in which technological capabilities, governance mechanisms, and environmental objectives are conceptually integrated rather than treated as isolated research streams.

The reference co-citation network highlights the intellectual underpinnings of the field. Foundational management theories, particularly the Resource-Based View (Barney, 1991), continue to serve as conceptual anchors for understanding how digital capabilities contribute to organizational advantage and sustainability performance. Contemporary works by Bag, Ahmad, Benzidia, and Baryannis extend this foundation by integrating digital transformation frameworks, risk analytics, and green operations management. This combination supports the emerging view that "the convergence of classical management theory and digital transformation is reshaping the intellectual architecture of sustainability research." Such intellectual coherence strengthens the theoretical maturity of the field and signals increasing alignment between established theories and new technological developments.

Across the literature, several research gaps become evident. Despite significant advancements, there remains a shortage of empirical studies that rigorously evaluate the measurable impacts of AI on circular agricultural performance and environmental efficiencies. Ethical considerations in AI governance, particularly in the context of food systems, also remain underexplored. Responsible AI governance is essential to ensuring transparency, fairness, and accountability in sustainable food chains [55–57]. Furthermore, while India, China, and Europe dominate research production, contributions from many regions in the Global South remain limited, creating a geographic imbalance in the evidence base. This suggests opportunities for broader inclusion, deeper contextualization, and more diverse methodological approaches.

5. Conclusion

The findings of this study show that research connecting artificial intelligence, sustainability governance, circular economy strategies, and agri-food supply chains is expanding rapidly but remains structurally imbalanced. The field is shaped by concentrated authorship, uneven institutional participation, and limited cross-country collaboration, indicating that the current knowledge base is progressing yet still fragmented. Thematic and burst analyses further reveal that influential developments are increasingly converging toward integrated, technology-driven sustainability solutions, reflecting a shift from isolated research streams toward more interconnected frameworks. Overall, this study provides a structured overview of the intellectual landscape of the field and clarifies how artificial intelligence is shaping sustainability-oriented transformations in agri-food supply chains. Based on these findings, future efforts would benefit from more integrated research designs that bridge technological innovation with governance mechanisms and sustainability objectives.

The implications of these findings are substantial for both academia and practice. Theoretically, the integration of AI with sustainability and circular economy principles offers fertile ground for extending frameworks within operations management, governance, and innovation studies. Practically, firms in agri-food supply chains stand to benefit from adopting advanced analytics, strengthening dynamic capabilities, and cultivating collaborative ecosystems. Numerous studies argue that firms that combine digital capabilities with sustainability-oriented strategies are more likely to achieve operational resilience [10, 58, 59], and the present findings provide empirical backing for this claim. Policymakers may also draw insights regarding the need to design governance structures that facilitate data sharing, encourage responsible AI adoption, and support circular resource flows.

This study is not without limitations. First, the exclusive reliance on the Scopus database ensures consistency of bibliographic metadata but may not capture the full breadth of global research, particularly studies indexed in other databases or regional outlets. Second, the specificity of the keyword query may influence the inclusion or exclusion of certain publications. Third, bibliometric techniques such as co-authorship analysis, keyword co-occurrence, clustering, and co-citation analysis emphasize structural relationships among publications but cannot fully capture the semantic depth or contextual nuances of individual studies. As a result, the interpretation of thematic clusters relies on aggregated publication patterns rather than detailed content analysis, which may limit the granularity of theoretical insights. Finally, the findings are primarily situated within the agri-food sector, and their generalizability to other industries may be constrained. Nevertheless, these limitations do not undermine the value of the study; rather, they define the contextual boundaries within which the results should be interpreted.

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