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Global Research Trends and Knowledge Structure of Integrated Sustainable Waste Management: Insights from a Decade of Bibliometric Evidence

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ABSTRACT: The growing complexity of waste governance has positioned Integrated Sustainable Waste Management (ISWM) as an important research domain within global sustainability studies. Although scholarly attention to ISWM continues to increase, a consolidated understanding of publication trends, disciplinary coverage, country contributions, and thematic structures remains limited. This study conducts a bibliometric analysis of ISWM research indexed in Scopus from 2015 to 2025. A total of 465 documents were retrieved using predefined search criteria. The data were cleaned and harmonized using Bibliomagika and OpenRefine, while VOSviewer was used to visualize bibliometric patterns. The results show that journal articles dominate the dataset, accounting for 55.70% of publications, followed by conference papers (20.22%) and book chapters (12.26%). English is the predominant publication language, representing 98.49% of the dataset, whereas Chinese and Korean each account for 0.43%, and German, Italian, and Persian each represent 0.22%. India records the highest publication output with 298 documents, followed by Indonesia (149) and Italy (98). Environmental Science is the leading subject area, accounting for 64.09% of publications, followed by Engineering (29.46%) and Energy (26.67%), with additional contributions from Social Sciences, Computer Science, Business, Economics, Agriculture, Chemistry, Medicine, and other fields. Keyword analysis identifies *Waste Management* as the most frequently occurring term (104 documents), followed by *Sustainability* (55 documents). These findings indicate that ISWM has evolved into an interdisciplinary field, with Environmental Science, Engineering, and Energy forming its primary knowledge base.

KEYWORDS: Integrated sustainable waste management; bibliometric analysis; waste management; sustainability; research trends

1. Introduction

Global waste generation has become an escalating environmental and governance challenge, as annual municipal solid waste (MSW) production already exceeds 2 billion tons and is projected to rise substantially by 2050. The composition of MSW further illustrates the scale of this challenge, with organic residues and recyclable materials forming a large proportion of

global waste streams. Alongside this increase, plastic pollution has intensified, placing additional pressure on recycling systems and weakening the transition toward a circular economy [1]. Poorly managed plastic waste not only disrupts material recovery but also contributes to toxic emissions through open burning, creates risks to public health, and accelerates the spread of microplastics in marine ecosystems [2]. These interconnected problems are closely linked to sustainable development because waste affects environmental quality, social well-being, and economic resilience. Addressing these challenges requires more than fragmented disposal-oriented practices; it calls for integrated and sustainable waste management approaches that coordinate environmental protection, resource recovery, stakeholder participation, and long-term sustainability [3].

ISW) is a multidimensional approach that integrates stakeholders, waste system elements, and strategic aspects to support more sustainable waste governance. ISWM recognizes that waste management cannot be addressed solely through technical disposal solutions but requires coordination among government institutions, industry actors, communities, and other stakeholders with diverse roles and interests [3−5]. Theoretically, ISWM provides an integrative framework by linking operational processes such as collection, sorting, reduction, reuse, recycling, recovery, and final disposal with broader financial, economic, environmental, political, institutional, socio-cultural, and technical dimensions [1], [6]. Practically, this framework supports policy design, institutional coordination, resource efficiency, recycling systems, and community participation while encouraging waste prevention and material recovery [7]. Its relevance has increased as circular economy principles increasingly emphasize waste elimination, material circulation, and the regeneration of natural systems [3]. Consequently, ISWM provides a comprehensive foundation for integrating environmental protection, social welfare, and economic resilience, while its growing intersection with the circular economy, governance innovation, and sustainable development has expanded the research landscape that warrants more systematic investigation.

ISWM has progressively evolved from a disposal-oriented model into an integrated, circular, technology-supported, and governance-oriented framework. Initially driven by concerns over the environmental consequences of uncontrolled waste disposal, ISWM has moved beyond end-of-pipe practices toward strategies that prioritize waste prevention, reduction, reuse, recycling, resource recovery, and long-term sustainability [8]. This transformation has been reinforced by the increasing adoption of digital technologies, data-driven monitoring systems, recycling innovations, circular economy principles, and policy instruments designed to support more adaptive waste governance. Across different national and local contexts, ISWM implementation also depends on institutional coordination, public–private collaboration, infrastructure readiness, community participation, and policies that respond to local socio-economic conditions [4−9]. These developments have expanded ISWM research into multiple domains, including environmental management, urban governance, public policy, technological innovation, community-based waste practices, and circular economy studies. Consequently, the literature has become increasingly multidisciplinary and dispersed across diverse themes, methods, geographical settings, and policy contexts. This growing complexity warrants systematic bibliometric mapping to clarify the evolution of ISWM research, identify dominant and emerging themes, and reveal how major knowledge areas within the field are intellectually connected [10].

The implementation of Integrated Sustainable Waste Management (ISWM) remains a complex practical and policy challenge because its effectiveness depends not only on technical waste-handling capacity but also on governance quality, institutional coordination, and public participation. In many contexts, limited environmental awareness, low community engagement, inadequate infrastructure, weak policy enforcement, and constrained funding continue to hinder recycling, waste reduction, and resource recovery initiatives [9, 11]. These challenges are particularly evident in regions where waste systems still rely on open dumping or poorly managed landfills, reflecting broader gaps in infrastructure readiness, regulatory capacity, and socio-cultural acceptance of sustainable waste practices [12, 13]. At the same time, these constraints have created new opportunities for ISWM development through digital waste management systems, recycling innovation, data-driven monitoring, public–private collaboration, and stronger community-based participation. As governments, industries, and civil society increasingly pursue more adaptive and inclusive waste governance models, ISWM has become a more diverse and policy-oriented field of inquiry. These implementation dynamics highlight the need to understand how practical, technological, institutional, and policy-related themes have evolved within the ISWM literature.

Previous review and bibliometric studies have contributed significantly to understanding the development of sustainable waste management and waste management within the circular economy framework. One previous study examined sustainable waste management research published between 2010 and 2021 using bibliometric and visual mapping techniques [14]. The study identified publication trends, influential authors, leading countries, dominant keywords, and relationships among publications, with VOSviewer used to visualize collaboration patterns and research trends. Similarly, another study provided a broad scientific overview of waste management within the circular economy framework from 2001 to 2020 by combining bibliometric analysis, text mining, and content analysis [15]. Its findings highlighted the expansion of waste management research, particularly in relation to the circular economy, plastic waste governance, and global collaboration. Although these studies provide valuable insights, their analytical scope is broader than ISWM as a distinct intellectual domain. Studies focusing on sustainable waste management or waste management within the circular economy do not fully capture how ISWM has evolved through its own conceptual, institutional, technological, and governance-related trajectories. Moreover, limited attention has been devoted to the intellectual structure and thematic evolution of ISWM research, particularly through the combined application of co-authorship, keyword co-occurrence, and collaboration network analyses.

Although bibliometric analysis has been increasingly used to identify research trends, thematic directions, and knowledge development in waste governance [1, 16], the existing literature has not yet sufficiently clarified how ISWM has evolved as a distinct and structured body of knowledge. Specifically, it remains unclear how scientific production, influential authors, leading institutions, productive countries, impactful journals, collaboration networks, dominant themes, and emerging topics have shaped the development of ISWM research. Furthermore, previous studies have not comprehensively integrated bibliometric techniques such as co-authorship analysis, keyword co-occurrence analysis, thematic evolution, and collaboration network analysis to explain the intellectual and thematic structure of the field. To address these gaps, this study maps the scientific production, influential authors, leading institutions, productive countries, impactful journals, collaboration networks, intellectual

structure, and emerging thematic trends in ISWM research published between 2015 and 2025 using the Scopus database. Specifically, this study addresses the following research questions: (1) How has the annual scientific production of ISWM research evolved over time? (2) Who are the most influential authors, institutions, and countries in ISWM research? (3) What are the most productive and impactful journals in the field? (4) How are collaboration networks structured among authors, institutions, and countries? (5) What are the dominant and emerging themes in ISWM research?

This study contributes to the ISWM literature in several ways. Theoretically, it provides a comprehensive map of ISWM research by clarifying how the field has developed as a distinct knowledge domain and by identifying its major knowledge clusters, thematic structures, and intellectual linkages. Practically, the study offers evidence-based insights for practitioners, policymakers, government agencies, industry actors, and other stakeholders seeking to understand the evolution of ISWM knowledge and translate it into more integrated, adaptive, and sustainable waste management strategies. By revealing dominant themes, emerging topics, and underexplored areas, this study also supports the development of a future research agenda that is more responsive to technological innovation, circular economy transitions, governance challenges, and sustainability-oriented policy needs.

2. Materials and Methods

This study employed a bibliometric analysis with a quantitative approach to map the development of research on Integrated Sustainable Waste Management (ISWM). Bibliometric analysis was considered appropriate because it enables the systematic examination of publication trends, thematic structures, intellectual linkages, and collaboration patterns within a specific research domain. In this study, the bibliometric procedure was designed to identify the growth of ISWM-related publications, dominant research topics, scholarly networks, and knowledge clusters. The methodological workflow consisted of four main stages: data collection, data processing and harmonization, data visualization and interpretation, and documentation of the research flow.

2.1. Data Collection.

The data were retrieved from the Scopus database on 1 June 2025. Scopus was selected because it provides broad coverage of peer-reviewed publications, structured bibliographic metadata, and compatibility with bibliometric analysis tools such as VOSviewer and biblioMagika®. Scopus provides metadata related to authors, titles, abstracts, keywords, affiliations, countries, source titles, citations, and publication years, making it suitable for mapping scientific production and knowledge networks in bibliometric studies [17]. Its advanced search function also allows researchers to apply filters based on keywords, publication years, document types, and subject areas, thereby supporting a more transparent and replicable data collection process [18].

The search was conducted using the following keyword combination: TITLE-ABS-KEY (“Integrated Sustainable Waste Management” OR “Sustainable Waste Management” OR “Integrated Waste Management” OR “Sustainable Waste Strategies”). The search covered publications from 2015 to 2025 and yielded 465 documents. This publication period was selected to capture the development of Integrated Sustainable Waste Management (ISWM) research over the most recent decade and to provide an updated overview of publication trends,

citation patterns, collaboration networks, and thematic development in the field. The year 2015 was chosen as the starting point because sustainability-oriented waste management research became increasingly relevant in line with the global sustainable development agenda. The year 2025 was used as the endpoint because the data retrieval was conducted on 1 June 2025; therefore, the dataset reflects publications indexed in Scopus up to the retrieval date.

For transparency and replicability, the complete search string was formulated as follows: TITLE-ABS-KEY (“Integrated Sustainable Waste Management” OR “Sustainable Waste Management” OR “Integrated Waste Management” OR “Sustainable Waste Strategies”) AND PUBYEAR > 2015 AND PUBYEAR < 2026. No additional restrictions were applied to document type, language, or subject area. The retrieved metadata were exported from Scopus in CSV format and subsequently processed using biblioMagika® and VOSviewer for bibliometric analysis.

2.2. Data Processing.

After data collection, the exported Scopus files, including *scopus export refine value.csv* and *scopus.csv*, were processed and harmonized before bibliometric analysis. Data cleaning was carried out using Bibliomagika, BiblioMagika@split, and OpenRefine to improve the consistency and reliability of the bibliographic dataset [19]. This stage was important because raw bibliometric metadata often contain inconsistencies in author names, keyword spelling, institutional affiliations, country names, and source titles. The data processing procedure involved several steps. First, the exported Scopus records were checked for duplicate entries and incomplete bibliographic information. Second, author keywords, source titles, institutional names, and country names were reviewed to identify spelling variations and inconsistent writing formats. Third, keywords with similar meanings or different spellings were harmonized where appropriate to reduce fragmentation in the keyword co-occurrence analysis. For example, terms referring to the same concept were standardized to ensure that they were counted as a single analytical unit. When necessary, a thesaurus file was prepared to support keyword standardization in VOSviewer.

Bibliomagika was used to organize the metadata and generate descriptive bibliometric indicators, including document types, source types, publication languages, subject areas, annual publication trends, most productive authors, institutions, countries, publication sources, and frequently cited documents. The cleaned dataset was also used to calculate frequency distributions and citation-related indicators. OpenRefine supported the manual checking and correction of inconsistent bibliographic entries, while BiblioMagika@split was used to separate and structure metadata fields that contained multiple values, such as authors, affiliations, countries, and keywords. Through this process, the dataset became more consistent and suitable for bibliometric mapping. The final cleaned and harmonized dataset consisted of 465 documents. This dataset served as the main corpus for descriptive bibliometric analysis and network visualization.

2.3. Data Visualization and Interpretation.

After the data cleaning and harmonization process was completed, bibliometric visualization was conducted using VOSviewer and supported by Bibliomagika. VOSviewer was used because it allows the construction and visualization of bibliometric networks based on relationships among keywords, authors, institutions, countries, and other bibliographic

elements. In this study, the visualization focused on two main types of analysis: keyword co-occurrence analysis and co-authorship analysis by country. These analyses were selected to identify the thematic structure of ISWM research and to examine patterns of international collaboration. For the keyword co-occurrence analysis, the unit of analysis was author keywords extracted from the Scopus dataset. The counting method used was fractional counting, with a minimum occurrence threshold of 5 occurrences per keyword. After applying this threshold, 42 keywords met the criteria and were included in the network visualization. The resulting keyword map was used to identify dominant research themes, thematic clusters, and relationships among key concepts in ISWM research. In the VOSviewer map, larger nodes indicate keywords with higher occurrence, thicker links indicate stronger co-occurrence relationships, shorter distances between nodes indicate closer thematic association, and different colors represent clusters generated by the VOSviewer algorithm. For the co-authorship analysis by country, the unit of analysis was country, and the counting method used was fractional counting. A minimum threshold of 10 publications per country was applied to focus the visualization on countries with substantial contributions to ISWM research. The resulting collaboration map was interpreted based on node size, link strength, and the position of countries within the network. Larger nodes represent countries with greater publication contributions, while links between nodes indicate collaborative relationships among countries.

Bibliomagika was used to support the descriptive part of the analysis by generating tables and frequency-based summaries, including citation metrics, document profiles, publication trends, source distribution, country contribution, and highly cited documents. VOSviewer was then used to provide network-based visualization that could reveal patterns not easily captured through descriptive tables alone. The interpretation of the bibliometric maps combined quantitative network indicators with conceptual reading of the clusters. This approach was used because bibliometric visualization provides structural patterns, but the meaning of each cluster still requires interpretation based on the context of Integrated Sustainable Waste Management research. Therefore, the clusters were not interpreted only by color or node size, but also by examining the main keywords and their conceptual relationships within the ISWM literature.

2.4. Research Flow and Methodological Boundaries.

The research procedure followed a PRISMA-style logic consisting of identification, screening, eligibility, and inclusion, as illustrated in Figure 1. In the identification stage, 650 records were retrieved from Scopus using the predefined TITLE-ABS-KEY search string. Before screening, 95 records were removed because they did not meet the publication-period criteria or contained incomplete bibliographic metadata. This refinement consisted of 85 records outside the selected publication period, no duplicate records, and 10 records with incomplete metadata. After this initial refinement, 555 records were screened based on their titles, abstracts, and keywords. At this stage, 60 records were excluded because they were not directly related to Integrated Sustainable Waste Management (ISWM) or sustainable waste management. The remaining 495 records were then assessed for eligibility to ensure that they matched the conceptual scope of the study and contained sufficient bibliographic information for analysis. During this stage, 30 additional records were excluded, consisting of 18 records that were not sufficiently focused on the ISWM concept, seven records with non-relevant document types, and five records with incomplete or unsuitable metadata. After completing the selection process, 465 documents were retained as the final corpus for bibliometric analysis, including

descriptive bibliometric analysis, citation analysis, keyword co-occurrence mapping, and collaboration network visualization.

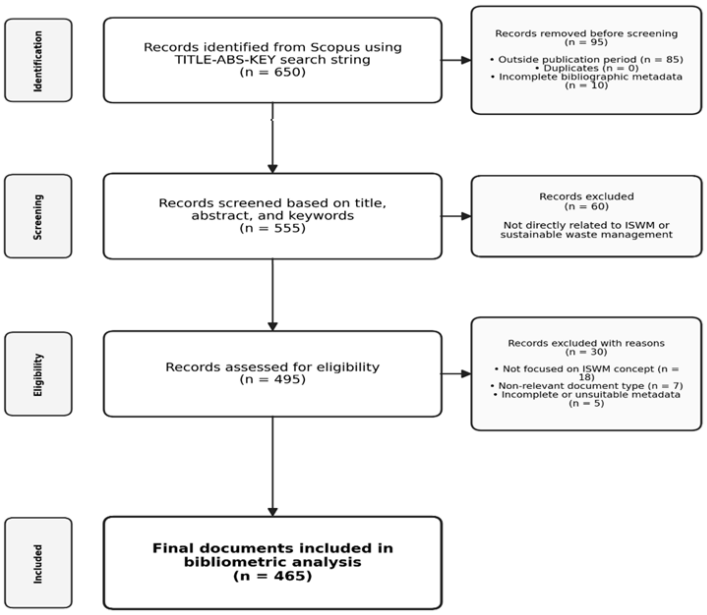

Figure 1. PRISMA Flow Diagram Bibliometric.

Several methodological boundaries should be noted. First, the study relied only on Scopus-indexed publications. Although Scopus provides structured metadata and broad coverage of peer-reviewed literature, relevant studies indexed in Web of Science, ScienceDirect, Dimensions, Google Scholar, regional databases, or non-English sources may not be fully represented. Second, the results depend on the selected search terms and the use of the TITLE-ABS-KEY search field; therefore, alternative keyword combinations could produce a broader or slightly different dataset. Third, bibliometric findings are influenced by citation patterns, indexing practices, and metadata quality. Finally, VOSviewer visualizations show structural relationships among bibliographic elements, but the meaning of each cluster still requires careful conceptual interpretation. Future studies may therefore complement bibliometric mapping with systematic literature review or qualitative content analysis to deepen the interpretation of ISWM research themes.

3. Results and Discussion

3.1. Document Profile.

Table 1 presents the citation metrics of publications related to Integrated Sustainable Waste Management indexed in Scopus from 2015 to 2025. The citation metrics were generated using biblioMagika® by importing CSV files exported from the Scopus database. These indicators provide an overview of the productivity, scholarly influence, and citation impact of the publication scopus. The dataset consists of 465 documents published over a ten-year period from 2015 to 2025. Of these documents, 338 received citations, with a total of 6,873 citations recorded across the dataset. This corresponds to 14.78 citations per document and 20.33 citations per cited publication, indicating that cited documents in this field have generated measurable scholarly attention. The annual mean citation count was 763.67, suggesting that ISWM-related publications have maintained visible academic influence during the period of analysis. The dataset involved 1,745 authors, with an average of 3.75 authors per document.

This pattern indicates that ISWM research is generally collaborative, reflecting the multidisciplinary nature of waste management studies. The citation-based author indicator shows an average of 3.94 citations per author. The h-core documents accumulated 5,942 citations, supporting an h-index value of 41. This means that 41 documents in the dataset received at least 41 citations each, indicating the presence of a relatively strong core of influential publications. The g-index of 70 further suggests that several highly cited documents contributed substantially to the overall citation impact of the field. Meanwhile, the m-index value of 3.727 reflects citation performance relative to the publication period. Overall, these metrics indicate that ISWM research has shown notable productivity, collaborative participation, and measurable scholarly influence.

Table 1. Citation Metrics.

Metric	Value
Publication Years	2015–2025
Total Publications	465
Citable Years	11
Number of Contributing Authors	1,745
Number of Cited Papers	338
Total Citations	6,873
Citations per Paper	14.78
Citations per Cited Paper	20.33
Citations per Year	763.67
Citations per Author	3.94
Authors per Paper	3.75
Citation Sum within h-Core	5,942
h-index	41
g-index	70
m-index	3.727

Source: Generated by the author(s) using biblioMagika® [19]

Document type refers to the classification of publications based on scholarly format, while source type refers to the publication outlet in which the documents appeared. This study identified 11 document types and 5 source types in the dataset Table 2.

Table 2. Document Types.

Document Type	TP	%
Article	259	55.70%
Conference Paper	94	20.22%
Book Chapter	57	12.26%
Review	29	6.24%
Editorial	10	2.15%
Book	6	1.29%
Conference Review	3	0.65%
Erratum	2	0.43%
Note	2	0.43%
Short Survey	2	0.43%
Letter	1	0.22%

Source: Generated by the author(s) using biblioMagika® [19]

Articles represent the largest document type, accounting for 55.70% of the dataset, or 259 documents. This dominance suggests that ISWM research is primarily disseminated through peer-reviewed journal articles, which are commonly used to present mature empirical, conceptual, and review-based contributions. Conference papers form the second-largest

category, with 94 documents or 20.22% of the dataset. Their relatively high proportion indicates that ISWM is also actively discussed in academic forums, where emerging ideas, technological innovations, and applied waste management solutions are often introduced before being developed into full journal publications. Book chapters contributed 57 documents, representing 12.26% of the dataset, while review articles accounted for 29 documents or 6.24%. These document types complement journal articles and conference papers by providing broader conceptual discussions, synthesis of existing knowledge, and contextual perspectives on sustainable waste management. Other document types appeared in smaller proportions, including editorials with 10 documents or 2.15%, books with 6 documents or 1.29%, conference reviews with 3 documents or 0.65%, errata with 2 documents or 0.43%, notes with 2 documents or 0.43%, short surveys with 2 documents or 0.43%, and letters with 1 document or 0.22%. This distribution indicates that ISWM research is mainly structured around journal articles and conference outputs, while other formats play a supplementary role in knowledge dissemination.

Table 3. Subject Area.

Subject Area	TP	%
Environmental Science	298	64.09%
Engineering	137	29.46%
Energy	124	26.67%
Social Sciences	84	18.06%
Computer Science	71	15.27%
Business, Management and Accounting	52	11.18%
Earth and Planetary Sciences	43	9.25%
Economics, Econometrics and Finance	32	6.88%
Agricultural and Biological Sciences	28	6.02%
Chemical Engineering	24	5.16%
Chemistry	23	4.95%
Medicine	19	4.09%
Physics and Astronomy	19	4.09%
Materials Science	16	3.44%
Mathematics	14	3.01%
Biochemistry, Genetics and Molecular Biology	12	2.58%
Decision Sciences	12	2.58%
Multidisciplinary	6	1.29%
Pharmacology, Toxicology and Pharmaceutics	3	0.65%
Arts and Humanities	2	0.43%
Health Professions	2	0.43%
Immunology and Microbiology	2	0.43%
Nursing	2	0.43%
Dentistry	1	0.22%

Source: Generated by the author(s) using biblioMagika® [19].

The disciplinary distribution presented in Table 3 indicates that ISWM research is concentrated in subject areas closely related to environmental systems, engineering solutions, and sustainability-oriented resource management. Environmental Science accounts for the largest share of publications at 64.09%, confirming its role as the core disciplinary foundation of ISWM research. Engineering follows with 29.46%, while Energy contributes 26.67%, suggesting that the field is strongly connected to infrastructure design, waste treatment technologies, energy recovery, and resource efficiency. Beyond these dominant subject areas, ISWM research also extends into Social Sciences at 18.06%, Computer Science at 15.27%, Business, Management and Accounting at 11.18%, Earth and Planetary Sciences at 9.25%, Economics, Econometrics and Finance at 6.88%, Agricultural and Biological Sciences at 6.02%, Chemical Engineering at 5.16%, Chemistry at 4.95%, Medicine and Physics at 4.09%, Materials Science at 3.44%, Mathematics at 3.01%, Biochemistry, Genetics and Molecular

Biology at 2.58%, and Decision Sciences at 2.58%. Because Scopus may assign one publication to more than one subject area, the total percentage across subject categories may exceed 100%. This distribution demonstrates the interdisciplinary character of ISWM research. Environmental Science, Engineering, and Energy form the core technical and environmental foundation of the field, while Social Sciences, Business and Management, Economics, and Computer Science indicate the growing relevance of governance, policy, digital systems, managerial strategies, and socio-economic dimensions. Therefore, ISWM can be understood not only as an environmental management topic but also as a multidisciplinary research domain that integrates technical, institutional, economic, computational, and social perspectives in addressing sustainable waste governance.

3.2. Publication Trends.

Table 4 presents the annual distribution of publications on ISWM from 2015 to 2025. Overall, the publication trend shows a clear upward movement, although the growth pattern was not entirely linear. In the early period, publication output increased from 18 documents in 2015 to 24 documents in 2016, followed by a slight fluctuation from 28 documents in 2017 to 25 documents in 2018. This early pattern suggests that ISWM research was still developing and had not yet reached a stable expansion phase. After this fluctuation, the number of publications increased more consistently and reached its highest point in 2025, with 132 documents, representing 28.39% of the total publications. Across the 2015–2025 period, 1,745 distinct authors contributed to the publication corpus, indicating broad scholarly participation in the development of ISWM research.

Table 4. Annual Research Output and Citation Metrics.

Year	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
2015	8	46	12	356	44.5	29.67	8	11	0.98
2016	18	62	14	1102	61.22	78.71	11	18	1.000
2017	24	96	19	349	14.54	18.37	9	18	0.900
2018	28	105	24	1066	38.07	44.42	16	28	1.778
2019	25	69	20	546	21.84	27.30	9	23	1.125
2020	31	90	26	425	13.71	16.35	12	20	1.714
2021	34	123	25	582	17.12	23.28	13	24	2.167
2022	53	220	49	1237	23.34	25.24	17	34	3.400
2023	50	188	39	645	12.90	16.54	15	24	3.750
2024	70	259	54	590	8.43	10.93	12	22	4.000
2025	132	533	68	331	2.51	4.87	8	13	4.000
Total	465	1745	338	6873	14.78	20.33	41	70	3.727

Note: TP=total number of publications; NCA=number of contributing authors; NCP=number of cited
Source: Generated by the author(s) using biblioMagika® [19]

Figure 2 presents the cumulative growth pattern of ISWM publications from 2015 to 2025. The trend is represented by the quadratic equation $y = 4.7235x^2 - 7.0311x + 35.317$, with a coefficient of determination of $R^2 = 0.9877$. The high R^2 value indicates a strong model fit between the cumulative publication trend and the quadratic growth pattern. Because the model is quadratic rather than exponential, the publication trajectory is more accurately described as an accelerated or non-linear upward trend. This pattern suggests that ISWM research has gained increasing scholarly attention over the last decade, particularly in recent years.

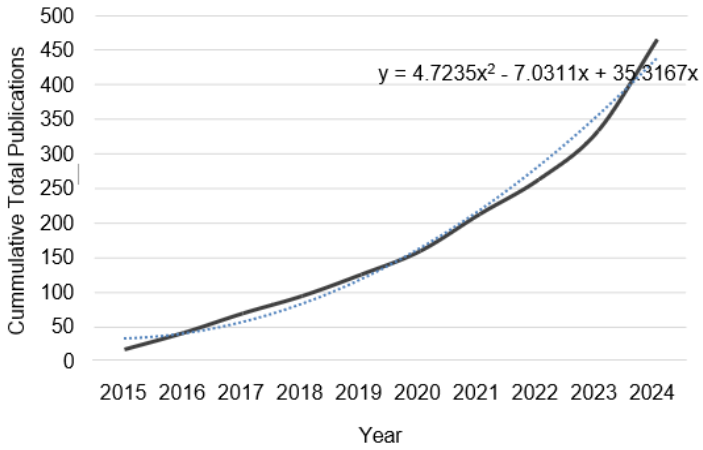

Figure 2. Publication Growth.
Source: Processed using biblioMagika®[19].

3.3. Author Productivity.

Table 5 presents the most productive authors in the field of ISWM, based on authors with at least two scholarly contributions. The results show that Irabien, Angel; Loizidou, Maria D.; and Moustakas, Konstantinos G. are the three most productive authors in this dataset. Their publication activity indicates sustained scholarly engagement with ISWM-related research topics. It is important to distinguish author productivity from author influence. The ranking in Table 5 reflects publication volume, not necessarily citation impact. Therefore, while these authors can be identified as the most active contributors, further citation-based indicators would be required to determine whether their publications are also the most influential within the field.

Table 5. Most Productive Author.

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Irabien, Angel	University of Cantabria	Spain	5	2	127	25.40	63.50	2	5	0.200
Loizidou, Maria D.	National Technical University of Athens	Greece	4	4	34	8.50	8.50	2	4	0.250
Moustakas, Konstantinos G.	National Technical University of Athens	Greece	4	4	34	8.50	8.50	2	4	0.250
Orji, Rita	Dalhousie University	Canada	3	3	29	9.67	9.67	2	3	0.333
Nkwo, Makuochi	Ebonyi State University	Nigeria	3	3	29	9.67	9.67	2	3	0.333
Banford, Anthony William	National Nuclear Laboratory	United Kingdom	3	2	34	11.33	17.00	2	3	0.222
Cheela, Venkata Ravi Sankar	MVGR College of Engineering (A)()	India	3	3	208	69.33	69.33	3	3	0.600
Suruliraj, Banuchitra	Dalhousie University	Canada	3	3	29	9.67	9.67	2	3	0.333
Aslanidis, Panagiotis Stavros C.	University of Thessaly	Greece	3	2	47	15.67	23.50	2	3	0.667
Tudor, Terry	The University of Northampton	United Kingdom	3	3	50	16.67	16.67	3	3	0.273
Halkos, George Emmanuel	University of Thessaly	Greece	3	2	47	15.67	23.50	2	3	0.667
Dominguez-Ramos, Antonio	University of Cantabria	Spain	3	1	123	41.00	123.00	1	3	0.111
Cobo, Selene	University of Cantabria	Spain	3	1	123	41.00	123.00	1	3	0.111

Full Name	Current Affiliation	Country	TP	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Deja, Agnieszka	Maritime University of Szczecin	Poland	3	3	38	12.67	12.67	2	3	0.286
Hasan, Mehedi	Bangladesh University of Engineering and Technology	Bangladesh	2	2	12	6.00	6.00	2	2	0.667
Xin, Jia	Ocean University of China	China	2	2	10	5.00	5.00	2	2	0.400
Barlaz, Morton A.	North Carolina State University	United States	2	1	128	64.00	128.00	1	2	0.091
Amankwah-Amoah, Joseph	University of Kent	United Kingdom	2	2	9	4.50	4.50	2	2	0.400
Hazra, Dipak Kumar	Bidhan Chandra Krishi Viswavidyalaya	India	2	2	13	6.50	6.50	1	2	0.200
Jarvis, Richard	National Nuclear Laboratory	United Kingdom	2	2	34	17.00	17.00	2	2	0.222
Hashem, Md. Abul	Khulna University of Engineering & Technology	Bangladesh	2	2	12	6.00	6.00	2	2	0.667
Margallo, María	University of Cantabria	Spain	2	1	4	2.00	4.00	1	2	0.100
Domingo, Jose Luis	Universitat Rovira i Virgili	Spain	2	2	101	50.50	50.50	2	2	0.182
Joseph, Robert A.	Idaho National Laboratory	United States	2	0	0	0.00	0.00	0	0	0.000
Dzhuguryan, Tygran	Maritime University of Szczecin	Poland	2	2	36	18.00	18.00	2	2	0.286

Note: TP=total number of publications; NCA=number oc contributing authos; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index, m=m-index. Source: Generated by the author(s) using biblioMagika®[19]

3.4. Institutional Productivity Analysis.

Table 6 presents institutional contribution to ISWM research. Ghent University, Amity University, Universiti Kebangsaan Malaysia, and the National Technical University of Athens recorded the highest publication volume, with 4 publications each. This indicates that institutional productivity in ISWM research is relatively dispersed, with no single institution overwhelmingly dominating the publication landscape. The results also show a distinction between quantity-based contribution and citation-based influence. Although Curtin University produced fewer publications than the most productive institutions, it recorded the highest citation impact, with an average of 98.00 citations per manuscript and a total of 196 citations. This suggests that institutional influence in ISWM research should not be assessed only by publication count, because institutions with smaller outputs may still contribute highly cited and influential studies.

Table 6. Most Productive Institution.

Institution Name	Country	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Ghent University	Belgium	4	6	4	80	20.00	20.00	3	4	0.273
Amity University	India	4	11	0	0	0.00	0.00	0	0	0.000
Universiti Kebangsaan Malaysia	Malaysia	4	7	4	44	11.00	11.00	3	4	0.375
National Technical University of Athens	Greece	4	8	4	34	8.50	8.50	2	4	0.250
Diponegoro University	Indonesia	3	9	2	9	3.00	4.50	2	3	0.250

Institution Name	Country	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Khulna University of Engineering & Technology	Bangladesh	3	11	3	159	53.00	53.00	3	3	0.600
University of Glasgow	United Kingdom	3	4	3	17	5.67	5.67	3	3	0.600
Maritime University of Szczecin	Poland	3	6	3	38	12.67	12.67	2	3	0.286
University of Thessaly	Greece	3	6	2	47	15.67	23.50	2	3	0.667
Ebonyi State University	Nigeria	3	3	3	29	9.67	9.67	2	3	0.333
Dalhousie University	Canada	3	7	3	29	9.67	9.67	2	3	0.333
Islamic Azad University	Iran	3	10	2	92	30.67	46.00	2	3	0.286
Kasetsart University	Thailand	3	10	0	0	0.00	0.00	0	0	0.000
University of Novi Sad	Serbia	3	9	3	28	9.33	9.33	3	3	0.300
Universitas Indonesia	Indonesia	3	14	3	24	8.00	8.00	2	3	0.400
Amrita Vishwa Vidyapeetham	India	2	10	2	10	5.00	5.00	1	2	0.167
CHRIST (Deemed to be University)	India	2	2	1	3	1.50	3.00	1	1	0.125
Hasanuddin University	Indonesia	2	6	2	5	2.50	2.50	1	2	0.143
Tokyo University of Agriculture and Technology	Japan	2	3	1	2	1.00	2.00	1	1	0.500
Chitkara University	India	2	7	0	0	0.00	0.00	0	0	0.000
Shri Ramswaroop Memorial University	India	2	5	2	10	5.00	5.00	1	2	0.250
Global Research Institute and Training Center	India	2	2	2	4	2.00	2.00	2	2	0.667
National Dong Hwa University	Taiwan	2	2	2	18	9.00	9.00	2	2	1.000
Moscow State University of Civil Engineering	Russian Federation	2	2	1	3	1.50	3.00	1	1	0.167
Curtin University	Australia	2	3	2	196	98.00	98.00	2	2	0.400

Note: TP=total number of publications; NCA=number of contribution authors; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index, m=m-index. Source: Generated by the author(s) using biblioMagika® [19].

3.5. Publication by Country.

Table 7 presents the ten leading countries contributing to ISWM research based on publication output and citation indicators. India ranked first, with 298 publications and a total of 3,301 citations, indicating its strong productivity and citation presence in the field. Indonesia ranked second with 149 publications, followed by Italy with 98 publications. These findings show that ISWM research has attracted substantial scholarly attention from both developing and developed countries. The results also reveal a difference between publication productivity and citation impact. While India, Indonesia, and Italy showed high publication volumes, the United

Kingdom recorded the highest average citations per publication, with 40.10 citations per document, despite having 68 publications. This pattern suggests that country-level contribution should be interpreted through more than one indicator. Publication count reflects productivity, whereas average citations per publication reflects citation-based impact. Therefore, rather than concluding that developed countries dominate the field, the results indicate a more nuanced pattern: countries such as India and Indonesia contribute strongly in terms of publication volume, while the United Kingdom demonstrates higher citation impact.

Table 7. Most Productive Countries.

Country	TP	NCA	NCP	TC	C/P	C/CP	*h*	*g*	*m*
India	298	298	204	3301	11.08	16.18	30	57	2.727
Indonesia	149	149	81	463	3.11	5.72	13	21	1.625
Italy	98	98	81	2488	25.39	30.72	29	49	2.636
United States	78	78	34	1075	13.78	31.62	15	32	1.364
Malaysia	78	78	58	1050	13.46	18.10	21	32	2.100
China	73	73	69	1478	20.25	21.42	23	38	2.091
United Kingdom	68	68	59	2727	40.10	46.22	28	52	2.545
Spain	60	60	42	1188	19.80	28.29	16	34	1.455
Iran	45	45	35	1439	31.98	41.11	20	37	2.500
Pakistan	44	44	33	270	6.14	8.18	10	16	1.429
South Korea	40	40	30	272	6.80	9.07	9	16	1.000
Poland	40	40	26	313	7.83	12.04	9	17	0.900
Bangladesh	39	39	36	325	8.33	9.03	8	18	1.333
Nigeria	34	34	32	649	19.09	20.28	8	25	0.889
Saudi Arabia	33	33	33	836	25.33	25.33	16	28	2.000
Japan	32	32	27	326	10.19	12.07	12	18	1.091
Thailand	30	30	14	350	11.67	25.00	7	18	0.636
Sweden	28	28	10	198	7.07	19.80	5	14	0.455
Turkey	24	24	23	295	12.29	12.83	10	17	1.000
Germany	23	23	19	762	33.13	40.11	11	23	1.000
Greece	22	22	20	282	12.82	14.10	9	16	0.900
South Africa	21	21	14	642	30.57	45.86	10	21	1.111
Egypt	21	21	21	862	41.05	41.05	11	21	1.000
Brazil	21	21	20	411	19.57	20.55	9	20	1.000
Australia	20	20	15	384	19.20	25.60	9	19	0.900

Figure 3 visualizes the country collaboration network using VOSviewer, based on countries with at least ten publications and the fractional counting method. In this map, larger nodes indicate countries with greater publication contributions, while links represent collaborative relationships among countries. India appears as the largest node, confirming its strong publication contribution to ISWM research. Indonesia and Italy also occupy visible positions in the network, suggesting their active participation in international research activity. The United States, China, Malaysia, and the United Kingdom form additional collaborative linkages, indicating that ISWM research is supported by cross-country scholarly interaction.However, the collaboration map should be interpreted cautiously. Without additional indicators such as total link strength, cluster membership, and the number of collaborative links, it is not possible to make strong claims about which countries lead global collaboration. The figure nevertheless indicates that ISWM research has developed through

international linkages involving both Global South and Global North countries, with different countries contributing through publication volume, citation impact, or collaborative positioning.

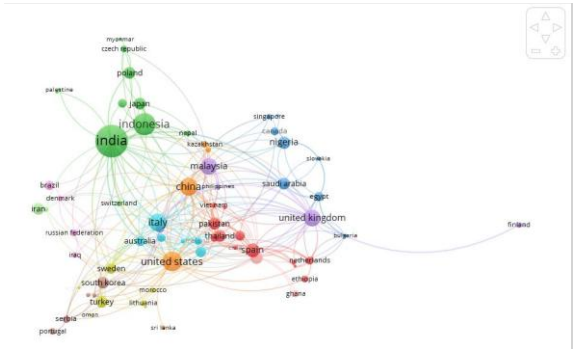

Figure 3. Visualization map of author collaboration networks by country with at least ten publications.

3.6. Publications by Source Name.

Table 8 presents the most active publication sources in ISWM research. The results show that Sustainability (Switzerland) is the most productive source, with 30 publications, followed by IOP Conference Series: Earth and Environmental Science, with 17 publications. This pattern indicates that ISWM-related studies are disseminated through both peer-reviewed journal outlets and conference-based publication channels. While Sustainability (Switzerland) reflects the strong presence of sustainability-oriented journal publications, IOP Conference Series: Earth and Environmental Science suggests that technical and applied discussions on waste management are also actively shared through conference proceedings.

Table 8. Most Active Source Tittle.

Source Title	TP	NCA	NCP	TC	C/P	C/CP	h	g	m
Sustainability (Switzerland)	30	116	28	582	19.40	20.79	13	23	1.182
IOP Conference Series: Earth and Environmental Science	17	62	6	17	1.00	2.83	3	3	0.429
Journal of Cleaner Production	15	65	15	530	35.33	35.33	11	15	1.100
Waste Management and Research	13	55	13	299	23.00	23.00	9	13	0.818
Environmental Science and Pollution Research	12	48	12	149	12.42	12.42	6	12	0.600
Waste Management	11	50	10	1,131	102.82	113.10	9	11	0.818
Journal of Material Cycles and Waste Management	10	34	8	200	20.00	25.00	6	10	0.545
Sustainability (Switzerland)	8	31	7	26	3.25	3.71	2	4	0.667
E3S Web of Conferences	8	21	5	31	3.88	6.20	3	5	0.300
International Journal of Environmental Science and Technology	6	18	5	81	13.50	16.20	4	6	1.000
Resources, Conservation and Recycling	6	22	6	386	64.33	64.33	6	6	0.545
Science of the Total Environment	5	23	5	280	56.00	56.00	4	5	0.364
AIP Conference Proceedings	5	15	3	8	1.60	2.67	1	2	0.125
Heliyon	4	23	4	26	6.50	6.50	2	4	0.400
Proceedings of the International High-Level Radioactive Waste Management Conference, IHLRWM 2022, Embedded with the 2022 ANS Winter Meeting	4	16	0	0	0.00	0.00	0	0	0.000
Lecture Notes in Civil Engineering	4	6	2	2	0.50	1.00	1	1	0.143
Green Energy and Technology	3	10	1	6	2.00	6.00	1	2	0.250
Journal of Engineering Science and Technology	3	14	2	5	1.67	2.50	1	2	0.200
Journal of Physics: Conference Series	2	6	1	1	0.50	1.00	1	1	0.167
Biomass Conversion and Biorefinery	2	11	2	14	7.00	7.00	2	2	0.667

The results also reveal an important distinction between source productivity and citation impact. Although Sustainability (Switzerland) recorded the highest number of publications, Waste Management demonstrated the strongest citation impact, with 102.82 citations per publication and a total of 1,131 citations. This indicates that a source with fewer publications may still exert greater scholarly influence when its articles receive higher citation attention. Similarly, Journal of Cleaner Production and Waste Management and Research showed notable citation impact, with 35.33 and 23.00 citations per publication, respectively. These patterns suggest that ISWM research is shaped not only by the quantity of publications produced by each source, but also by the citation influence of journals that publish highly referenced works in waste management, cleaner production, and sustainability-related research.

3.7. Most Frequently Cited Documents.

Table 9 presents the ten most frequently cited documents in the dataset based on Scopus citation records. In this table, TC refers to the total number of citations received by each document, while C/Y indicates the average number of citations per year. These indicators are used to identify documents with the highest citation impact and to understand the main scholarly references that have shaped research on ISWM and related waste management topics.

Table 9. The 10 Most Frequently Cited Documents.

No.	Title	Source Title	TC	C/Y	Ref.
1	Waste to Energy – Key Element for Sustainable Waste Management	Waste Management	468	39.00	[20]
2	'Wasteaware' Benchmark Indicators for Integrated Sustainable Waste Management in Cities	Waste Management	196	16.33	[4]
3	Sustainable Waste Management: Waste-to-Energy Plant as an Alternative to Landfill	Energy Conversion and Management	177	17.70	[11]
4	Solid Waste Generation and Characterization in the University of Lagos for Sustainable Waste Management	Waste Management	156	15.60	[10]
5	Unlocking the Surge in Demand for Personal Protective Equipment (PPE) and Improvised Face Coverings Arising from the Coronavirus Disease (COVID-19) Pandemic: Implications for Efficacy, Re-use, and Sustainable Waste Management	Science of the Total Environment	153	25.50	[21]
6	Application of Protection Motivation Theory to Investigate Sustainable Waste Management Behaviors	Sustainability (Switzerland)	152	15.20	[8]
7	Zero Waste Approach Towards Sustainable Waste Management	Resources, Environment and Sustainability	147	24.50	[5]
8	Applying Life Cycle Assessment to Support Environmentally Sustainable Waste Management Strategies in Brazil	Resources, Conservation and Recycling	137	15.22	[22]
9	Application of LCA Modelling in Integrated Waste Management	Waste Management	128	18.29	[23]
10	Sustainable Waste Management of Medical Waste in African Developing Countries: A Narrative Review	Waste Management and Research	127	21.17	[9]

Source: Generated by the author(s) using biblioMagika® [19]. Note: TC = total citations; C/Y = citations per year.

The most frequently cited document is “Waste to energy - key element for sustainable waste management” [20], published in *Waste Management*, with 468 total citations and 39.00 citations per year. This result indicates that waste-to-energy has become one of the most influential themes in sustainable waste management research, particularly in relation to energy recovery and the role of waste treatment technologies as alternatives to landfill-based systems. The second most frequently cited document is “Wasteaware” benchmark indicators for integrated sustainable waste management in cities” [4], also published in *Waste Management*, with 196 total citations and 16.33 citations per year. The citation performance of this document

suggests that benchmark indicators and assessment frameworks have become important references for evaluating integrated and sustainable waste management systems, particularly in urban contexts. Beyond the two leading documents, the other highly cited publications indicate that ISWM research has evolved through several interconnected thematic directions. One important stream concerns waste-to-energy, landfill alternatives, and the use of life cycle assessment to evaluate integrated waste management systems, suggesting that technological evaluation, environmental assessment, and system-based thinking have become central elements in the field's citation structure [11, 20, 23]. The scope of the highly cited literature also extends to operational, behavioral, and strategic dimensions of sustainable waste management. Studies on solid waste generation and characterization, sustainable waste management behavior, and zero-waste approaches show that the field is not limited to waste treatment technologies, but also engages with how waste is produced, managed, reduced, and governed in practice [5, 8, 10]. In addition, several highly cited documents reflect the growing importance of context-specific waste management challenges. These include research on personal protective equipment waste during the COVID-19 pandemic, sustainable medical waste management in African developing countries, and the application of life cycle assessment to support environmentally sustainable waste management strategies in Brazil [9, 21, 22].

3.7. Author Keyword Analysis

Author keyword analysis was conducted using VOSviewer to identify the dominant themes and thematic relationships within Integrated Sustainable Waste Management (ISWM) research. In the keyword co-occurrence network, node size represents the frequency of keyword occurrence, link thickness indicates the strength of co-occurrence relationships, the distance between nodes reflects the closeness of thematic association, and colors represent thematic clusters generated by the VOSviewer clustering algorithm. The network is organized around several interconnected keyword clusters, with "waste management," "sustainable waste management," "sustainability," and "circular economy" appearing as central concepts in the field (Figure 4).

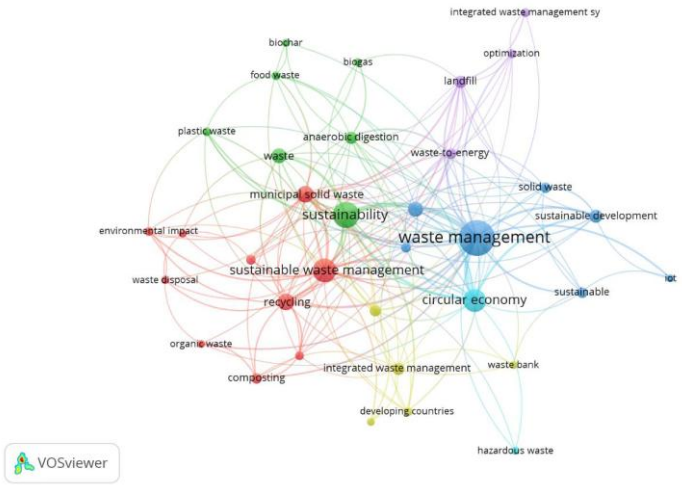

Figure 4. Visualization map of author keywords
Source: Generated by the author(s)

The keyword co-occurrence map reveals five major thematic clusters that collectively describe the structure of ISWM research. The red cluster is organized around "sustainable waste management" and is associated with terms such as "recycling," "composting," "waste disposal," "organic waste," and "environmental impact." This cluster reflects a stream of research concerned with practical waste management activities and their environmental implications. The prominence of "sustainable waste management" within this group suggests that much of the literature pays close attention to how recycling, composting, disposal practices, and organic waste treatment can contribute to more environmentally responsible waste systems. The green cluster is closely related to "sustainability," "municipal solid waste," "waste," "anaerobic digestion," "food waste," "plastic waste," "biochar," and "biogas." These keywords indicate a research orientation toward waste valorization and biological treatment. Rather than viewing waste solely as a disposal problem, this cluster shows that a substantial part of the literature examines how different waste streams can be converted into useful resources. The presence of terms such as anaerobic digestion, biochar, and biogas also highlights the increasing relevance of resource recovery and biologically based treatment approaches in supporting sustainability-oriented waste management.

The blue or turquoise cluster is centered on "waste management" and is linked to "circular economy," "solid waste," "sustainable development," "sustainable," "UK," and "hazardous waste." This cluster can be understood as representing the connection between waste management, circular economy, and sustainable development. The proximity between "waste management" and "circular economy" suggests that recent ISWM research increasingly positions waste management within the broader agenda of resource efficiency and circular material flows. In this sense, waste management is not only discussed as an operational activity, but also as part of a wider sustainability transition. The purple cluster includes keywords such as "waste-to-energy," "landfill," "optimization," and "integrated waste management system." This group reflects a more technology- and system-oriented stream of research. The keywords suggest that scholars in this area are concerned with improving waste treatment systems, optimizing landfill and energy recovery processes, and designing more integrated approaches to waste management. Meanwhile, the yellow cluster, which includes "integrated waste management," "developing countries," and "waste bank," points to research that is more closely connected with local implementation contexts. This cluster emphasizes the importance of community-based waste practices, institutional arrangements, and locally embedded waste governance, particularly in developing-country settings. The keyword structure shows that ISWM research has developed around several interconnected themes: sustainable waste management practices, waste valorization and biological treatment, circular economy-oriented waste management, waste-to-energy and system optimization, and integrated waste management in developing-country contexts. The central position of "waste management," along with its connections to "circular economy," "sustainable waste management," and "sustainability," indicates that the field has moved beyond a narrow focus on waste handling. It has increasingly become a multidisciplinary research area that links environmental management, resource recovery, circular economy principles, technological innovation, and sustainable development.

3.8. Discussion.

The bibliometric analysis indicates that research on waste management, particularly within the framework of Integrated Sustainable Waste Management (ISWM), has developed as a multidisciplinary field that connects technical, social, institutional, environmental, and economic dimensions. This pattern suggests that waste management research is no longer confined to operational issues of collection, sorting, transportation, treatment, and disposal, but has increasingly expanded toward broader questions of governance, sustainability, stakeholder coordination, and resource recovery [5, 9]. The prominence of ISWM-related themes reflects the growing recognition that effective waste management requires more than technical intervention; it also depends on institutional capacity, community participation, policy support, and locally appropriate implementation strategies. The dominance of integrated and sustainable waste management themes indicates that the field has shifted from fragmented, disposal-oriented practices toward a more holistic model. This interpretation is consistent with the foundational ISWM paradigm introduced by Klundert and Anschutz, which emphasizes three key dimensions: stakeholders, technical elements of the waste management system, and supporting aspects such as social, environmental, economic, and policy factors 9, 24]. These dimensions remain central to the development of waste management research because they explain why sustainable waste governance cannot be separated from actor coordination, infrastructure readiness, and socio-economic context. The principles of equity, effectiveness, efficiency, and sustainability further reinforce ISWM as a comprehensive framework for addressing complex waste challenges [25]. The findings also suggest that stakeholder collaboration has become an important theme in ISWM research. The implementation of ISWM requires coordination among government agencies, private actors, community groups, field officers, and local institutions.

The findings are consistent with earlier literature that positions ISWM as a comprehensive framework for linking technical waste management processes with social, institutional, and economic considerations. This perspective is particularly relevant in urban areas and low- and middle-income contexts, where waste management problems are shaped not only by infrastructure limitations, but also by stakeholder coordination, institutional capacity, and socio-economic conditions [5]. The present bibliometric results extend this view by showing that these concerns remain visible in the thematic structure of ISWM research, especially through recurring attention to integrated management, sustainability, stakeholder participation, and resource-oriented waste practices. Compared with previous bibliometric studies in waste management and circular economy research, the present findings show both alignment and a more specific contribution. Previous bibliometric work has generally shown that waste management research has increasingly moved toward circular economy, recycling, waste-to-energy, resource recovery, and life cycle assessment as dominant areas of scholarly attention [12]. The results of this study follow the same broader direction, but they also show that ISWM research is not organized only around technological or resource recovery issues. It also gives substantial attention to governance, institutional coordination, public participation, and sustainable implementation, which are central to the ISWM perspective.

This pattern is also in line with studies that emphasize equity, effectiveness, efficiency, and sustainability as core principles of ISWM [8]. The repeated appearance of these principles in the literature suggests that ISWM research has developed around the need to balance environmental protection, social inclusion, operational feasibility, and economic viability.

Rather than focusing narrowly on disposal or treatment, the field increasingly reflects a governance-oriented and sustainability-driven approach to waste management. The findings also correspond with studies showing that local waste management implementation depends on coordination, supervision, and a clear division of responsibilities among institutional actors [13]. This reinforces the interpretation that ISWM is not merely a conceptual framework, but also a practical governance approach for managing waste systems across multiple actors. In this regard, the role of communities, government institutions, and private entities becomes central, particularly in contexts where successful ISWM adoption requires collaboration beyond formal waste management agencies [26].

The emphasis on waste reduction and source classification further supports the broader ISWM focus on prevention, sorting, reuse, and recycling [16]. This connection is important because it shows that ISWM research is closely related to circular economy debates, but with a stronger concern for the social and institutional conditions that make circular practices possible. While circular economy studies often highlight material recovery and resource efficiency, the ISWM perspective adds attention to household behavior, community participation, local governance, and operational readiness. From a bibliometric perspective, these findings demonstrate the usefulness of mapping tools for identifying research trends, collaboration patterns, and emerging areas of inquiry in waste management studies [12]. However, the value of bibliometric analysis in this study is not limited to describing publication patterns. It also helps clarify how ISWM has become connected to innovation, strategic partnerships, cross-sector collaboration, and sustainability-oriented governance. This makes the present analysis more specific than general bibliometric mapping of waste management, because it highlights ISWM as an integrative domain that connects circular resource use with the institutional and social arrangements required for sustainable waste management.

The findings clarify that waste management research has developed into a field structured around the interaction between technical systems and governance processes. The ISWM framework helps explain this intellectual structure because it integrates stakeholders, operational waste system components, and supporting social, environmental, economic, and policy dimensions. This means that waste management should not be understood only as a technical or engineering issue, but as a multidimensional sustainability challenge [27]. The clustering of themes around integrated management, stakeholder participation, waste reduction, recycling, and sustainability reflects several conceptual streams within the field. First, the technical stream focuses on sorting, collection, transportation, treatment, and final disposal. Second, the governance stream emphasizes institutional coordination, public policy, regulatory support, and supervision. Third, the socio-economic stream highlights community participation, public awareness, cost efficiency, job creation, and local economic empowerment. Fourth, the sustainability stream links waste management to environmental protection, circular resource use, and the Sustainable Development Goals. These theoretical streams suggest that ISWM provides a useful lens for positioning waste management as a distinct research domain. Rather than treating waste as an isolated environmental problem, ISWM encourages researchers to examine how waste systems are shaped by actor networks, institutional arrangements, public behavior, economic mechanisms, and technological adaptation. This strengthens the conceptual foundation for future studies that seek to explain why some waste management systems are more sustainable, inclusive, and resilient than others.

The findings have important practical and policy implications. For practitioners, the emphasis on integrated waste management suggests that operational improvement should begin not only with better collection or treatment technology, but also with stronger coordination across the entire waste chain. Waste reduction at the source, sorting by type, recycling, treatment, and final disposal need to be designed as connected processes rather than isolated activities. Waste classification at the source can improve opportunities for reuse and recycling, making household and community participation central to practical waste management improvement [28]. For policymakers, the discussion highlights the need to strengthen institutional capacity, regulatory clarity, public education, and economic incentives. Weak public awareness, limited infrastructure, inadequate regulation, and low community participation remain major barriers to effective ISWM implementation. These barriers are especially relevant in contexts where waste systems still depend on poorly managed disposal practices. Policy interventions should therefore focus on integrated planning, public communication, infrastructure investment, and incentives that encourage sustainable waste behavior [29]. For managers and local government agencies, the findings emphasize the importance of supervision, role clarity, and multi-actor coordination. This implies that ISWM implementation should be supported by clear governance mechanisms, trained personnel, monitoring systems, and collaboration among government, private actors, and communities. In this sense, bibliometric findings can help decision-makers identify which themes have received strong scholarly attention and which areas require more practical experimentation and policy support.

Future research on waste management and ISWM can be developed in several directions. First, future studies may expand the geographical scope of analysis, particularly by examining underrepresented regions, low- and middle-income countries, and local contexts where waste infrastructure and institutional capacity remain limited. Such studies would help explain how ISWM principles are adapted under different socio-economic and governance conditions. Second, future research may combine bibliometric analysis with systematic literature review, content analysis, interviews, or case studies. This mixed-method approach would allow researchers to move beyond mapping publication patterns and provide deeper theoretical interpretation of the identified research clusters. Third, future studies should examine emerging themes related to digital waste management, circular economy, waste-to-energy, community-based recycling, sustainable financing, and policy innovation. These themes are important because they reflect the growing intersection between technological development, environmental sustainability, and governance reform. Fourth, interdisciplinary collaboration should be strengthened among environmental science, public policy, engineering, management, economics, and social sciences. Waste management challenges are multidimensional; therefore, future research should integrate technical, behavioral, institutional, and economic perspectives more explicitly. Fifth, future studies may connect bibliometric findings with empirical investigations. For example, themes identified through keyword analysis or network mapping can be tested through field studies to examine whether dominant academic discussions are reflected in actual waste management practices.

Finally, future bibliometric studies may extend the dataset beyond Scopus by comparing records from Web of Science, Dimensions, ScienceDirect, Google Scholar, or other relevant databases. Although Scopus provides structured metadata and broad coverage of peer-reviewed literature, relying on a single database may introduce database-related bias. Some relevant

studies, particularly regional publications, local journals, conference papers, policy reports, book chapters, or non-English publications, may not be fully represented in Scopus. As a result, the present findings should be interpreted as a reflection of ISWM research indexed in Scopus rather than as a complete representation of the entire body of ISWM knowledge. Publication bias may also influence the bibliometric patterns identified in this study. Highly visible journals, English-language publications, and older documents tend to accumulate more citations, while recent studies or locally focused research may appear less influential even when they have practical relevance. This means that citation counts and network centrality should not be interpreted as direct measures of research quality, but rather as indicators of scholarly visibility within the indexed dataset. Future studies could reduce this limitation by conducting cross-database comparisons, testing alternative keyword combinations, and combining bibliometric analysis with qualitative content review. Longitudinal bibliometric analysis would also be useful for tracing how ISWM themes evolve over time and how new research fronts emerge in response to sustainability challenges.

4. Conclusions

This study examined the development of Integrated Sustainable Waste Management (ISWM) research based on 465 Scopus-indexed publications published between 2015 and 2025. The bibliometric results show that ISWM has grown into a multidisciplinary research area that connects sustainable waste management, integrated governance, circular economy, resource recovery, and environmental protection. The keyword and network analyses indicate that the field is no longer limited to technical waste handling, but has expanded toward broader concerns such as waste-to-energy, recycling, zero waste, life cycle assessment, policy support, and sustainable development. The main contribution of this study lies in providing a structured overview of the intellectual and thematic development of ISWM research. By combining descriptive bibliometric indicators with keyword clustering and network visualization, this study identifies the dominant themes, influential documents, publication patterns, and knowledge connections that shape the field. These findings help position ISWM as a distinct research domain rather than merely a subtopic of general waste management. The mapping provides a clearer basis for identifying mature themes and emerging areas that require further investigation. The results highlight the importance of integrated approaches that combine technological solutions, institutional coordination, community participation, and resource-oriented strategies. Such evidence can support more informed decision-making in designing sustainable waste governance, particularly in contexts where waste problems involve multiple actors and overlapping environmental, social, and economic challenges. This study has several limitations, the analysis was based only on Scopus-indexed publications, so relevant studies from other databases may not have been captured. The results are also influenced by the selected keywords, citation patterns, indexing coverage, and possible inconsistencies in bibliographic metadata. Although data cleaning was conducted using Bibliomagika and OpenRefine, some variations in author names, keywords, affiliations, or source titles may remain. In addition, VOSviewer visualizations provide structural patterns, but the meaning of each cluster still requires careful interpretation. Future research may extend this study by comparing Scopus data with other databases such as Web of Science, Dimensions, ScienceDirect, or Google Scholar. Further studies may also broaden the search strategy by

including related terms such as circular economy, municipal solid waste, zero waste, resource recovery, waste governance, and sustainable waste systems.

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Author Contribution

Rita Ambarwati: Conceptualization, Methodology, Data Collection, Data Analysis, Writing, Supervision.

Competing Interest

All authors should disclose any financial, personal, or professional relationships that might influence or appear to influence their research.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request

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