

Article

Recent Developments in Research on Food Waste and the Circular Economy

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Abstract: Food waste is a global challenge, with profound implications for food security, resource utilization, and sustainability. A circular economy represents a promising solution in addressing food waste effectively by keeping food materials and products in use and circulating them within the economy. To provide an overview of the research on food waste and the circular economy model in the past decade, this study examines 1022 documents on food waste and circular the economy to ascertain the state, themes, and knowledge structure of the field. The results showed that the number of publications has increased greatly in the past decade. “Circular economy of food”, “bioenergy”, “waste valorization”, “waste management”, “resource recovery”, and “environmental assessment” were the major research themes. Earlier studies focused on resource recovery from organic waste and the bioeconomy of bio-products; recent research interests shifted to sustainability and the valorization of agri-food waste. On the other hand, some highly cited documents and productive authors were important in the development of research on food waste and the circular economy. Furthermore, three groups of journals—“food and environmental sciences”, “open access”, and “environmental sustainability and resource management”—and five clusters of international collaboration—“European Union Group”, “advanced economy group”, “agricultural economies”, “global influencers”, and “isolated countries”—were identified. This study provides readers with an overview of the research field of food waste and the circular economy.

Keywords: bibliographic coupling; co-authorship; co-citation; co-occurrence; knowledge structure



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1. Introduction

Of all basic needs, food comes first. Foods nourish our bodies and keep us alive. Because of the growth of the global population, people are concerned about the possibility of feeding the world [1]. However, food waste is a critical issue plaguing societies worldwide. Food waste is defined as any edible food substance, raw or cooked, that is unnecessarily discarded, lost, or uneaten [2]. It encompasses all stages throughout the supply chain, from production to consumption. [3]. In essence, food waste represents a glaring inefficiency in our food systems, with significant social, economic, and environmental repercussions [4].

The Food and Agriculture Organization of the United Nations (FAO) estimated that every year, almost 1.3 billion tons, or one-third, of all food produced for human use is lost or wasted [5]. The World Bank [6] also reported that high levels of food organic waste exist in the majority of countries around the world. Food waste occurs at various supply chain stages, ranging from farming, processing, distribution, and retail to consumption [7]. Food waste represents a loss of valuable resources, estimated at USD 1 trillion annually globally. Socially, it perpetuates food insecurity and inequality, as resources that can alleviate hunger are squandered [8].

According to the FAO, there are differences in environmental, economic, and social situations between countries, which contribute to a variety of reasons for food waste [4].

Food waste primarily arises from production, postharvest handling, storage, and processing in low-income countries [9]. One of the main reasons for food waste is technological and managerial shortcomings [5]. The issues were further described by Beretta et al. [10] as being overproduction, poor infrastructure, antiquated technology, and a lack of funding. Food waste, however, mostly happens during the distribution and consumption of food in high- and middle-income countries [9]. In addition, consumer behaviors and governmental laws have an impact on food waste rates in both wealthy and developing countries [5].

Addressing food waste requires concerted global efforts and cooperation. Organizations like the United Nations, FAO, etc., along with governments, NGOs, and businesses have initiated campaigns and policies aimed at reducing food waste [11]. At the international level, the Sustainable Development Goals (SDGs), particularly Goal 12, emphasize the importance of responsible consumption and production, advocating for halving global food waste by 2030 [12]. Additionally, collaborations between countries facilitate knowledge exchange, technological innovations, and capacity building to tackle this multifaceted issue effectively [13]. At the national level, it is imperative to comprehend the causes and mechanisms underlying food waste in the whole process of the food value chain, from supply to demand ends, so that effective measures can be implemented to reduce food waste [9].

Many researchers consider a circular economy the solution to the problem of food waste [9,14,15]. Unlike the traditional linear economy model, which discards food materials as waste after use, a circular economy recycles the materials and circulates them within the economy. The goals of the circular economy model encompass preserving resources, such as raw materials, energy, and water, and reducing waste, while also minimizing carbon emissions and environmental impacts [9,14]. Common strategies include composting, anaerobic digestion, waste reduction, and the redistribution of food surplus [16].

It was estimated that 39% of the global emissions of greenhouse gases could be reduced by a circular economy [17]. Furthermore, a circular economy creates economic opportunities. The United Nations Environment Programme (UNEP) estimates that the circular economy makes up 8.6% of the world economy [18]. The European Commission indicated that a circular economy could create new jobs, promote sustainable economic growth, and increase competitiveness [19].

Nonetheless, the success of the circular economy model relies on the collaborated efforts of numerous stakeholders, such as governments, consumers, and friendly industry or sector-to-industry collaboration. A paradigm shift is required for stakeholders to engage with the environment, natural resources, and raw materials on various levels [9]. Following the same reasoning, Chizaryfard et al. [20] argued that a radical change in attitudes, values, and norms is necessary to implement the circular economy.

In recent decades, a sizable number of research papers have emerged to discuss the issues of food waste and the circular economy at the worldwide, national, and even local levels [21]. Bhattacharya et al. [3] categorized the existing literature into four groups: The first group focuses on management strategies for food waste, e.g., recycling, composting, anaerobic digestion, etc. [22,23]. The second group examines the causes of food waste concerning particular stages [24,25] or the whole process of the food supply chain [26]. The third group examines country-specific actions on food waste and the circular economy [27]. The fourth group is interested in quantifying the data on food waste and the circular economy [28].

A few literature reviews have been conducted to provide an introduction to food waste and circular economy research. For example, based on 52 articles selected from the Web of Science, Ouro-Salim and Guarnieri [14] indicated that food waste and circular economy research was mainly focused on discussions about economic and environmental impacts and implications. The majority of scientific papers are published in developed countries. Santagata et al. [29] reviewed the literature on food waste conversion based on 27 scientific works. Food waste recovery and biological conversion were identified as major interests. Oliveira et al. [30] reviewed 40 articles and reported that food waste's definition,

quantification, solutions, circular economy examples, and the relationship between food waste and a circular economy are popular research themes. Although the above literature reviews can bring readers some information about the research field, the selection of papers is mainly based on the subjective judgment of the authors, the number of documents involved is generally relatively small, and there is often a tendency to select a small number of influential authors and works [31].

On the other hand, some scholars have adopted a bibliometric approach to cover an extensive collection of publications so that an overview of the current status and focus of the research field can be provided. A bibliometric review refers to the use of quantitative methods to summarize, evaluate, track, and analyze the meta-data of publications to describe and summarize the macro-characteristics and situation of a specific research area [32]. By introducing a systematic, transparent, and reproducible procedure, a bibliometric analysis can improve the quality of the review [33]. Baybars et al. [34] conducted a bibliometric review of food waste based on 1384 documents from the Web of Science. They indicated that food waste intersected the issues of sustainability, circular economy, and consumer behavior; the highly discussed topics were solid waste management, waste prevention, food production, recycling, energy, meat, food consumption, the environment, life cycle assessment, ecological footprint, sustainable consumption, sustainability, and the food supply chain. Kumar et al. [11] explored the relationship between food waste and sustainability using 944 articles from various bibliographic databases. They found that food waste, anaerobic digestion, the environment, life cycle assessment, and sustainability were the most frequently occurring keywords and research topics on food waste. Environmental protection is conducted worldwide using various methodologies, including determining the causes of food waste, environmental impact factors, recycling food waste, food security, and sustainability. Ranjbari et al. [16] analyzed 962 journal articles indexed in the Web of Science. They reported that food waste was a newly emerged keyword in the literature on the management of bio-based waste. The research themes included turning food waste into resources and bioproducts by valorization, energy production through the anaerobic digestion of food waste, contributions of anaerobic biorefinery to the regional economy, the innovative disposal of food waste, biomass waste from agriculture and farming, life cycle assessment of food packaging, and the conversion of food waste into biochar through pyrolysis [16]. Because these bibliometric reviews limited their scopes to particular issues or aspects of the field, they lacked a holistic vision of the entire research area. As a result, we still need to familiarize ourselves with the knowledge structure and recent development of this research area.

This study intends to fill the research gap by examining the relevant publications on food waste and the circular economy in the past ten years (2014–2023). Specifically, major research themes and the key authors, studies, and journals that contributed to the development of food waste and circular economy research are identified and mapped. This study can provide a valuable resource for researchers and policymakers who wish to learn more about the field, particularly its knowledge structure and current state of development. It can also be used to understand unexplored areas that deserve further research.

2. Materials and Methods

This study conducted a systematic bibliometric analysis of the literature on food waste and the circular economy. The methodology involved five steps (Figure 1).

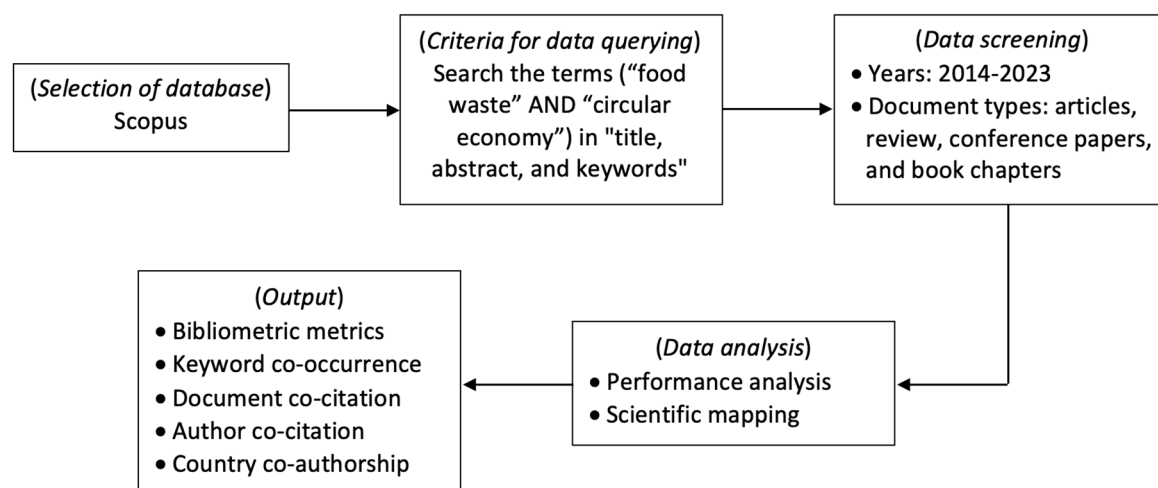


Figure 1. The methodology of this study.

2.1. Data Sources and Retrieval

This study chose Scopus for the literature information and data collection, because it is the world's largest literature citation database, with over 90 million records, and has the most comprehensive coverage of study categories [35]. Scopus has long been recognized as the best choice for bibliometric research [36]. In addition, Scopus includes entries (i.e., journals, books, etc.) that have proven to have an international impact and representative data [37].

The extraction of bibliographic data was conducted on 25 March 2024. Initially, this study searched for ("food waste" AND "circular economy") in the "Title, Abstract, and Keywords" for the initial search procedure, which yielded a total of 1131 documents. The second search criterion was to select documents from the past decade (i.e., 2014 to 2023), and a total of 1041 documents were found. For the third search criterion, only full-sized individual papers (i.e., journal articles, reviews, conference papers, and book chapters) were selected. In other words, books, editorials, short communications, etc., were excluded, and finally, 1022 documents were collected for the bibliometric analysis.

2.2. Bibliometric Methods and Visualization

The downloaded data were cleaned and calibrated to meet the requirements of a bibliometric analysis. Specifically, inconsistent terms such as British vs. American English, singular vs. plural, author's full name vs. abbreviation, etc., were removed. A bibliometric analysis has two main components: performance analysis and scientific mapping [38]. Combining performance analysis and scientific mapping helps to understand the knowledge structure and growth process of a field [32].

The performance analysis evaluates the performance of the literature, authors, organizations, and countries based on various performance parameters, including publication type count, number of documents, number of citations, year of publication, keywords, authors, sources, and countries. The number of citations can be further used to calculate Citescorers and H-indexes to reflect the influences of the journal and authors, respectively. A journal's Citescorer is derived by dividing the total number of citations by the total number of papers published in the previous three years [39]. An author's H-index is the number of publications (h) that have been cited at least h times per paper [40].

Scientific mapping uses bibliometric methods to map and reveal the knowledge structure and dynamics of a scientific field. In this study, the co-occurrence, co-citation, bibliographic coupling, and co-authorship are used to analyze the scientific mapping of keywords, studies, individuals, and countries. Co-occurrence refers to the occurrence of two keywords in a single piece of literature, and a co-occurrence analysis is used to identify major research themes in a scientific field through the co-occurrence [41]. Co-citation refers

to the situation where two studies cite the same text, reflecting the existence of a link between the two texts [42]. In this study, a co-citation analysis is conducted to reveal the relationship between the texts and between the authors. Bibliographic coupling refers to the situation where two documents are cited by the same document, reflecting the connection between the two cited documents [43]. This study conducts a bibliographic coupling analysis to reveal the relationship between academic journals. Finally, co-authorship refers to the co-authorship of a document by multiple authors. It can be utilized to discover global research collaboration networks.

In this study, VOSviewer (version 1.6.18) is used to visualize the results of the bibliometric analysis. The visualization is based on an optimization algorithm that minimizes the weighted sum of the Euclidean distances between all nodes to fit the location of the dots on the network map [44]. On the network map, nodes represent bibliometric items connected by lines, representing their relationships. The size of the nodes reflects the number of bibliometric items, while the thickness of the lines indicates the strength of the connections. The proximity between nodes indicates the degree of their association [45]. Similar items are grouped into clusters represented by different colors [46].

3. Results and Discussion

3.1. Overview

In the past decade, papers on food waste and the circular economy have risen rapidly, from 1 in 2014 to 295 in 2023 (Figure 2). The rapid increase in the number of papers published in the past decade indicates that food waste and the circular economy is a booming research area that has attracted much attention from the academic circle.

Number of documents

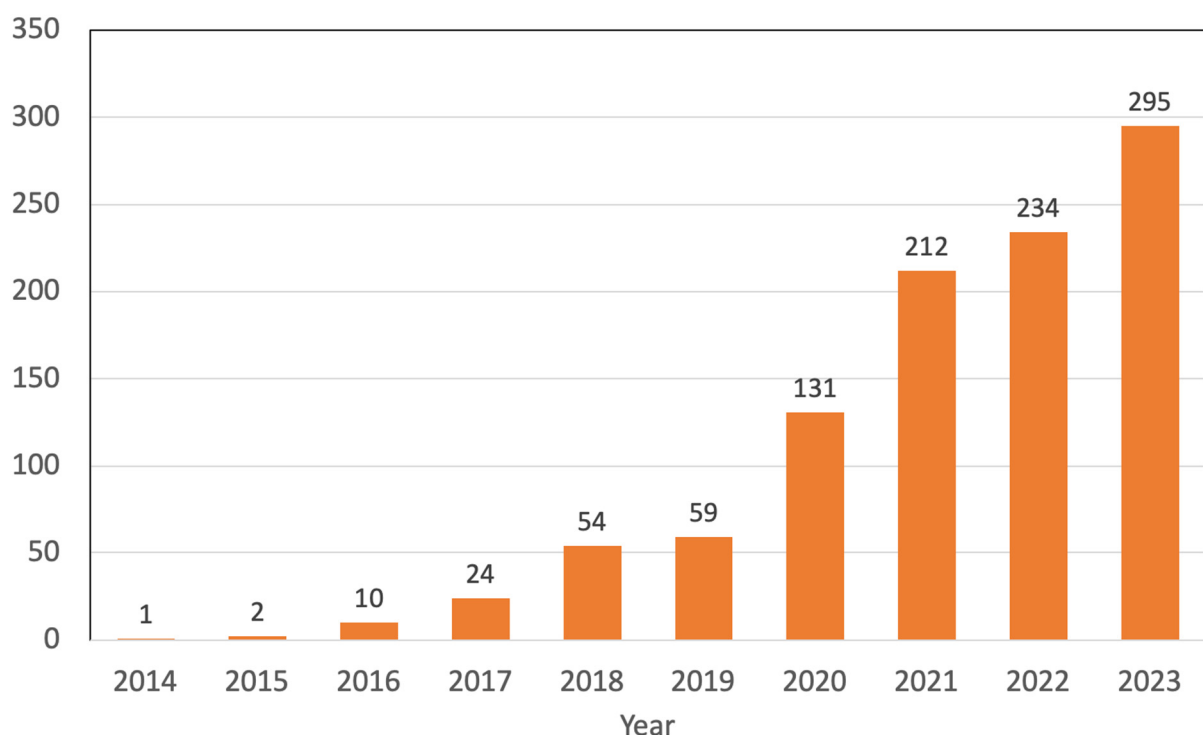


Figure 2. Numbers of documents on food waste and the circular economy (2014–2023).

The most popular subject area was “Environmental Science” (549 documents), next to it were “Energy” (290 documents), “Engineering” (246 documents), “Agricultural and Biological Sciences” (192 documents), “Social Sciences” (167 documents), “Chemical Engineering” (126 documents), “Business, Management and Accounting” (115 documents), and “Biochemistry, Genetics and Molecular Biology” (103 documents) (Table 1). The number of

papers in other subject areas was less than 100. These statistics reflect the interdisciplinary nature and diversity of food waste research, highlighting the significant attention given to food waste issues in the fields of Environmental Science, Energy, and Engineering.

Table 1. Subject areas of the literature on food waste and the circular economy (2013–2024).

Rank (nth)	Subject Area ¹	Number of Documents ²
1	Environmental science	549
2	Energy	290
3	Engineering	246
4	Agricultural and biological sciences	192
5	Social sciences	167
6	Chemical engineering	126
7	Business, management, and accounting	115
8	Biochemistry, genetics, and molecular biology	103
9	Chemistry	97
10	Computer science	78
11	Economics, econometrics, and finance	69
12	Immunology and microbiology	47
13	Materials science	42
14	Medicine	39
15	Pharmacology, toxicology, and pharmaceuticals	36
16	Mathematics	28

¹ Only the subject areas that have more than twenty papers are shown; ² The total count is larger than the total number of documents, because some papers belong to more than one subject area.

The 1022 documents on food waste and the circular economy in this study were predominantly written in English (1012 papers, 99.0%). because English is the international language, and most prestigious journals are in English. No more than two papers were published in other languages.

3.2. Keywords

There were 2874 keywords in the literature on food waste and the circular economy from 2014 to 2023. Among the many keywords, the most popular ones were “circular economy” (550 occurrences), “food waste” (301 occurrences), and “sustainability” (Table 2) (117 occurrences), followed by “anaerobic digestion” (70 occurrences), “waste management” (63 occurrences), “life cycle assessment” (45 occurrences), “biorefinery” (42 occurrences), “biogas” (31 occurrences), and “recycling” (31 occurrences). The rest of the keywords occurred less than 30 times (Table 2).

Table 2. Keywords in the literature on food waste and the circular economy (2013–2024).

Rank (nth)	Subject Area ¹	Number of Documents
1	Circular economy	550
2	Food waste	301
3	Sustainability	117
4	Anaerobic digestion	70
5	Waste management	63
6	Life cycle assessment	45
7	Biorefinery	42
8 and 9	Biogas, recycling	31
10 and 11	Food loss, valorization	29
12	Waste valorization	27
13	Bioeconomy	26

Table 2. Cont.

Rank (nth)	Subject Area ¹	Number of Documents
14	Food supply chain	25
15	Waste	24
16	Bioactive compounds	22
17 and 18	Biofuel, resource recovery	20
19	Food security	18
20 to 22	Biowaste, health professions, sustainable development	17
23 to 26	Circular bioeconomy, fermentation, food waste valorization, organic waste	15

¹ Only the keywords that occurred at least 15 times are shown.

Using at least 12 occurrences as the threshold for the keyword co-occurrence analysis, 32 keywords met the criteria (Figure 3). The co-occurrence analysis divided the 32 keywords into 6 clusters. The two most prominent nodes, “circular economy” and “food waste”, are located at the center of the network map, indicating that they occupy a pivotal role in the knowledge network. The other keywords are more or less related to them.

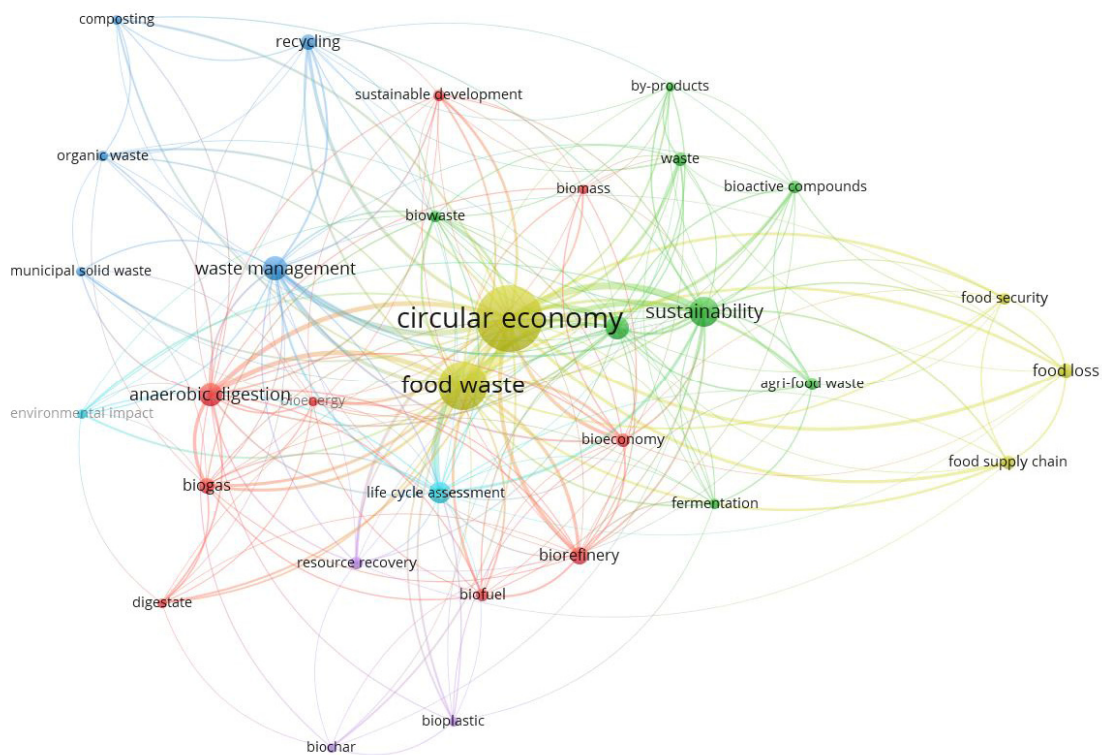


Figure 3. The network map of co-occurrence, showing keyword clusters on food waste and circular economy (2013–2024).

The yellow cluster consists of five keywords. Its theme is “circular economy of food”, as it covers many key issues related to food waste and the circular economy. Led by the two most important keywords, “food waste” and “circular economy”, the other keywords are “food loss”, “food security”, and “food chain supply”. The red cluster is “bioenergy”, which consists of nine keywords. This cluster focuses on the production of “bioenergy”, such as “biofuel” and “biogas”, in a “biorefinery” through “anaerobic digestion” of “biomass”. The “bioeconomy” is essential for “sustainable development”. The green cluster consists of eight keywords with the theme “waste valorization”. This cluster revolves around the “valorization” of “waste”, “agri-food waste”, and “by-products” through “fermentation”.

It is also interested in extracting “bioactive compounds” and creating values from waste. The blue cluster is “waste management”, which consists of five keywords, including “waste management”, “municipal solid waste”, “recycling”, “composting”, and “organic waste”. These clusters represent research interests in the energy system transition to a more environmentally friendly direction. The theme of the purple clusters is “resource recovery”; the other keywords are “biochar” and “bioplastic”. The turquoise group has only two keywords, “environmental impact” and “life cycle assessment”, with the theme “environmental assessment”. While the above clustering results are generally consistent with the existing literature, e.g., [11,16,34], this study identifies a few topics, e.g., agri-food waste, resource recovery, and environmental impact, which are not mentioned by previous bibliometric studies on food waste.

Based on the order of the average time of occurrence of the keywords, it is possible to understand the research trend in food waste and the circular economy (Figure 4). Purple or blue keywords appear first, followed by green, and more recently, yellow. Early research focused on “anaerobic digestion”, “organic waste”, “recycling”, and “resource recovery”. Subsequently, the focus of the study shifted to “waste management”, “waste”, “municipal solid waste”, “biowaste”, “composting”, “fermentation”, “biorefinery”, “bioplastic”, and “biochar”. The most recent research focuses on “sustainable development”, “food security”, “valorization”, “agri-food waste”, “bioactive compounds”, and “by-products”.

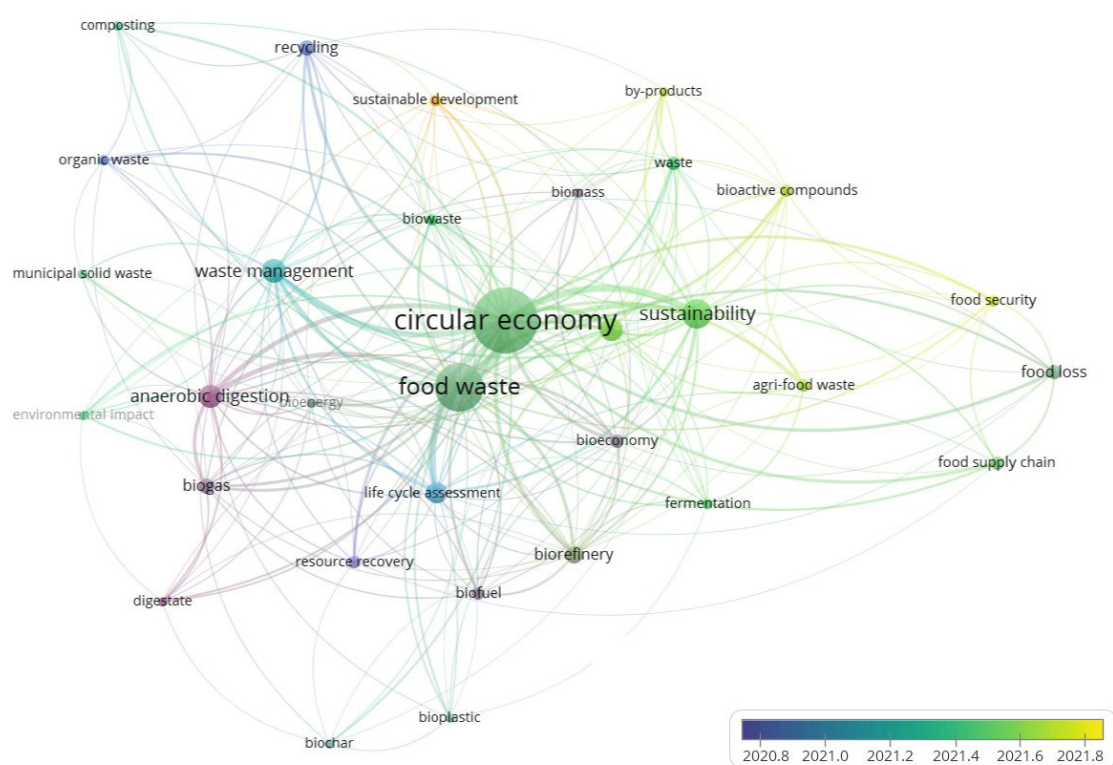


Figure 4. The network map showing the average co-occurrence time of keywords on food waste and the circular economy (2013–2024).

3.3. Documents

Among the 1022 papers collected in this study, 55 were cited more than 100 times. Due to the space limitation, only the documents with more than 200 citations are listed in Table 3. The four most cited papers were Mirabella et al. [47] (cited 775 times), Jurgilevich et al. [48] (cited 423 times), Nizami et al. [46] (cited 375 times), and Geueke et al. [49] (cited 326 times). Many influential papers were published in the Journal of Cleaner Production, Science of the Total Environment, Bioresource Technology, and Sustainability (Switzerland).

Table 3. Highly cited documents on food waste and the circular economy (2013–2024).

Rank (nth)	Document ¹	Title	Year	Journal	Number of Citations
1	Mirabella et al. [47]	Current options for the valorization of food manufacturing waste: A review	2014	Journal of Cleaner Production	755
2	Jurgilevich et al. [48]	Transition towards circular economy in the food system	2016	Sustainability (Switzerland)	423
3	Nizami et al. [49]	Waste biorefineries: Enabling circular economies in developing countries	2017	Bioresource Technology	375
4	Geueke et al. [50]	Food packaging in the circular economy: Overview of chemical safety aspects for commonly used materials	2018	Journal of Cleaner Production	326
5	Guillard et al. [51]	The next generation of sustainable food packaging to preserve our environment in a circular economy context	2018	Frontiers in Nutrition	280
6	Chojnacka et al. [52]	Bio-based fertilizers: A practical approach towards circular economy	2020	Bioresource Technology	269
7	Sherwood [53]	The significance of biomass in a circular economy	2020	Bioresource Technology	262
8	Kumar et al. [54]	A critical review on biochar production from anaerobic digestion of food waste and sludge	2021	Journal of Cleaner Production	257
9	Sharma et al. [55]	Waste-to-energy nexus for circular economy and environmental protection: Recent trends in hydrogen energy	2020	Science of the Total Environment	244
10	Mak et al. [56]	Sustainable food waste management towards circular bioeconomy: Policy review, limitations and opportunities	2020	Bioresource Technology	229
11	Shirvanimoghaddam et al. [57]	Death by waste: Fashion and textile circular economy case	2020	Science of the Total Environment	227
12	Borrello et al. [58]	Consumers' perspective on circular economy strategy for reducing food waste	2017	Sustainability (Switzerland)	225
13	Teigiserova et al. [59]	Towards transparent valorization of food surplus, waste and loss: Clarifying definitions, food waste hierarchy, and role in the circular economy	2020	Science of the Total Environment	215

¹ Only the documents with more than 200 citations are shown.

Using the minimum number of 12 papers as the threshold for the co-citation analysis of the documents, 31 papers met the criteria and were categorized into 4 clusters (Figure 5). The red cluster is composed of 13 papers that include some policy documents of intergovernmental organizations (e.g., *Global Food Losses and Food Waste* [5], *Transforming Our World, the 2030 Agenda for Sustainable Development* [12], *The State of Food and Agriculture 2019* [60], and the *Food Waste Index Report 2021* [61]) and research articles on food waste [22,62,63].

These documents provide policy frameworks and research findings that outline the global state of food waste and the importance of addressing it within the context of sustainable development goals. The green cluster consists of seven papers that delve into the circular economy [64,65] and the issues related to food waste, such as consumer behaviors [66], supply chain management [67], and environmental impacts [68]. These papers offer insights into the theoretical foundations, challenges, and opportunities associated with a circular economy in the context of food systems. They contribute to the academic discourse on circular economy principles and provide valuable knowledge for developing effective strategies to reduce food waste and promote sustainability. The blue cluster comprises six papers on the “transition towards a circular economy”, represented by [7,47,48]. These studies provide empirical evidence and practical recommendations for policymakers, businesses, and stakeholders to support the transition toward circularity in food production and consumption. The yellow cluster comprises five papers on “food waste reduction”, represented by [69–71]. This group includes research articles investigating the operational aspects, behavioral drivers, and intervention strategies for reducing food waste along the supply chain and at the consumer level.

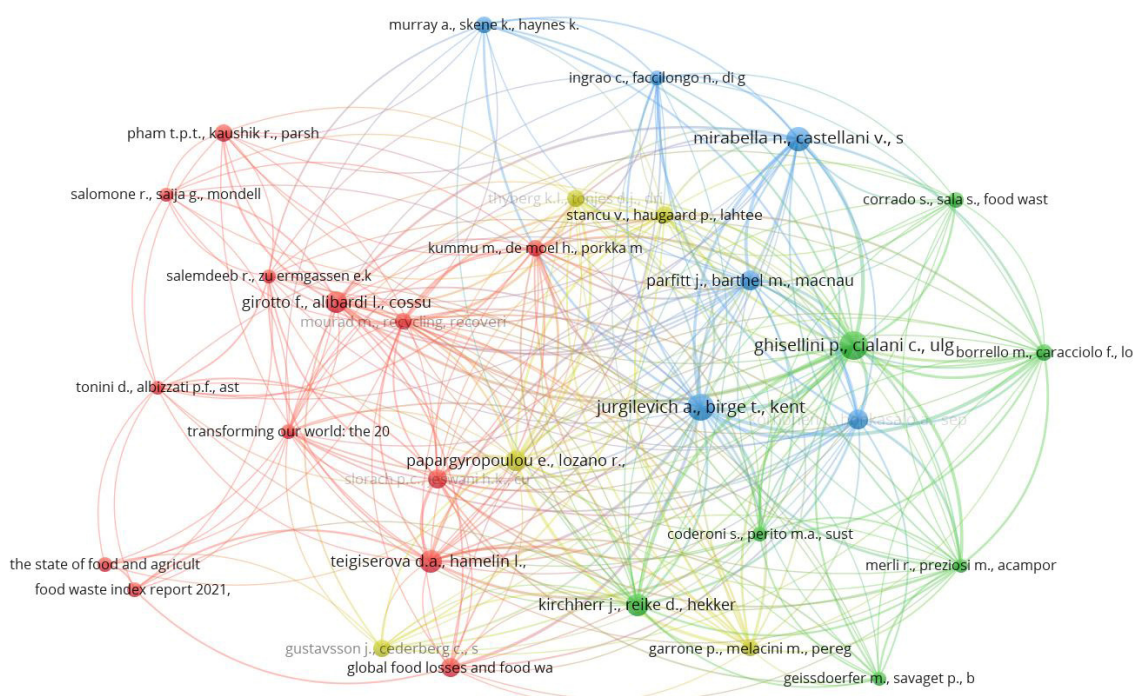


Figure 5. The network map of co-citation, showing document clusters on food waste and circular economy (2013–2024).

3.4. Authors

From 2014 to 2023, 1009 authors had published research on food waste and the circular economy. Table 4 lists the authors who had published at least five papers on food waste and the circular economy and also provides the H-index of each of these authors. Tsang, D.C.W. (H-index = 122) and Sharma, M. (H-index = 27), who published eight papers on food waste and the circular economy, were the most productive authors in this research field, followed by Bhat, R. (seven papers, H-index = 53) and Streimikiene, D. (seven papers, H-index = 37). The authors on the left had published less than seven papers on food waste and the circular economy.

Table 4. Productive authors on food waste and the circular economy (2013–2024).

Rank (nth)	Author ¹	Number of Documents	H-Index
1	Tsang, D.C.W.	8	122
2	Sharma, M.	8	27
3	Bhat, R.	7	53
4	Thomsen, M.	7	37
5	Ramakrishna, S.	6	168
6	Azapagic, A.	6	70
7	Gupta, V.K.	6	65
8	Zorpas, A.A.	6	42
9	Hamelin, L.	6	23
10	Teigiserova, D.A.	6	7
11	Ok, Y.S.	5	145
12	Barros, L.	5	83
13	Yu, I.K.M.	5	40
14	Kazancoglu, Y.	5	16

¹ Only the authors who published at least five papers are shown.

Using a minimum of 120 citations as the threshold for the authors’ co-citation analysis, 49 authors met the criteria and were divided into 4 clusters (Figure 6). The red group is the largest group, with 26 members, and is led by Zhang Y., Liu Y., Li Y., and Wang Y. The blue cluster consists of five authors, overlapping with the red cluster. The green color consists of 17 authors. Led by Sala S., who is an author of Mirabella et al. [44] (1st most cited paper) and Corrado and Sala [56] (18th most cited paper), the representative authors of the green cluster included Lin, C.S.K., Zhang Z., Liu G., and Pandey A. The yellow cluster consists of four authors, represented by Tsang D.C.W. (1st most productive author) and Ok Y.S. (11th most productive author).

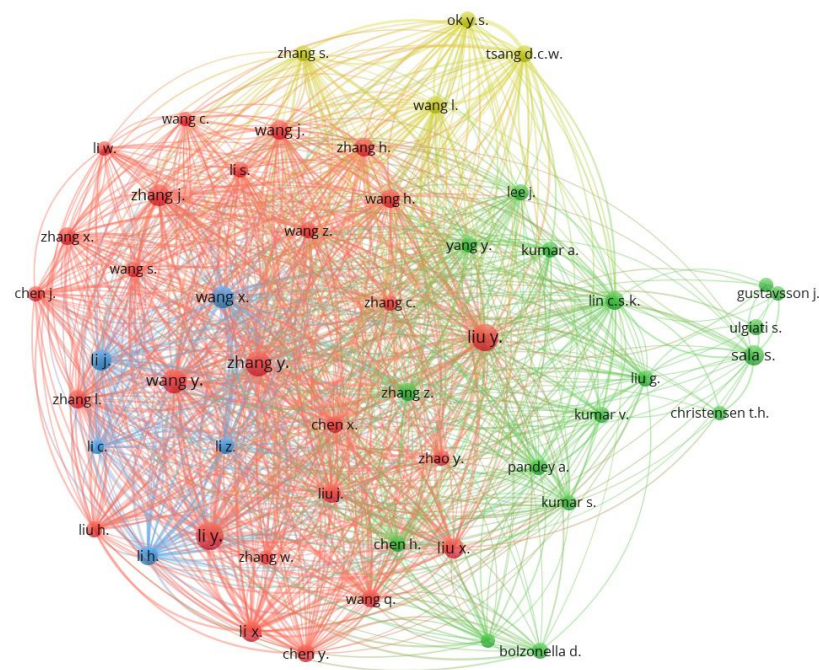


Figure 6. The network map of co-citation showing author clusters on food waste and the circular economy (2013–2024).

3.5. Journals

The 1022 documents on food waste and the circular economy in this study were published in 398 journals. Table 5 lists the journals that had published at least eight papers.

The journal with the highest number of papers on food waste and the circular economy is *Sustainability (Switzerland)* (69 papers). The *Journal of Cleaner Production* (57 papers) has the second highest number of papers, and *Science of the Total Environment* (41 papers) has the third highest number, respectively. The journals with a higher number of papers are *Resources, Conservation and Recycling* (27 papers), *Waste Management* (25 papers), *Foods* (25 papers), *Bioresource Technology* (24 papers), *Energies* (22 papers), and *Molecules* (20 papers).

Table 5. Productive journals on food waste and the circular economy (2014–2023).

Rank (nth)	Journal ¹	Number of Documents	Citescore
1	<i>Sustainability (Switzerland)</i>	69	5.8
2	<i>Journal of Cleaner Production</i>	57	18.5
3	<i>Science of the Total Environment</i>	41	16.8
4	<i>Resources, Conservation and Recycling</i>	27	20.3
5	<i>Waste Management</i>	25	15.1
6	<i>Foods</i>	25	5.8
7	<i>Bioresource Technology</i>	24	10.9
8	<i>Energies</i>	22	5.5
9	<i>Molecules</i>	20	6.7
10	<i>Waste Management and Research</i>	15	7.4
11	<i>Environmental Science and Pollution Research</i>	13	7.9
12	<i>Journal of Environmental Management</i>	12	13.4
13	<i>Sustainable Production and Consumption</i>	10	12.5
14	<i>Waste and Biomass Valorization</i>	9	6.9
15	<i>Fermentation</i>	9	3.7
16	<i>Environmental Footprints and Eco-Design of Products and Processes</i>	9	1.1
17	<i>Processes</i>	8	4.7

¹ Only the journals that published at least eight papers are shown.

Among these 17 productive journals in Table 5, 15 have a Citescore above 4.0. The most productive journal on food waste and circular economy is *Sustainability (Switzerland)*, with a Citescore of 5.8. Seven journals with a Citescore higher than 10 are *Resources, Conservation and Recycling* (Citescore = 20.3), *Journal of Cleaner Production* (Citescore = 18.5), *Science of the Total Environment* (Citescore = 16.8), *Waste Management* (Citescore = 15.1), *Journal of Environmental Management* (Citescore = 13.4), *Sustainable Production and Consumption* (Citescore = 12.5), and *Bioresource Technology* (Citescore = 10.9).

Using a minimum of 5 papers as the threshold for the bibliographic chance analysis of journals, 38 journals met the criteria and were divided into 3 clusters (Figure 7). The red cluster, consisting of 13 journals, is represented by *Environmental Science and Pollution Research*, *Food Research International*, *British Food Journal*, *Food Waste Valorization*, and *Waste Management and Research*. These journals cover various issues of “food and environmental sciences”, such as waste management, pollution research, food production, and food loss. The green cluster also consists of 13 journals with the theme “multi-disciplinary”. The represented journals are *Sustainability (Switzerland)*, *Foods*, *Molecules*, *Energies*, *Applied Sciences (Switzerland)*, *Fermentation*, *Processes*, *Resources*, and *Animals*. These are “open access” journals covering various topics in various scientific disciplines related to foods. The blue cluster comprises 12 journals entitled “environmental sustainability and resource management”. The represented journals are the *Journal of Cleaner Production*, *Science of the Total*

Environment, Resources, Conservation and Recycling, Bioresource Technology, Waste Management, and Sustainable Production and Consumption. These journals publish interdisciplinary research on food waste and the circular economy from a global perspective.

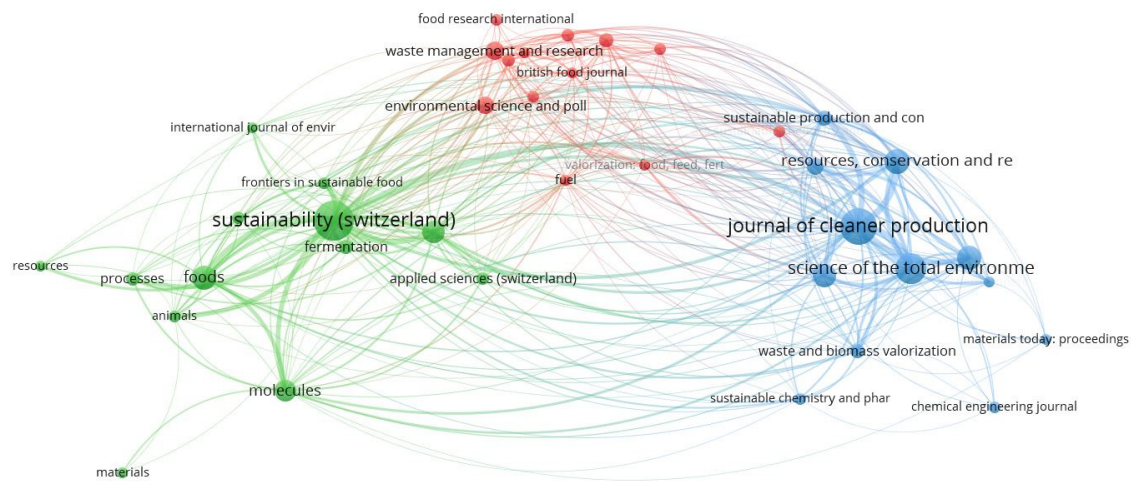


Figure 7. The network map of bibliographic coupling, showing journal clusters on food waste and the circular economy (2013–2024).

3.6. Countries

From 2014 to 2023, 87 countries had published papers on food waste and the circular economy (Figure 8). The country with the highest number of publications was Italy (226 papers), followed by the United Kingdom (115 papers), China (89 papers), Spain (81 papers), India (79 papers), and the United States (60 papers). The rest of the countries had published less than 60 papers.

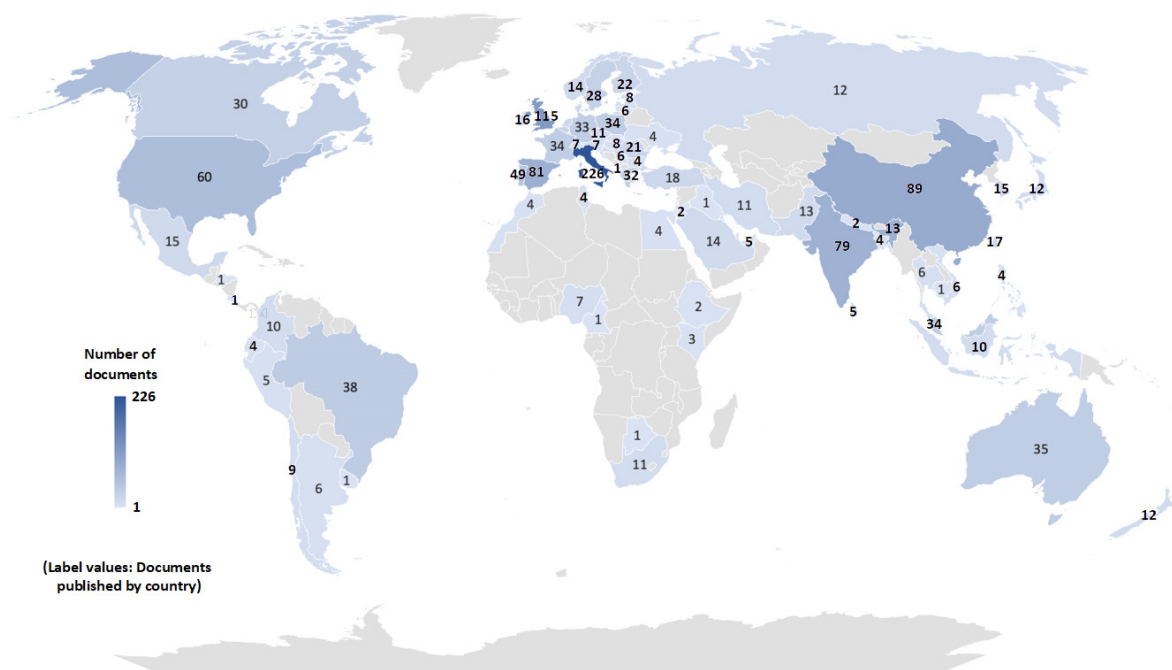


Figure 8. The map showing the countries that had published papers on food waste and the circular economy (2014–2023).

Using a minimum of 8 documents as the threshold for co-authorship analysis of countries, 43 countries met the criteria and were grouped into 5 international research

collaboration clusters (Figure 9). The green cluster has 11 members. It is named the “European Union group”, because the members are mainly European countries, including Italy, Spain, Portugal, France, Greece, Hungary, Denmark, Ireland, and Romania. The European Union has more or less united policies and regulations to reduce food waste and promote a circular economy, e.g., the Circular Economy Action Plan [72]. The red cluster, the “advanced economy group”, also has 11 members. The red cluster includes some economic powerhouses in the Pacific area (e.g., Australia, Indonesia, Japan, Singapore, and South Korea) and Europe (e.g., Germany, Poland, Finland, Norway, and Sweden). The blue cluster consists of 10 members. Many members of the blue clusters are well-developed “agricultural economies”, including India, Canada, Chile, Colombia, Mexico, Belgium, the Czech Republic, the Russian Federation, and South Africa. The yellow group comprises eight countries and is named “global influencers”. Led by the United Kingdom, the United States, and China, other representative countries include Hong Kong, New Zealand, and Turkey. The purple group consists of three small Asian countries, namely Taiwan, Iran, and Malaysia. These are “isolated countries” politically or economically, so they strive to develop local circular economy models tailored to their needs.

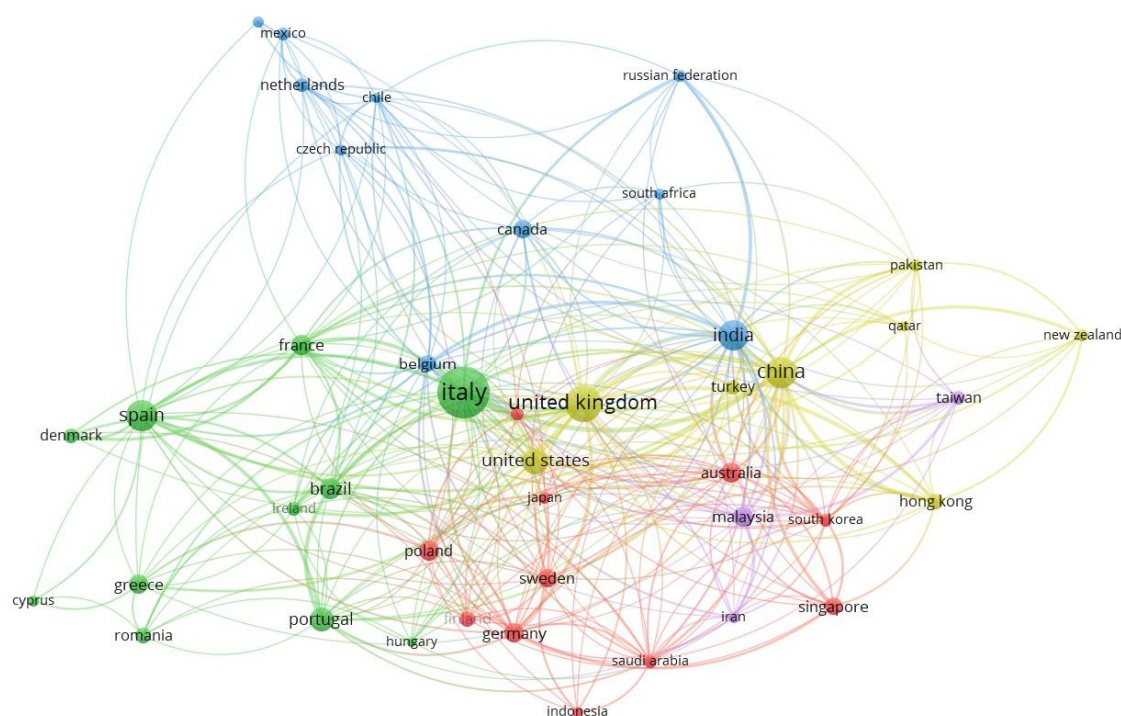


Figure 9. The network map of co-authorship, showing clusters of countries on food waste and the circular economy (2014–2023).

4. Conclusions

4.1. Summary of Findings

The field of food waste and circular economy research has developed rapidly over the past decade. A comprehensive bibliometric review is necessary to serve as a guide for readers to understand the current state of this research area. In this study, 1022 relevant documents retrieved from Scopus were examined using complementary bibliometric methods to determine and identify the status, themes, and knowledge structure of the field. The results revealed a rapid increase in the number of documents over the past decade. The major research themes included “circular economy of food”, “bioenergy”, “waste valorization”, “waste management”, “resource recovery”, and “environmental assessment.” Earlier studies focused on resource recovery from organic waste and the production of bio-products within the bioeconomy. Recent research has shifted towards sustainability and the valorization of agri-food waste. Additionally, some highly cited documents and

productive authors were identified as key contributors to the development of this research area. Furthermore, three groups of journals (“food and environmental sciences”, “open access”, and “environmental sustainability and resource management”) and five clusters of international collaboration (“European Union Group”, “advanced economy group”, “agricultural economies”, “global influencers”, and “isolated countries”) were identified.

4.2. Theoretical and Practical Implications

Referring to theoretical implications, this study demonstrates the necessity of complementary bibliometric methods to determine and characterize the multiple facets of knowledge structure of food waste and the circular economy. Furthermore, the identification of important themes, documents, authors, journals, and countries contributing to the development of food waste and circular economy research not only acquaints readers with the research field but also casts light into the agenda of future research.

For the practical implications, understanding the diversity of knowledge about food waste and the circular economy can inform policies on food waste and the circular economy and plans and programs for public engagement. Moreover, a few international collaboration clusters on food waste and circular economy research are identified, and an understanding of their connections, in terms of economics, politics, culture, or geography may help break the academic barriers and enhance international collaboration.

4.3. Limitations and Recommendations

A few limitations in this study should be noted for future research. First of all, although Scopus is the largest literature citation database in the world, the selection of indexed documents is, after all, the decision of the person in charge according to the purpose and scope of the database, which means that there are some limitations and biases. To increase the representativeness of the samples, it is suggested that other international databases (e.g., Web of Science) and databases in other languages (e.g., CNKI database) can be used together in the future. Secondly, this study examines only journal articles, conference papers, book chapters, reviews, and books, but other formats are excluded. To cover a wider scope of research, other forms of written work could be included in future studies. Thirdly, bibliometric methods rely on statistical counting, which potentially leads to confusing results. For example, when counting the number of papers and citations, each author of a co-authored paper is treated as an independent author instead of apportioning the statistics. Therefore, the results of the bibliometric analysis must be interpreted with caution.

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