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Circular Economy and Solid Waste Management: Connections from a Bibliometric Analysis

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Abstract: The aim of this study is to conduct a meta-analysis of the research published between 2012 and 2022 on solid waste management (SWM) and the circular economy (CE) using bibliometrics. To this end, the Scopus and Web of Science (WoS) databases were used as sources of publications. Processing was conducted using the R language version 4.2.2 and the Bibliometrix software package version 4.1.2. A theoretical basis was built on the terms in order to present their interactions in the context of scientific debate. The results show that there is a need to create indicators to facilitate the evaluation of SWM. They can be identified from the data collected during the management process. Examples include the volume of material collected, operating costs, and recycling rates. Indicators are important in the waste management process because they help quantify the effectiveness of the management practices adopted, help to identify areas that need improvement, and make it possible to monitor the progress of work over time and the achievement of previously set targets. Two other important results are the maximization of the use of resources by increasing the useful life of the product and the emergence of new sustainable business models with recycling as a driving force. Finally, and perhaps the most disruptive discovery, is the integration of SWM and CE with blockchain technology to reduce the levels of waste production. This shows how new technologies can be used as partners in solving complex problems, such as solid waste (SW).

Keywords: circular economy; solid waste management; R language; bibliometrics

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1. Introduction

In 2016, the world generated approximately 2.01 billion tons of municipal solid waste (MSW) and is expected to produce 3.40 billion by the year 2050 [1]. This problem is related to the waste promoted by modern society as a result of the linear economic model [2], which is considered to be the main cause of the depletion of natural resources [3].

Population [4], urban growth, and consumption growth [5] are factors that burden the economy with disproportionately high levels of waste flows, generating waste management costs and limiting the ability to properly dispose of these materials. This leads to the pollution of water bodies, the spread of disease, an increase in greenhouse gases, the contamination of groundwater [6], and the exhaustion of landfills due to the high per capita production of waste [7]. As a result, due to new consumer societies and the constant pace of industrial activity, emissions into the environment and the generation of solid waste are becoming increasingly serious problems [8].

The need to ensure sustainable production and consumption patterns has been recognized in the United Nations Sustainable Development Goals (SDGs), specifically in Goal 12.5, which aims to "significantly reduce waste generation through conservation, reduction, recycling and reuse by 2030" [9].

This intention is in line with the proposal of the CE, a concept that has great potential for more sustainable development practices by seeking solutions to the problems of production, consumption, and waste [10].

In a CE, the value of products and goods is maintained for as long as possible. Waste and resource use are minimized, and when a product reaches its end of life, it is used again to create more value. This can create many economic benefits, contributing to aspects of innovation, growth, job creation, and the reduction in SW [11].

From an economic point of view, the CE can be based on a spiral system that minimizes matter, energy flow, and environmental deterioration without restricting economic growth or social and technical progress [12].

Proper solid waste management is an important step in the transition to a CE, as it helps to maximize the recovery and reuse of materials, which reduces the pressure on new natural resources [13].

The literature on the CE shows that it is possible to use mechanisms to promote regenerative industrial transformations that will open up ways to achieve sustainable production and consumption practices [14].

Some initiatives around the world have applied the principles of the CE to SWM and have tried to highlight the problems faced in its operationalization. Examples include the use of waste as industrial resources [15], the practice of selective collection [16,17], and the reuse of industrial waste [18]. In addition, the CE can also effectively use the biodegradable and non-biodegradable fractions of SWM in integrated closed-loop refinery platforms for resource recovery, bioenergy, and the manufacture of value-added products [19].

A CE requires social actors to work together towards providing solutions to a collective problem, and this capacity is embedded in an institutional context [20]. The institutional capacity signifies the ability of a community of social actors to collectively deal with issues of common concern [21]. Its construction is necessary to achieve common goals [22]. The transition from the linear to the circular economy must occur through a political shift to create a partnership between the business community, policymakers, and institutions [23]. The collective objectives, institutions, and resources are crucial elements of collective action, reflecting both the organizational aspects and institutional capacity and highlighting the relevant role of social actors throughout this process [24].

One example is the importance of environmental education as a trigger to sensitize these actors as driving agents of selective collection, since the act of segregating dry from wet waste not only corroborates environmental issues but also economic and social ones, since it allows for an improvement in living conditions for many waste pickers, especially in developing countries, who conduct this activity as a means of subsistence [25].

However, despite this positive relationship, the literature highlights gaps in knowledge about how current management systems can be transformed into circular models, incorporating CE strategies in different sectors. Studies show that more research efforts are required in this direction. In addition, there is a need to find the missing link between the shortcomings of industrial sectors and the collaboration of others to enable a CE [26], and there is also a lack of research conducted on the role of governments in implementing a CE [10].

Although the research conducted on the CE has only made its most significant contributions in the last decade, several reviews can be found in the scientific literature. The current state of the research on the CE shows that, although the concept is widely researched and several case studies analyze its application in different contexts, there are few tools and criteria for measuring the degree of circularity of products, companies, or regions [27].

The aim of this study is therefore to perform a meta-analysis of the research published between 2012 and 2022 on solid waste management and the circular economy using bibliometrics. The aim of the study is to answer the following questions: What is the profile and evolution of the scientific research on the CE and SWM over the last ten years? What are the most relevant perceptions of the CE and SWM?

This article is organized into four sections, including the Introduction, which describes the problem and the aim of the study. Then, the theoretical basis addresses the concepts of the linear and circular economy and solid waste management, highlighting some of the problems and challenges related to them. The third section is the Methodology, which de-

tails the steps followed by the researchers to present the criteria for choosing the databases and selecting the articles used in the analysis.

The fourth and final section presents the Results in the form of graphs, maps, tables, and diagrams. Then, in the same section, there is a discussion of the research to highlight the potential of SWM for the development of a CE based on the perception of the authors who have published works more extensively on the topics, as well as establishing their connections. Finally, the article presents suggestions for future research and its limitations.

2. Theoretical Basis

In this section, we observe some of the challenges arising from the linear economy, the current obstacles to SWM, and the concept and advantages of using a CE. We also present some disruptive strategies that can help solve the problems posed by different types of SWs.

The current global economic system, inherited from the Industrial Revolution of the 19th century [28], considers the planet's resources to be infinite and the Earth to have a high regenerative capacity. This linear model is summed up in the pillars "take, make, dispose of", i.e., capture the resources needed to meet human needs, produce goods that can be sold for increasing profits, and dispose of what is no longer needed [2].

Some of the consequences of this system are higher greenhouse gas (GHG) emissions, increased waste generation [8], a reduction in the useful life of landfills, and permanent environmental damage [29]. These are constant challenges for public managers and decision makers, as well as going against the grain of sustainable development.

In general, waste becomes a problem as soon as it is generated and not properly treated. Poor management also negatively affects the urban environment and human health, leading to reduced productivity and economic development [30]. In addition, they can also contaminate the soil and groundwater [31].

Developing countries traditionally send their waste to open-air landfills, known as dumps, controlled landfills, or sanitary landfills, with little or no recovery of materials that can be recycled [32]. In developed countries, waste is burned in power plants to generate electricity [33].

In this way, adopting modern SWM practices with efficient collection mechanisms and encouraging the work of waste-picker cooperatives, setting up landfills that are built correctly from a technical perspective, and recovering waste for energy (waste to energy) are consolidated as relevant opportunities for improving the urban environment, as well as adding value to post-consumer materials and by-products [34,35].

On the other hand, SWM can be characterized as a considerable problem [2,36], i.e., complex and difficult to solve because it involves legal, environmental, social, economic, cultural, institutional, and technical aspects. It requires equally complex means of management that are based on a paradigm shift.

This is the case, for example, when incineration is performed to reduce the volume of waste and generate electricity. This practice can pose obstacles to public health and contribute to global warming when not conducted correctly or within acceptable parameters [37].

To reduce the challenges presented by the linear economy, or the SWM, there was a need to transition to another model: the circular model [38].

In a CE, the value of products and goods is maintained for as long as possible. Waste and resource use are minimized, and when a product reaches its end of life, it is used again to create more value. This can create many economic benefits, which contribute to innovation, growth, and job creation [11].

A CE is a new paradigm for sustainable development and promises to overcome the contradiction between economic and environmental prosperity [39]. This concept describes the Earth as a closed, circular system with a limited assimilative capacity and shows that the economy and environment must coexist in a state of equilibrium [40].

In contrast to the current model of waste management, which operates from a linear perspective, i.e., transporting waste to landfills or dumps [19], a CE seeks to maximize the use value of these materials by creating a closed-loop economy [41].

A CE is built on social production–consumption systems that maximize the service produced from the nature–society–nature flow of material and energy [14]. From this perspective and in line with eco-industrial development, a CE is the realization of the flow of materials in a closed cycle throughout the economic system [42]. In this way, it is understood that, in association with the principles of the 3Rs (reduce, reuse, and recycle), the central point of a CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases [43].

Considerable problems arise in transformation initiatives in the presence of high complexity, considerable uncertainty, profound conflicts, and divergence between stakeholders, as well as the incompatibilities of scale relating to spatial, temporal, and institutional processes [44].

It presents a conceptual model capable of adequately guiding the use of natural resources and waste management initiatives [45].

Some innovative alternatives have emerged in the context of the CE and SWM. One of these is the integration with blockchain (blockchain technology is one of the most recent innovations that can be considered a paradigm for regulating human and business activities [46]. It consists of a distributed mechanism used for storing transactional information in a peer-to-peer (P2P) network [47]). One example is the redesign of plastics by molecular tagging as a way to ensure that they are kept in an infinite cycle and support closed-loop recycling activities [48].

Another path is to consider new circular business models based on 3D printing, RFID (radio frequency identification) tags, Industry 4.0, and the Internet of Things (IoT) [49].

CE has therefore emerged as a viable alternative capable of "curbing" or imposing more intelligent measures on current consumption, provided that it is implemented correctly through its guiding principles in the context of SWM.

3. Methodology

This research was exploratory and qualitative–quantitative, and the data collection procedure used was a literature review, which represented the initial step to aid in the process of identifying the most relevant documents [50].

Bibliometrics made it possible to identify, through qualitative and quantitative analyses, the connections between the circular economy and solid waste management in the literature. There are many elements to be explored, but some can be highlighted, such as (a) trends and relevant emerging topics; (b) connections between researchers and universities; (c) metrics that help to assess the quality of research; (d) identification of the gaps in the literature; (e) support for the creation of public policies; and (f) the direction for new research. All these aspects help researchers and managers to focus more thoroughly on areas that require greater attention, especially in areas important to society, such as solid waste. Thus, the bibliometric study facilitated an understanding of the relationships between the circular economy and waste management, with the aim of contributing to the advancement of new discoveries and the search for alternatives for sustainable development.

The starting point was a bibliometric analysis of the publications on the circular economy and solid waste management between 2012 and 2022. This was because, during this period, there was a growing increase in consumer awareness of environmental issues [51]. In addition, there has been a prioritization of waste policies, especially in Europe, where social change is of great importance for SW [52].

The methodological steps were as follows: (a) a selection of the databases; (b) the identification of the keywords that served as search arguments; (c) a choice of the data processing tool; (d) a definition of the parameters to be applied; (e) the identification of the publications returned in the search; (f) a joint analysis of the results in order to eliminate duplicates; and (g) qualitative and quantitative analyses of the results.

The databases selected were WoS and Scopus, as they collated articles obtained from renowned journals with a high impact factor and were widely appreciated by the entire academic community. The research was conducted between January and February 2023, and the keywords defined for the search were "CIRCULAR ECONOMY" and "SOLID WASTE MANAGEMENT".

The inclusion and exclusion criteria for the selected articles considered the relationship between the terms "circular economy" and "solid waste management". To perform this task, the title, abstract, and keywords of the non-repeated articles were read. The search for interconnections between the terms was the main focus of the selection of the articles. In order to ensure that the process was more robust, repeated articles were discarded because two different databases were used. In order to deal with possible biases, the selection criteria identified above needed to be clear and well applied, so as to maintain as much impartiality as possible.

The software used to process the data was the R language, together with the Bibliometrix and Shiny packages. They represent a set of state-of-the-art tools that serve the bibliometric flow [53]. The Bibliometrix package was installed in R Studio (the graphical interface for manipulating databases) and used a posteriori to process the imported metadata. The Shiny package consists of a user-friendly graphical interface that displays the processed information (output) in a simple and intuitive way, making it much easier for researchers to analyze it.

After consulting the Scopus and WoS databases, it was observed that the exported file formats were varied, but not all of them were accepted by the data processing tools. These formats can be observed in Table 1.

Table 1. Laws governing the bibliometric study.

Laws	Measure	Criteria	Main Objective
Bradford Law	Journal's degree of attraction	Reputation of the journal	Identify the most relevant journals that provide the most information on a specific topic
Zipf Law	Frequency of keywords	Ordered list of themes	Estimate the most recurrent themes related to a field of knowledge
Lotka Law	Author's productivity	Size and frequency	Estimate the impact of an author's production on a specific field

In order for the R language and the Bibliometrix and Shiny packages to process the data, BibText files with the extension bib were selected from the databases.

The search string used in the WoS database was as follows:

TS = ("Circular Economy") AND TS = ("Solid Waste Management")

In this context, the keywords "circular economy" and "solid waste management" were the search strings used and applied together using the Boolean "AND". This informs the database algorithm that both words should be searched together. The acronym TS stands for topic searched.

In order to filter the search by time, the time frame of interest was: "1 January 2012 to 31 December 2022". In the end, 253 articles in this classification were returned to the WoS database.

For the Scopus database, the search was conducted as follows:

(TITLE-ABS-KEY("Circular Economy") AND TITLE-ABS-KEY("Solid Waste Management")) AND PUBYEAR > 2011 AND PUBYEAR < 2023

The search method was the same, with a few minor variations that were specific to the platform. In this case, the search strings were entered using the "TITLE-ABS-KEY" command. Here, it was requested that the works returned be from the year 2012 onwards (in this case, as the Boolean used was only greater than ">", the algorithm did not consider

the year 2011 within the time interval, i.e., the count started from 2012). Likewise, the end date considered articles published before the year 2023 as exclusive. In the end, the search on Scopus returned 341 scientific articles. The two databases (Scopus and WoS) were then imported into R Studio and processed using the Bibliometrix package.

The first step was to merge the two databases and perform a joint analysis. The aim was to exclude duplicate files, and at the end of this stage, a total of 594 scientific articles were obtained. After excluding the duplicates, a sample of 421 results (metadata) was obtained. Figure 1 shows a summary of this stage.

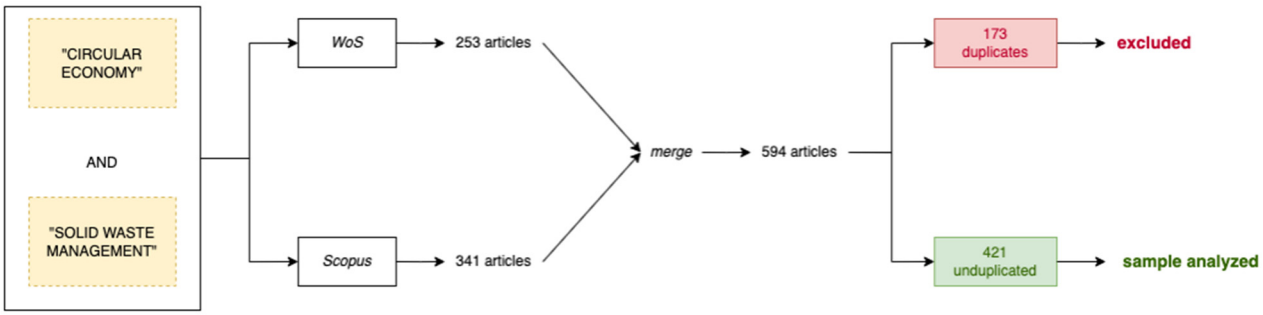

Figure 1. Data collection and sample definition step.

The initial investigation was quantitative, and the items analyzed were their metadata, such as (a) the evolution in the number of publications over the years according to the time frame established (2012 to 2022); (b) the most relevant journals addressing the subject under investigation; (c) the countries where the subject was best known; (d) the main authors and the impact of their production in a given area of knowledge; (e) the collaboration network between countries; (f) the correlation between keywords plus, authors, and affiliations; and, finally, (g) the most relevant and recurring keywords in all the publications.

4. Results Analysis

Section 4.1 uses graphs, maps, diagrams, and tables to answer the first question presented in this study. The data were organized according to the outputs processed by the software and analyzed independently by the authors. In the end, a consensus was reached regarding the results we presented.

The second question is answered in Section 4.2, which presents the studies of some authors who became salient during the bibliometric analysis.

4.1. Overview of Publications

This subsection presents an overview of the most important characteristics of the 421 publications considered in the bibliometric analysis, discussing some of those selected that align with the proposal of this work. The following section continues the discussion of the articles, however, with a particular focus on the contributions that the CE makes to SWM and vice versa.

Figure 2 presents the quantitative evolution of scientific article publications between 2012 and 2022. It shows that the number of papers published until 2018 was low, resulting in zero publications in 2013. In 2016, the number of publications more than tripled, from 3 to 10, increasing considerably the following year when it reached 23, decreasing slightly in 2018. However, further publications were made in 2019 and did not stabilize, reaching 105 papers in 2021 and 127 in 2022. Over the last 10 years, the annual number of publications has increased from 2 in 2012 to 127 in 2022, representing an increase of 6250%. Thus, it is possible to conclude that the themes of the "circular economy" and "solid waste management" are still expanding and receiving greater attention from the research community around the world.

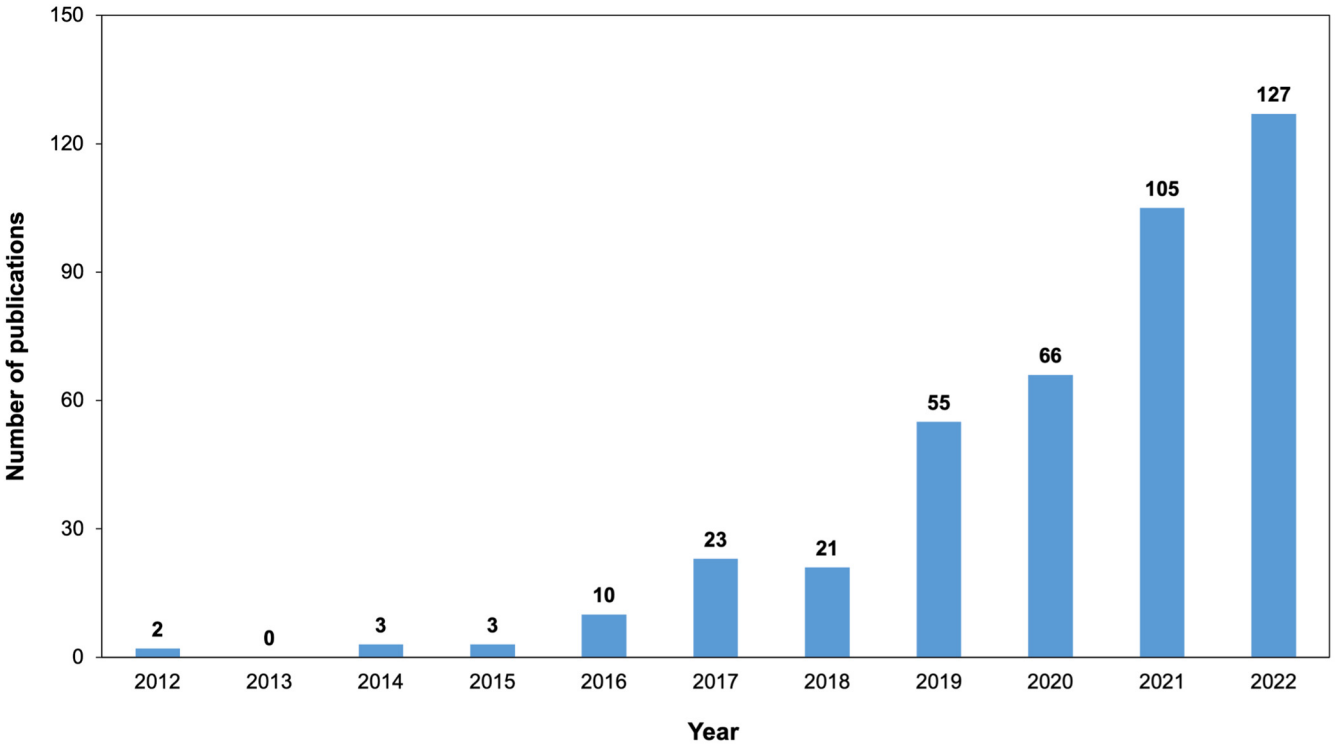

Figure 2. Evolution of the number of publications per year from the WoS and Scopus databases.

Figure 3 presents the top ten journals published within the context of the sample studied, their respective numbers, and impact factors. There are 201 publications, which represents 47.7% of the total. Waste Management has 34 publications and the highest h-index impact factor of 15. On the other hand, the journal Sustainability is at the top of the list with 35 published papers, but with an h-index impact factor of 9.

When analyzing the graph, it can be inferred that journals publishing articles on the circular economy and solid waste management have a bias towards sustainable issues, environmental management, and energy. This highlights the strong connection between these keywords, reinforcing the idea that solutions to the problems caused by solid waste can be identified in the principles of a CE.

An interesting way to visualize scientific production in a CE and SWM is through maps. Figure 4 and Table 2 present the ten nations with the highest scientific outputs in the CE and SWM between 2012 and 2022. China and Italy account for 27.31% (115 papers) and 25.17% (106 papers) of the total, respectively. Together, this figure reaches 52.48% (221 papers). Some authors highlight that Italy has a strong tradition of partnerships and collaborative work between universities, research institutes, companies, and the government. These interactions can facilitate the sharing of knowledge, resources, and funding for research projects concerning both the CE and SWM.

In the case of China, intense investments in the research and development of this area exist, addressing the innovations in technologies used for recycling, waste treatment, and the circular economy. In addition, the financial support received from the government and partnerships with universities and companies that boost scientific research in these areas are evident.

On the map, their territories are marked with a darker shade, indicating the highest productivity levels. Brazil appears in third place with 87 publications, corresponding to 20.66%.

Figure 5 presents the ten authors with the highest number of publications and their respective impact factors (h-index). In terms of productivity indices, Navarro FERRONATO and Vincenzo TORRETTA together account for around 5.7% of all publications on the CE

and SWM between 2012 and 2022. Costas VELIS is in third place with seven publications, followed by a tie between Sunil KUMAR, Marcelo Antonio Gorritty PORTILLO, and Elena Cristina RADA with five papers each. The following positions are occupied by Nibin CHANG, Obiora EZEUDU, Eleni IACOVIDOU, and Tonni KURNIAWAN, with four articles each.

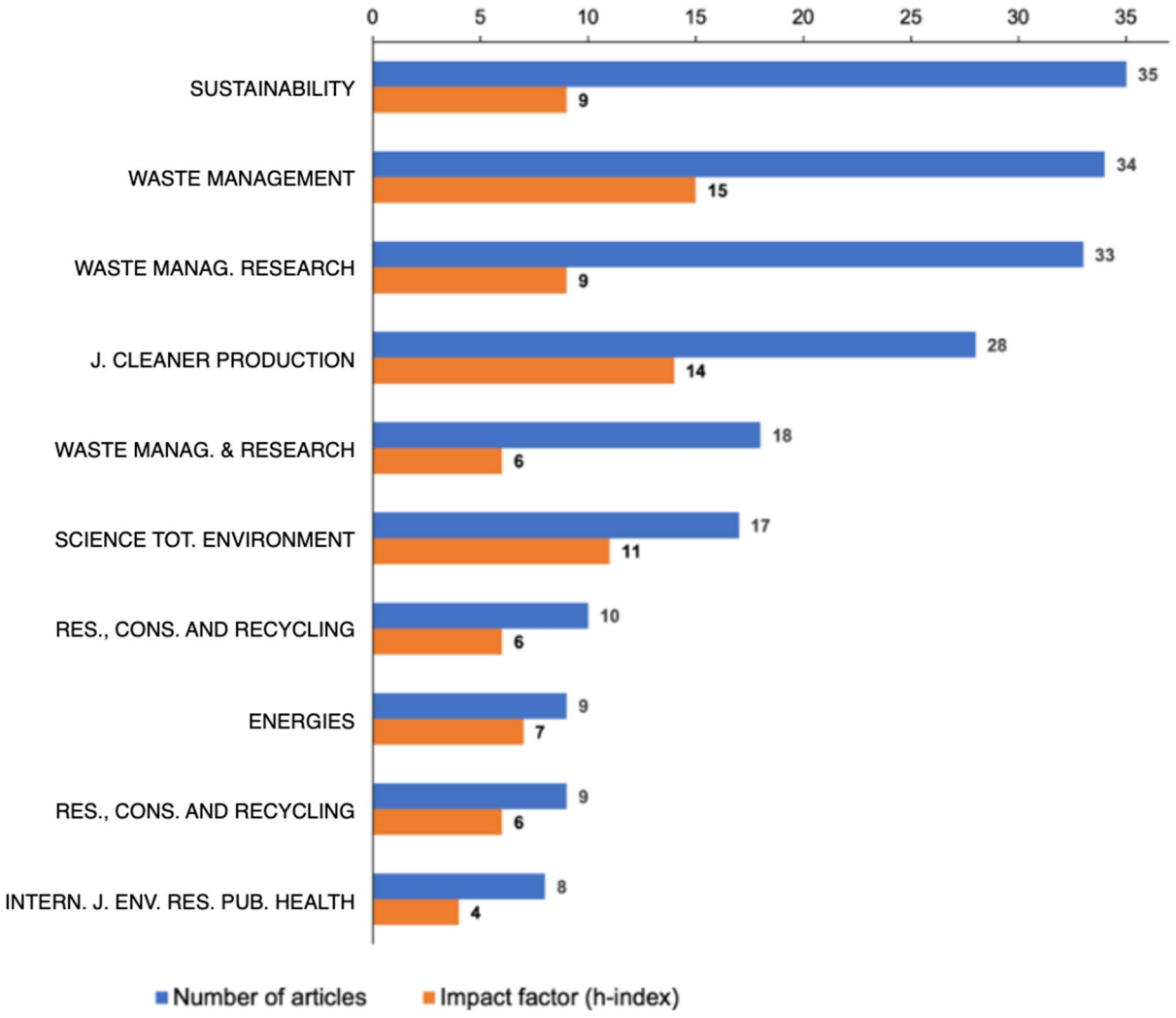

Figure 3. Ten most relevant journals by quantity and impact factor (h-index).

Table 2. Ten countries with the highest scientific production levels in the CE and SWM between 2012 and 2022.

Placement	Country	Number of Publications
1	China	115
2	Italy	106
3	Brazil	87
4	India	71
5	United Kingdom	61
6	United States	49
7	Spain	47
8	Germany	40
9	Malaysia	35
10	Greece	33

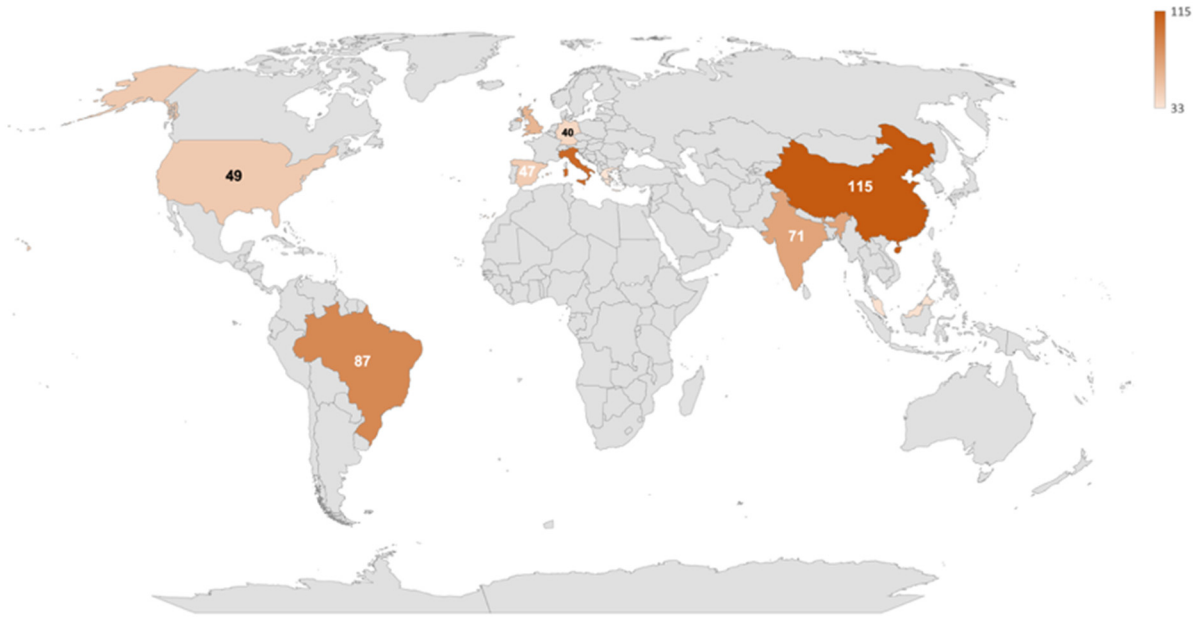

Figure 4. Countries with the highest scientific outputs in the circular economy and solid waste management between 2012 and 2022.

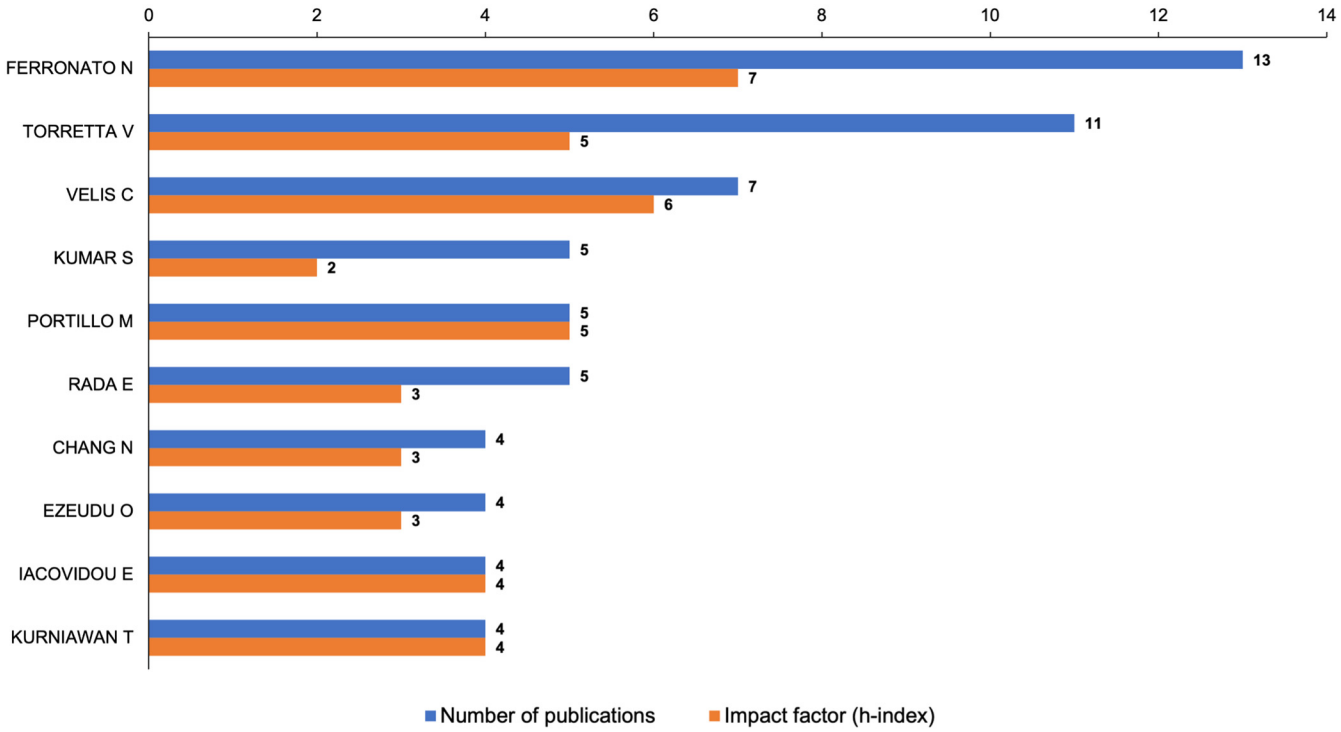

Figure 5. Ten authors with the highest number of publications and impact factors (h-index).

The collaboration between countries was another key point to consider in the scientific production process. In the context of this research, Figure 6, together with Table 3, presents this relationship and shows greater and lesser proximity results between the nations. The numbers and size of the circles represent the number of publications (the more publications, the larger the circle), and the thicker the connecting line between the nodes, the greater the degree of collaboration. Based on the results, Italy–Bolivia (10) is followed by China–Malaysia (9) and together lead the ranking of joint publications. Other partnerships, such as China–Ireland (4), Italy–Romania (4), Spain–Colombia (4), Brazil–Portugal (3), Brazil–Spain

(3), Brazil–United Kingdom (3), China–Japan (3), and China–United Kingdom (3), appear with lower frequencies but are relevant for broadening the debate.

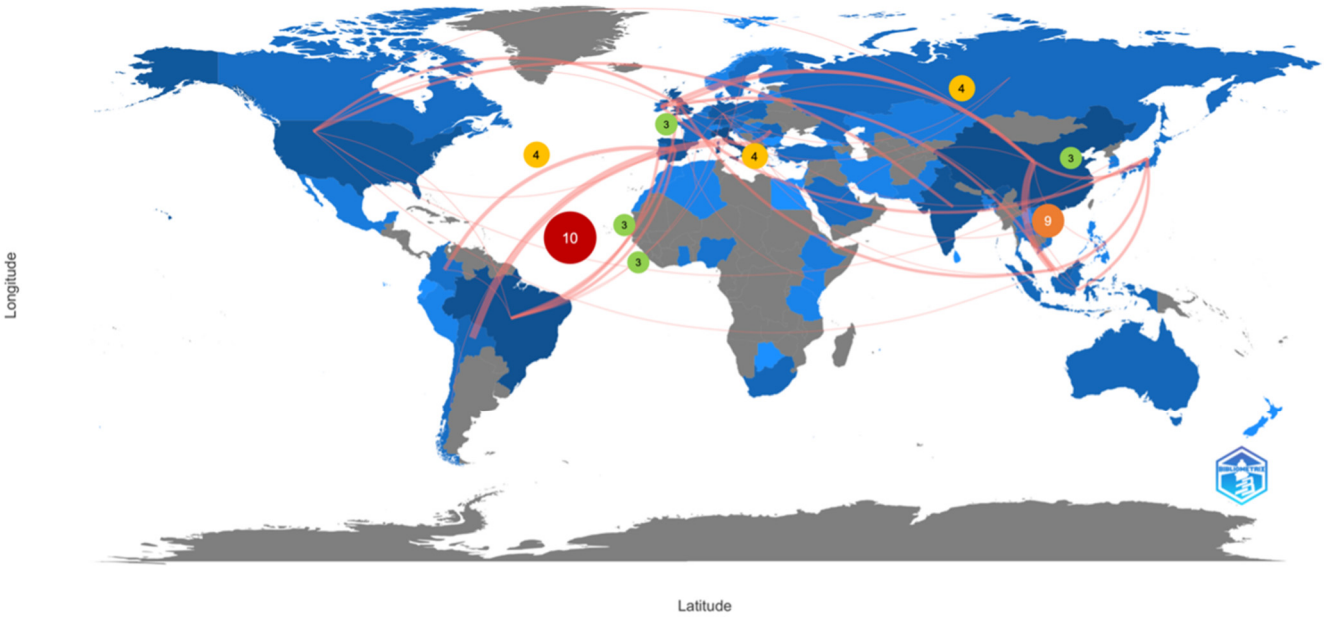

Figure 6. Collaboration network between countries on the themes of the circular economy and solid waste management.

Table 3. Collaboration between countries.

Placement	from	to	Frequency
1	Italy	Bolivia	10
2	China	Malaysia	9
3	China	Ireland	4
4	Italy	Romania	4
5	Spain	Colombia	4
6	Brazil	Portugal	3
7	Brazil	Spain	3
8	Brazil	United Kingdom	3
9	China	Japan	3
10	China	United Kingdom	3

Figure 7 presents the Sankey diagram, which presents the connection between the elements arranged in three columns by means of different curved lines and thicknesses, starting from the left and shifting to the right. The greater the thickness, the greater the relationship.

The first column shows the most frequently used keywords, the center shows the most productive authors, and the right shows the affiliations (universities) that published the highest number of articles within the proposed time frame (2012–2022).

Ferronato, Torreta, and Velis stood out in terms of the number of publications evident. Their research focused on recycling, municipal solid waste, the circular economy, and waste management, and they were affiliated with Insubria, Trento, and Leeds Universities. It is therefore possible to infer that these terms are closely related and should be considered together when discussing specific public policies.

Recycling, waste management, and the circular economy were the most-studied terms. The frequency with which they co-occur with other keywords indicates certain research trends and shows that, in the last ten years, they have gained worldwide prominence and importance among scholars.

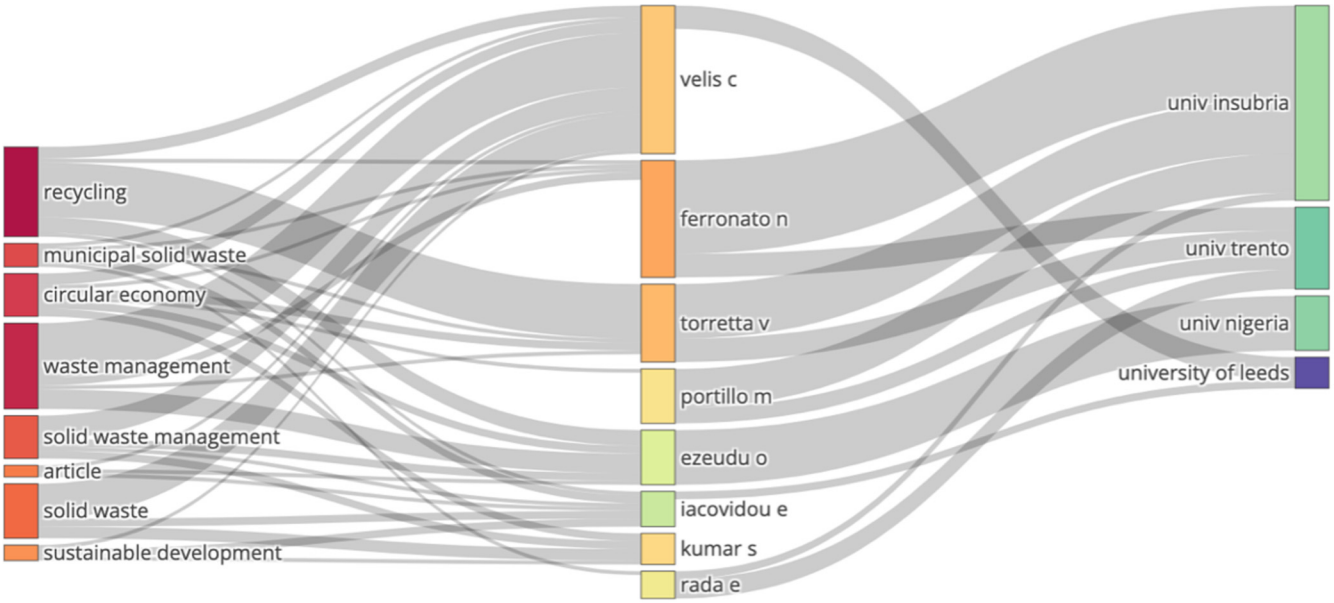

Figure 7. Correlation between keywords plus, authors, and affiliations.

The top ten occurrences of the authors' keywords are presented in Table 4. Recycling is in first place with 169 occurrences. Waste management, circular economy, municipal solid waste, solid waste management, and solid waste are in sixth place, with a total of 535 appearances. This shows that the subject discussed in this study is being debated in a relevant way and as an important alternative for solving the issues linked to the problems caused by solid waste.

Table 4. Frequency of the top ten keywords.

Ranking	Keywords	Occurrences
1	Recycling	169
2	Waste management	153
3	Circular economy	111
4	Urban solid waste	102
5	Solid waste management	97
6	Solid waste	72
7	Articles	65
8	Sustainable development	49
9	Waste disposal	48
10	Economic aspect	41

To analyze the co-occurrence of the keywords, we considered those written by the authors in the titles of the articles, i.e., the so-called keywords plus, as they were more comprehensive and more likely to portray the content discussed in the article. For a set of fifty words, the Bibliometrix algorithm created a word cloud, which can be observed in Figure 8.

Following the logic of this type of graph, the size of the words was proportional to their frequency, i.e., the larger they were, the more frequently they appeared. The terms "recycling", "waste management", "circular economy", and "municipal solid waste" stood out, demonstrating their importance in this context.

The gradual increase in the number of publications using these terms highlighted new perspectives that reinforced the debate about the problems caused by SWM errors and the lack of public policies aligned with the principles of the CE. The papers innovatively presented novel approaches so that effective solutions could be presented to society.

Figure 8. Cloud of the authors' top fifty keywords (keywords plus).

In summary, some articles could be cited, based on the authors' perceptions of the connection between the CE and SWM. For example, one of the papers written by Ferronato et al. [54] showed that the CE could represent an important alternative for improving SWM activities around the world, as it advocated the recovery and recycling processes of materials to boost developing economies.

In relation to planning practical actions to solve the problems posed by waste, it is worth highlighting the work conducted by Velis et al. [55], where they present recycling by the informal sector as a rapid and cheap solution to pollution, especially plastics. They advocated the idea of three interventions in the management process that were in line with the principles of the CE: (a) Reducing barriers to collection; (b) increasing revenues from materials through a better sale price, providing better remunerations for waste pickers; and (c) increasing the quality of the materials. According to the authors, once properly developed and implemented, these interventions can boost collection rates, reduce plastic pollution levels, and help many people escape poverty.

Finally, the work of Rena et al. [56] evaluated the technological interventions and innovative solutions as necessary to deal with the environmental impacts of waste accumulation. According to the authors, the perception of considering waste as a resource and recycling it to obtain value from it has considerably changed the approach to SWM. Technological eco-innovations can also be highlighted, which include the automation of separation and collection processes, route optimization, and digital applications to improve communication and treatment technologies.

It is also important to highlight the role of cooperation in the relationship between SWM and the CE. Once internalized by the social actors, the possibility of the circular principles maturing can be increased, making practices aimed at dealing with SWs gain traction in a practical context, which can help managers and policymakers conduct their work more efficiently and effectively.

4.2. Connections between Solid Waste Management and the Circular Economy

Within the time frame of 2012 to 2022, several authors from different countries presented important ideas about the CE and SWM in order to establish connections or points of convergence. Below, we present some of the works identified during the bibliometric analysis of the authors who stood out the most and contributed to broadening the debate on the thematic proposal of this article. Our aim was to provide an answer to the second research question.

The discussion began with addressing the results obtained by Di Foggia and Beccarello [57]. The study analyzed the imbalance in waste management activities conducted

throughout Italy, estimating the quantities of materials to be treated using different technologies. In addition, the authors estimated the impact that a system compatible with the CE objectives would have on the cost of waste management.

The research suggests that waste management capacity plays a major role in meeting the CE targets, such as reducing the disposal of municipal waste in landfills to 10%. This is an important conclusion, given the high levels of recyclable and non-recyclable materials that end up being sent for final disposal without receiving adequate selective collection treatments, considerably reducing the useful life of landfills.

The authors concluded that the inclusion of CE elements in the SWM process in Italy could reduce the use of landfills by 11.5% and increase the capacity to convert waste into energy by 4.6% compared to the current scenario. There would also be an increase in the treatment potential of the organic fraction by 8.3%, a positive impact on the environment, and annual savings in the cost of managing the system of between 0.07% and 0.27% in the treatment and final disposal phases [57]. It can therefore be inferred that this practice has great potential to provide rapid results if implemented in other countries, consolidating itself as an interesting strategy for connecting the CE with SWM.

From a more theoretical perspective, Rada et al. [58] presented a preliminary critical analysis of the literature and emphasized the need to build indicators to facilitate the evaluation of SWM based on the principles of the CE. They advocated the development of indices for material reuse processes, green energy production (such as biofuels), and the sustainability of the management system as a whole.

However, a problem in adopting indicators is related to low-income regions, where there is inadequate waste collection or even the absence of a culture of data generation in the management system [58]. Thus, in order to conduct waste management more effectively within the context of the CE, it is necessary to generate accurate data so that the indicators have a high potential to help administrators make decisions.

Generating these data can be an obstacle, as they can be difficult to obtain, requiring good planning and coordination practices between public managers and the population.

With a local focus, the article presented by Ferronato et al. [17] provided the results for a waste recycling and recovery project conducted in La Paz (Bolivia). The aim was to share the best practices and real challenges when implementing appropriate SWM systems in a real context in developing countries that intended to incorporate the benefits of a CE.

A very relevant aspect of the discussion between SW and the CE was linked, according to the authors, to environmental pollution, social inequality, a lack of resources, and economic discrepancies that were consolidated as challenges still present in the 21st century. The results of this research provide two main indications: Firstly, that cooperation between the interdisciplinary actors and financial support can improve the system, thus bridging the gap between theoretical discourse and practice; secondly, political instability, a lack of local technical knowledge, and the absence of long-term planning are barriers to the implementation of actions aimed at developing the CE in this context. The authors concluded their work by stating that global reflections were required to measure the benefits created by small-scale projects with local applications [17].

Nevertheless, from a local perspective, there is an increasing awareness that the effective management of waste is essential for the circular transition and, with it, for achieving sustainable development goals. To this end, inter-municipal cooperation acts as a governance solution with great potential to generate economies of scale and reduce the financial costs of the waste management process [59].

The focus of the study was a qualitative case study in the city of Cuenca, Azogues, metropolitan region (Ecuador). The authors discovered that municipalities that invested in more complex cooperation systems achieved a better performance in the process of managing waste, especially in the final disposal stage. In addition, significant results were achieved in terms of citizen participation, the inclusion of waste pickers, and environmental sustainability [59].

Finally, it is worth highlighting the work of Lugo, Ail, and Castaldi [60], where the authors focused on the relevance of reuse as a catalyst for reducing greenhouse gases in New York City. The most recent data, according to the authors, showed that the net emissions reduced annually as a result of reuse were close to 122 × 106 kg of carbon dioxide equivalent (CO_2e) units.

The article discussed the role of reuse in the context of the CE, where the use of resources was maximized when the useful life of the product was increased, causing it to reach its maximum point of reuse [60]. This avoided the need to capture virgin materials from the natural environment within the cycles of the production chain.

In addition to the works highlighted above, we highlighted the future research that the bibliometric analysis identified. The first work was presented by Islam; Iyer-Raniga; and Trewick [49], where the CE enabled the creation of new sustainable business models and recycling was one of the most important strategies for achieving them.

The study developed by Bhubalan et al. [48], where the authors addressed the integration of SWM with blockchain and the CE to minimize waste production activities, was also relevant. This will be made possible once this technology supports green principles through the transparency, reliability, and automation of information.

Additionally, of significance is the research conducted by Tejaswini; Pathak; and Gupta [61], where the authors highlighted the importance of so-called urban mining practices, i.e., the economic valuation of recyclable materials that are collected in cities as an incentive for waste pickers. New development models, such as the circular economy, bioeconomy, and industrial ecology (IE), have emerged in the field in response to a dominant paradigm strictly geared towards targeting economic efficiency [62] and innovation in public policies [63].

The debate involving the CE and SWM is expanding, and the prospects point to an inseparability between them. The creation of effective strategies not only involves the public authorities but also the relevant companies and society. Actions, such as selective collection, reverse logistics, environmental education, and the application of CE principles, are proving to be effective in combating waste generation and the problems caused by it. However, for solutions to exist and to be successfully implemented, greater integration is required between the social actors involved in the process.

The results suggest the need to consider new alternatives that can successfully unite the principles of the circular economy and solid waste management. Decision makers and/or policymakers can focus their efforts on creating new circular waste management models based on the cooperation between social actors. This can provide greater visibility to the circular economy as an interesting and viable path. One option would be, for example, to adapt Elinor Ostrom's IAD framework to suit this reality, bearing in mind that cooperation is its central operating mechanism.

5. Final Considerations

At present, in the context of the linear economy, SWM is the alternative method used by municipalities to solve the problems caused by post-consumer by-products. The CE has therefore emerged as a viable alternative capable of proposing sustainable solutions through sharing, maintenance, reuse, remanufacturing, and recycling methods. It emphasizes the importance of designing products that, when they reach the end of their lives, can serve as raw materials for the production of others, thus reducing the ecological footprint of natural resources. However, despite the fact that this idea has become highly relevant in academic and business contexts in recent years, further research must be performed.

This study conducted a bibliometric analysis of scientific articles over a ten-year period (2012 to 2022) on the circular economy and solid waste management. The purpose was to identify the evolution of the themes in this time frame, as well as their definitions and connections, in order to provide sustainable treatments for SW. It emerges that the CE, through its guiding principles, has great potential to improve the current waste management system and also to promote the creation of new circular business models that

create jobs and generate income for people who work with the collection and processing of recyclable materials. The results were obtained by selecting articles using inclusion and exclusion criteria based on the relationship between the circular economy and solid waste management. The data were then processed using R language algorithms and Bibliometrix software and carefully analyzed by the researchers to provide the best possible insights.

The methodology chosen for processing the data was the R language and Bibliometrix and Shiny packages. After scanning the Scopus and WoS databases and applying the inclusion and exclusion criteria, 421 (four hundred and twenty-one) articles were returned and considered for the exploratory study. The most relevant articles were selected to promote a debate on SW and the CE to identify their mutual connections and contributions to society. It was observed that the topics had been studied in several countries, with the collaboration between Italy and Bolivia standing out, followed by China and Malaysia. However, other partnerships appeared in the results, such as China and Ireland, Italy and Romania, Spain and Colombia, Brazil and Portugal, Brazil and Spain, Brazil and the United Kingdom, China and Japan, and China and the United Kingdom. Individually, China, Italy, Brazil, India, the United Kingdom, the United States, Spain, Germany, Malaysia, and Greece stood out.

Considering the content of the papers, the relevance of the CE to SWM and vice versa was clear. By adopting reuse and recycling strategies, the volume of discarded materials can be reduced, and those that remain are absorbed by companies or waste-picker cooperatives that use them as a source of income and work. These actions extend the useful life of landfills and reduce local environmental impacts. However, the participation of social actors is crucial to the success of this relationship. These include public authorities, the business sector, and civil society.

The CE offers great opportunities for municipalities to adapt their SWM systems to their realities. This can be achieved by optimizing the useful life of landfills by increasing the treatment of organic waste, encouraging waste-picker cooperatives, and the provision of selective collection programs for small and large generators. In addition to the benefits provided to the final disposal area, there was also a reduction in the financial costs of the system as a whole, making the system more durable and sustainable.

This paper presented an overview of the publications on SWs and the CE, outlining aspects, such as the evolution of the practices over the last ten years, the important journals, countries, authors, collaboration networks, and the frequency of the main keywords in the relevant databases. It showed the emergence of north–south bridges, especially with partnerships between countries located in Europe, Latin America, and China.

The aim of the study was to contribute to new debates, especially in countries that have not yet incorporated the CE into their modus operandi, notably developing economies. A research gap we identified was the need to adapt the principles of the circular economy to create new circular systems in order to stimulate the optimization of consumption, reuse, repair, and recycling practices.

Other methodological approaches can also be used, such as Pearson's correlation analysis, case studies, and systematic literature reviews. In addition, exploring articles written in languages other than English can provide an alternative perspective to the one presented in this paper, providing a broader view of solid waste and the CE.

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