UFSM

ReA UFSM
Revista de Administração da UFSM

ISSN 1983-4659
OPEN ACCESS

Rev. Adm. UFSM, Santa Maria, v. 16, n. 1, e9, 2023 https://doi.org/10.5902/1983465971448
Submitted: 24/08/2022 • Approved: 15/01/2023 • Published: 29/03/2023

Circular economy and sustainable development goals: main research trends

Economia circular e objetivos de desenvolvimento sustentável: principais tendências de pesquisa

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ABSTRACT

Purpose: This work aimed to analyze the scientific literature related to the Circular Economy (CE) and the Sustainable Development Goals (SDGs) to identify its main research trends.
Design/methodology/approach: For this purpose, bibliometric and scientometric analysis of the scientific production indexed in the Web of Science database was applied. The scientometric analysis was performed using the CiteSpace software, one of the most influential network software currently.
Findings: The results point out trends and challenges for the evolution of sustainability research based on aspects of the 2030 Agenda and the Circular Economy. In particular, trends involve great advances in the number of publications and citations, interdisciplinarity and multidisciplinarity of research categories, dense research network between countries, author co-citation analysis, network of main keywords, identification of keywords with citation burst and their distribution in timelines, and, finally, classification of studies in thematic clusters.
Practical implications: The implication of the study is twofold: it will support the development of sustainability based on the 17 SDGs, with the circular economy being one of the areas in growth and development of solutions for sustainability, and it will help guide the overcoming of thematic gaps.
Originality/value: This study is the first one that we are aware of to carry out a scientometric and bibliometric analysis aligning the two themes, CE and SDGs. Thus, we contribute to the literature by unveiling the main trends in the field and identifying research directions, which is particularly useful in new and challenging themes for the academic community and for managers.

Keywords: Circular economy; Sustainable development goals; Scientometrics; CiteSpace

RESUMO

Objetivo: este trabalho objetivou analisar a literatura científica relacionada à Economia Circular (EC) e aos Objetivos de Desenvolvimento Sustentável (ODSs) com vistas a identificar suas principais tendências de pesquisa.
Design/metodologia/abordagem: Para tanto, foi aplicada análise bibliométrica e cientométrica da produção científica indexada na base de dados *Web of Science*. A análise cientométrica foi realizada com auxílio do software CiteSpace, um dos mais influentes softwares de rede da atualidade.
Resultados: Os resultados apontam tendências e desafios para a evolução da pesquisa de sustentabilidade baseada nos aspectos da Agenda 2030 e da Economia Circular. Em particular, as tendências envolvem grande avanço do número de publicações e de citações, interdisciplinaridade e multidisciplinaridade das categorias de pesquisa, rede densa de pesquisa entre países, análise de cocitação de autores, rede de principais palavras-chave, identificação de palavras-chave com explosão de citações e sua distribuição em linhas do tempo, e, por fim, classificação dos estudos em cluster temáticos.
Implicações práticas: A implicação do estudo é dupla: apoiará o desenvolvimento da sustentabilidade baseada nos 17 ODS, tendo na economia circular uma das áreas em crescimento e desenvolvimento das soluções para a sustentabilidade, e auxiliará no direcionamento da superação de lacunas temáticas.
Originalidade/valor: Este estudo é o primeiro de que temos conhecimento a realizar análise cientométrica e bibliométrica alinhando os dois temas, EC e ODS. Assim, contribuímos com a literatura ao desvendar as principais tendências do campo e identificar direções de pesquisa, o que é particularmente útil em temáticas novas e desafiadoras para a comunidade acadêmica e para gestores.

Palavras-chave: Economia circular; Objetivos de desenvolvimento sustentável; Cientometria; CiteSpace

1 INTRODUCTION

Due to the continuous growth of consumption and mass production, the acceleration of global warming and the increasing loss of biodiversity, among other factors, the 21st century has presented a series of challenges to the fulfillment of the principles of sustainability. It is important to highlight that in the last three decades, sustainable development has been discussed on a global scale, based on the first insights into environmental issues and the effect of unregulated industrial activity.

The 2030 Agenda is a United Nations (UN) initiative that proposes a comprehensive agreement on sustainable development. The agenda was formed by 193 countries in 2015 and is divided into 17 Sustainable Development Goals (SDGs) - encompassing 169 goals that must be achieved by 2030. The scope is broad and diverse requiring the connection of their purposes.

Several multidisciplinary studies seek to find solutions to the unsustainability of current economic models, seeking new alternatives based on the sustainability tripod (Lewandowski, 2016; Kirchherr et al., 2017; Whalen et al., 2018; Alonso-Almeida &

Rodriguez-Anton, 2019). In this perspective, the circular economy (CE) stands out as a principle that aims to seek sustainability in the local, national and global spheres. Kirchherr et al. (2017) conceptualize it as an economic system that seeks to reduce, reuse, recycle and recover resources through sustainable business models.

In this sense, CE represents an opportunity for significant changes in business, as it requires them to think beyond their environmental and energy efficiency goals (Leitão, 2015). CE principles suggest the transition to a system in which the value of products, materials and resources is preserved in the economy for as long as possible, with the least generation of waste, thus encouraging new forms of sustainable innovation and regional development (Kalmykova et al., 2018). Reflecting on the main current economic models and their consequences is a challenge that extends from the local to the global, from the quality and protection of individuals to the survival of ecosystems, taking into account the critical and immediate needs of developing countries (Goyal et al., 2018).

Despite this broad interest in the growth of academic research in this field, gaps still exist in the knowledge quest for a truly circular economy and the widespread adoption of its most promising strategies. In this sense, the fact that CE is a relatively new topic makes it difficult to disseminate its concepts and evaluate them (Kalmykova et al., 2018). However, despite the absence of a consensual definition, several scholars approach it as a systemic transition to an economically viable but regenerative paradigm, based on the reintroduction of used materials through material cycles (technological and biological) (Geissdoerfer et al., 2017).

CE encourages resource use, waste reduction and pollution reduction, while maintaining socioeconomic stability (Ghisellini et al., 2018). Furthermore, Schroeder, et al. (2019) explain how two strands will help the European Commission to achieve the 17 Sustainable Development Goals (SDGs). The first is the implementation of circular strategies with the objective of reducing or reusing resources in the distribution of value. The second reduces waste disposal directly into the environment.

Thus, thinking about sustainable business models based on CE and its effects on the environment has challenged both locally and globally in the definition of goals for SDGs. CE appears as an opportunity to think beyond environmental practices, seeking to incorporate a more efficient system that encompasses products, primary materials and resources that generate less waste, facilitating regional development and innovation (Leitão, 2015). In this scenario, it is important to point out that modifying the current linear paradigm is not possible only through theoretical or technological propositions, but a transformation is necessary that seeks to direct companies and different sectors in the formulation of effective strategies, with the objective of promoting efficient political interference and influence consumer behavior (Favot et al., 2018).

Furthermore, this research seeks to present different practical and theoretical studies that present at their core theoretical innovations as well as applied studies with the CE and ODS themes at a global level. In addition, the contributions presented in the results through the Web of Science research in the period from 2015 to 2020 aim to provide an information platform on the different emerging methodologies, use of technologies applied worldwide, case studies, among other practices that foster a resource management focused on sustainable premises and that is rooted in the essence of CE. With this, the objective of the study emerges, which is to analyze the scientific literature related to the circular economy and the sustainable development goals to identify its main research trends.

The theoretical concepts of the study will be presented below.

2 THE IMPORTANCE OF THE CIRCULAR ECONOMY IN THE CONTRIBUTION OF THE SUSTAINABLE DEVELOPMENT GOALS (SDGS)

The interfaces of the current economy are still based on an open linear system, that is, a circuit that extracts, transforms, distributes, consumes and discards data (Veiga, 2019). In this sense, it is evident that industrialization is one

of the most fundamental causes of environmental degradation, resulting in unsustainable production models. Burger et al. (2019) suggest that a production system based on sustainability principles, or a circular model, is necessary. The concept of circular economy originates according to Martins-Rodrigues et al. (2020), in the theory of thought of the Economics of Sustainable Development (eco-development), based on the balance between economy and environment, called green economy and related to green jobs (Sulich, Rutkowska, & Popławski, 2020).

In this scenario, the theme that has stood out since the 1970s is the circular economy (Ryen et al., 2018). Different authors, such as Ghisellini et al., 2016 and Zink & Geyer (2017) point out that the first understanding of the topic was by Pearce & Turner (1989), who highlighted that those natural resources impact the economy and supply for manufacturing and consumption. However, this concept was based on the study by Bouding (1966) who described the planet earth as a closed and limited circular system, concluding that economic activity and the environment should exist in parity.

It is important to highlight that CE was already practiced by our ancestors, but without this designation. This concept has been explored in depth in recent years (Kirchherr et al., 2017). Although, we can consider its peak in 2015 marked fundamentally by the action plan for the circular economy of the European Union, the Sustainable Development Goals and the Paris Agreement.

Leitão (2015) highlights that the circular economy represents a relevant change for companies, as it forces them to rethink the economic practices of today's society, to generate economic growth, and contribute to balanced and sustainable development. In this vein, companies must include, in the mission, the guiding principles of the circular economy: promoting research, sustainable development, innovation, and a collaborative strategy, which are the basis for the circular economy. In this perspective, the articles found for the foundation were listed in the table below, which allowed us to present an overview of some concepts of circular economy.

Table 1 – Main Concepts of Circular Economy

Concept	Authors
It aims to minimize waste and improve public health and environmental conditions.	Agrawal, *et al.* (2021, p.1053)
Possible solution to problems such as increasing global demand for resources, price volatility for raw materials, and the growing population and consumption around the world.	Alonso-Almeida e Rodriguez-Anton (2019, p. 710)
Product recovery and recycling srategy, aiming maintenence product and materials in use, and regenerating natural systems and promoting their value.	MacArthur, Zumwinkel & Stuchtey (2015) (EMF, 2015)
Aims resources maintenance within the economic system for the longest possible.	(European Commission, 2020)
Strategy aiming reduction of entry of virgin materials and the productions of waste, closing the economic an ecological cycles of resource flows.	Haas, *et al.* (2015, p.765)
Key elemento to break direct relationship between economic growth and the increase of consumption of natural resources.	Hazen *et al.*, (2016); Geisendorf e Pietrulla, (2017); PCM (2017)
Main transformative and integrative philosophy, which is the basis of the ecological and economic policies of the public-private partnership.	Oriekhova (2019, p.415).
Aims at valuing resources, especially renewable and recyclable ones, through in-depth knowledge of the technological, social, environmental, cultural and economic processes, associated with the metabolisdm of the economy.	PNCT (2017, p.3)
Economic system, based on business models which replace the concept of "end of life" with reduction alternatively reuse, recicling and recovery of materials in production/distribution and consumption processes, with the aim of achieving development, which implies creation of environmental quality, economic prosperity and social equity, for the benefit of current and futures generations.	Kirchherr *et al.* (2017, p. 229)
It aims to promote eficiente use and productivity of resourcesit stimulates through products, processes and business models based on dematerialization, reuse, recicling and recovery of materials, extracting the economic value and usefulness of materials, equipments and goods as long as possible.	MdA (2017, p.10)
Closed cyclic system aiming zereo waste, recovering and recycling products which are in the decline phase of its life cycle, into new products.	Stahel (2016)
Its objective is to decoupling social benefits and human well-being from the increasing use, production and consumption of new resources.	(Van Hoof *et al.*, 2018)

Based on the aforementioned concepts, it is important to emphasize that, through CE, the economy is reinvented, boosting its growth and making it more competitive and sustainable. In addition, CE stimulates innovation, reduces carbon and greenhouse gas emissions (Choudhary et al., 2015), improves the security of supply of raw materials; provides a reduction in energy use (Zhalechian et al., 2016), optimizes waste management, among others.

Implementing the circular economy implies: zero waste; and keeping a product's end-of-life materials in the economy whenever possible, so they can be used productively, creating value. It is clear that the shift from a linear economy to a circular economy requires changes at the heart of the company. In this sense, Morseletto, Biermann & Pattberg (2017) denote in their study that for the circular economy to be effective in the company, strategies aimed at optimizing resources must first be developed. Based on these practices, the circular economy has the potential to contribute to sustainability, as it impacts on the reduction and reuse of resources and on the degradation of the environment (Babbitt et al., 2018).

However, knowing the importance of the circular economy today as well as in conferences, roundtables, seminars, among others, studies still need to be deepened regarding the contribution of the CE to the 2030 agenda, contemplating the 17 Sustainable Development Goals guiding the organizations in managing goals and objectives (Sousa-Zomer et al., 2018). It is important to emphasize that the 1970s were the beginning of the first actions on environmental issues interconnected with economic and social issues and in 1987, the Brundtland Report (WCED, 1987), called Our common future, presented by the United Nations World Commission on Environment and Development emerged, where the concept of sustainable development emerged.

According to WCED (1987) there are two concepts at the origin of the term sustainable development, the first, the basic needs of the poor of the global village, which must have priority; and the second, the limitation of natural resources, which can prevent both current and future generations from meeting the needs of both current

and future generations, that is, obtaining economic growth without depleting natural resources for the future. For Chen, et al. (2008) these three concepts: basic needs of the poor, limitation of natural resources and economic development, converge towards sustainable development, aiming at a balanced integration of the three pillars of sustainable development (economic, social and environmental). The three pillars must coexist and interact harmoniously with each other.

Yet, it is only in the 21st century that this paradigm shift occurs, and the first actions effectively emerge. Among the actions by the UN, an agenda called the Millennium Development Goals emerged, which brought together different world leaders in New York, where member countries should insert into their practical strategies aimed at confronting socio-environmental-economic issues in a period of fifteen years, or that is, it ended in 2015. The document consisted of eight Millennium Development Goals (MDGs) and lasted for fifteen years on the world development panorama UN, 2015).

With the goals of the Millennium Development Goals coming to an end and having as parameters the lived experiences, the UN prepared a post-2015 agenda that will last for fifteen years. The document encompasses the 17 Sustainable Development Goals (SDGs) and 168 goals integrating the environmental, social and economic premises of sustainable development, named Transforming our world: the 2030 Agenda for Sustainable Development (United Nations, 2015).

The SDGs include topics such as: poverty, hunger, health, education, global warming, gender equality, water, sanitation, energy, urbanization, environment and social justice. Along with this theme, CEis added in terms of categories that envision a positive impact on the planet and individuals. In this bias, the 17 SDGs, which total 169 goals and 232 indicators, incorporate for measurement and help in the search for CE, contributing to a globally sustainable world (Govindan et al., 2020).

Bashtannyk et al. (2020), highlight the importance of CEfor economic growth, encouraging that emerging technologies and practices can be used in conjunction with other SDGs programs, helping to reduce greenhouse gas emissions and the

use of natural resources (Lieder & Rashid, 2016). At this juncture, international agreements and policies are demanding CE-related initiatives as a prerequisite, making related initiatives a competitive advantage (Filippini et al., 2019).

However, it is important to highlight that in recent years, the circular economy has gained increasing attention as a tool for an integrative and multidisciplinary approach, presenting itself as a solution to some of the most urgent challenges at a global level in the context of sustainable development. Likewise, the United Nations General Assembly defined the 17 Sustainable Development Goals (SDGs) in 2015, with the aim of strengthening global peace and recognizing that eradicating poverty in all spheres and levels, including extreme poverty, is the greatest global challenge is an essential requirement for development. In this sense, it is expected that in the future the CE and the ODS will contribute to the evaluation of companies that practice these principles in essence, providing different possibilities for the global economy and for society, adding resilience, responsibility, and sustainability.

3 METHODOLOGY

According to Araújo & Alvarenga (2011), the method for carrying out this study is bibliometrics, quantitative and statistical. Bibliometric analysis must be systematic, having a fundamental role for Greenhalgh (1997), Café & Bräscher (2008) and Pimenta, et al. (2017) in the analysis of the performance and behavior of the production of scientific knowledge, and must derive from primary studies; in addition, it must act in the exposition of relevant literature in the different areas of research, have clearly expressed methods, and be guided through a clear and reproducible methodology.

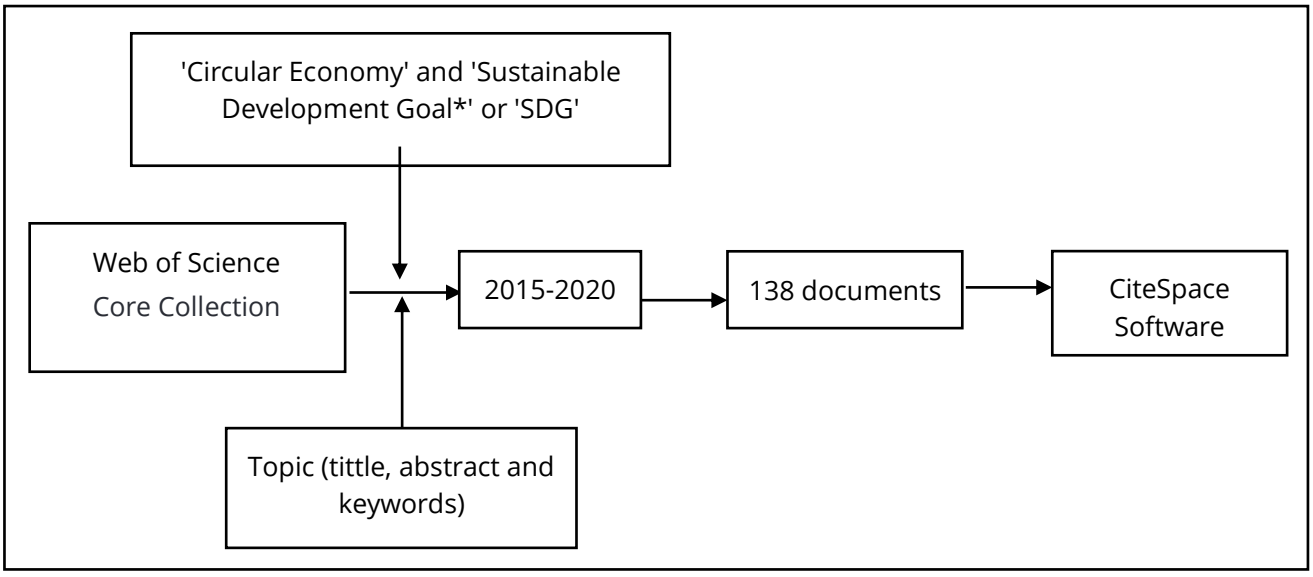
The authors Araújo (2006) and Garousi (2015) define bibliometrics as a set of techniques and procedures that are used to measure the dissemination of scientific knowledge and the diffusion of production on a given subject, with the objective of

evaluating the growth of this production in periodicals, books, articles or databases. Bibliometric analysis is fundamental, as the results show a solid view of the historical evolution on the subject, so that the data serve as a basis for application in future investigations. Scientometric analysis, on the other hand, involves the analysis of co-citation of authors, documents, co-occurrence of words and research categories, countries and their variations, whose relationships can be visualized through networks, graphs, temporal structures, among others (Chen, 2006; 2017).

Bibliometric analysis can use scientometric analysis combined with traditional bibliometric indicators, such as allocation of works overtime, diversified indices of impact, collaborations and citations, whether by authors, organizations, journals, countries and research categories (Araújo, 2006; Zupic & Čater, 2015). It should be noted that bibliometric methods, when correctly applied, can provide objectivity to literature reviews, while they can help researchers in the elaboration of research in line with new trends, as well as contributing to editors in the evaluation of publications and in the direction of policies. and decisions (Zupic & Čater, 2015).

As shown in Figure 1, in April 2021, data were collected for scientometric and bibliometric analysis of scientific production on circular economy and sustainable development goals.

Figure 1 – Research method



Given the specificity of studies on circular economy and their necessary intersection with sustainable development goals, this article carried out a survey in the Web of Science database with the terms 'Circular Economy' and 'Sustainable Development Goal*' or 'SDG' in the field topic, in the indexes of the Core Collection of the Web of Science, for the period between 2015-2020. Therefore, 138 articles were collected, which constituted the work base of the present study. The Web of Science database was chosen due to its relative prominence in the academic setting. The term was used in quotation marks to ensure the identical occurrence of the terms in the search results. in addition, the use of an asterisk at the end of the word "goal" allows the inclusion of variations of that word, such as its plural. finally, the choice of topic (title, abstract and keywords) for the research was due to the representativeness of data collection.

With the CiteSpace software (version 5.7.R2), scientific mapping was performed by co-citation and co-occurrence of authors, documents, keywords and research categories (Chen, 2006). The fundamental assumption of co-citation and co-occurrence analysis is that the more frequent the concomitant appearance of two documents, keywords or authors, the more they are related (Zupic & Čater, 2015). CiteSpace software was employed as it is one of the most prominent tools for network analysis. (Chen, 2006).

The parameters chosen in CiteSpace involve: temporal distribution from 2015 to 2020, annual slice = 1; text processed using author keywords and keywords plus, abstract and title; node typologies: analysis of co-citation of documents, co-citation of authors, co-citation of documents, co-occurrence of categories, countries and keywords; and selection criteria: selection criteria for the fifty most cited works per year.

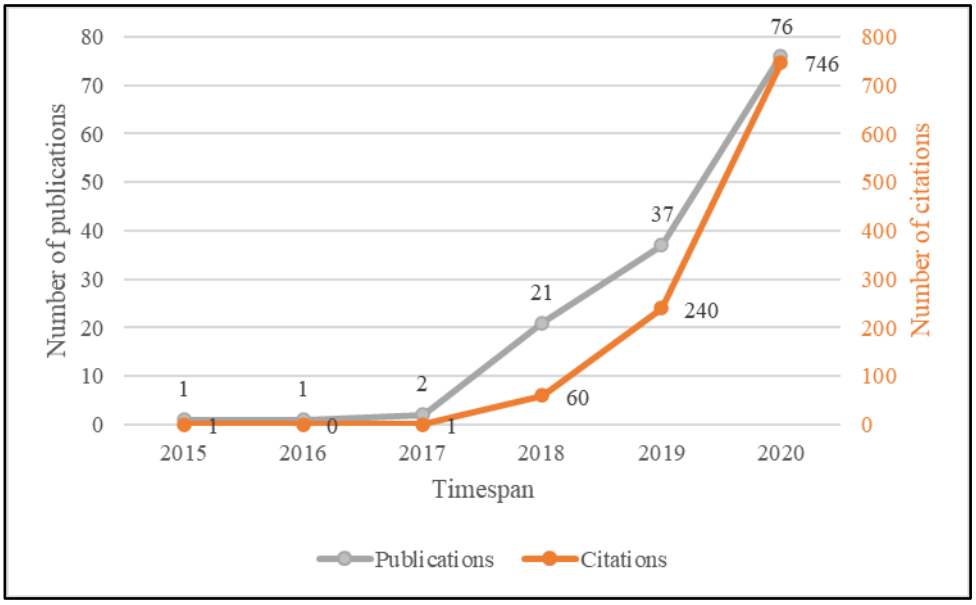
Next, the results of the study are presented and discussed.

4 RESULTS

4.1 Temporal distribution

Figure 2 shows the temporal distribution of the publications and citations of studies on circular economy and sustainable development from 2015 to 2020.

Figure 2 – Temporal distribution of publications and citations



We noticed an important growth from 2017 to 2018, where the number of publications jumps from 2 to 21 works (increase of 950%). The SDGs emerged in 2015, but it was officially in 2016 that they came into force (Hák et al., 2016), which was reflected in research and citations in the following years.

Regarding citations, there was an increase of 5900% between 2017 and 2018, whose citations increased from 1 to 60 in the following year. This demonstrates the recentity of the topic and points to a fertile opportunity for studies, since the field is relatively new and has been the subject of interest of researchers from all over the world.

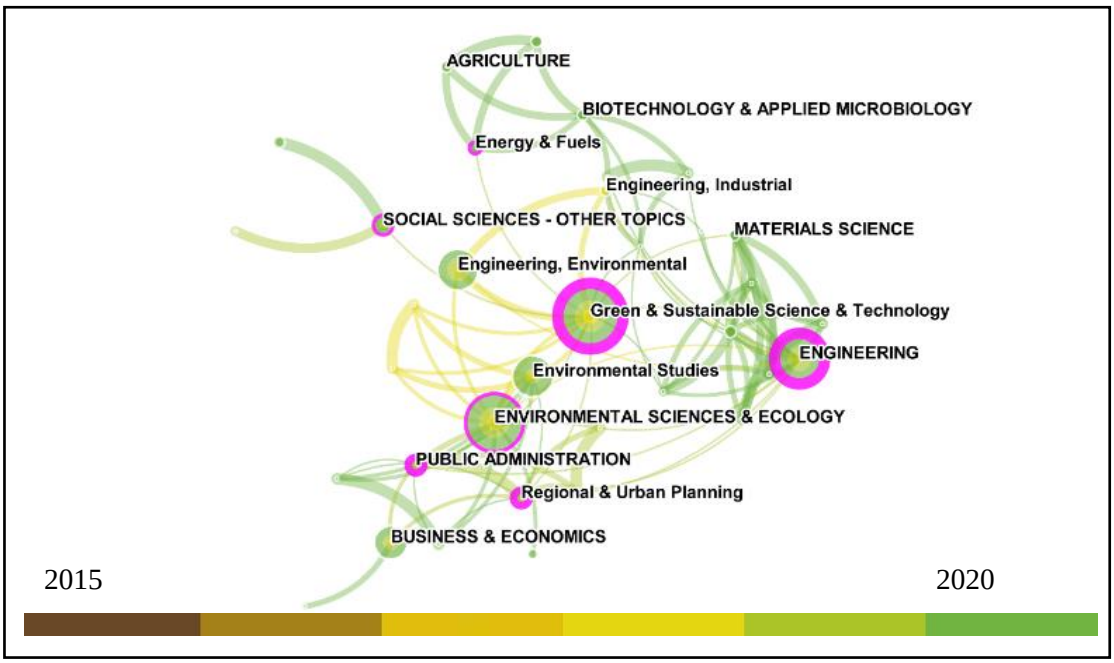
This is because the intersection between circular economy and sustainable development goals reveals challenges and potential for the economy, education,

health, well-being, and for the organization of society itself as an entity that seeks global development. In short, the overlap between the fields reveals promising research trends for the field of sustainability studies.

4.2 Research categories

First, we analyze the thematic areas of the circular economy and sustainable development themes in the period from 2015 to 2020. According to Figure 3, the main research categories in studies on circular economy and sustainable development goals demonstrate a multidisciplinary field, marked by areas research fields such as engineering, sustainable sciences and green technologies, environmental sciences and ecology, public administration, urban and regional planning, social sciences and energy and fuels.

Figure 3 – Research categories network



These areas have a high centrality of intermediation, a fact informed by the purple ring, and thus, they are fields that represent a role of connection with other

fields of knowledge. The most prominent node circles represent the areas with the highest number of citations.

The colors of the edges between the nodes of the network represent the connections established between the areas in terms of their recency. Thus, areas with more recent relationships are graphed in green. The areas whose relationships date back to the beginning of publications, around 2015, are: environmental sciences, environmental engineering and social sciences.

The field, in addition to being multidisciplinary, is therefore marked by interdisciplinarity, given the concomitant and multifaceted relationship between different fields of knowledge. In view of this, it is evident that researchers of circular economy and sustainable development goals should consider the need to articulate multiple scientific knowledge.

The agriculture and biotechnology categories are related to SDG 2 – Zero Hunger and Sustainable Agriculture. The energy and fuel categories are probably related to SDG 07 – Clean and Affordable Energy. In turn, the urban and regional planning and engineering categories seem to be related to SDG 11 – Sustainable Cities and Communities and SDG 06 – Drinking Water and Sanitation. The industrial engineering and materials science categories are related to SDG 09 – Industry, Innovation and Infrastructure and SDG 12 – Responsible Consumption and Production. The sustainable science categories relate to SDG 14 – Life on Water, SDG 15 – Life on Earth, SDG 13 – Action against global climate change. Finally, it is understood that the categories of public administration, business and economics, and social sciences are related to SDG 10 - Reduction of Inequalities, SDG 08 - Decent Work and Economic Growth, SDG 05 - Gender Equality, SDG 04 - Quality Education, SDG 03 – Health and Well-being and SDG 01 – Eradication of Poverty, SDG 16 – Peace, Justice and Effective Institutions, SDG 17 – Partnerships and Means of Implementation.

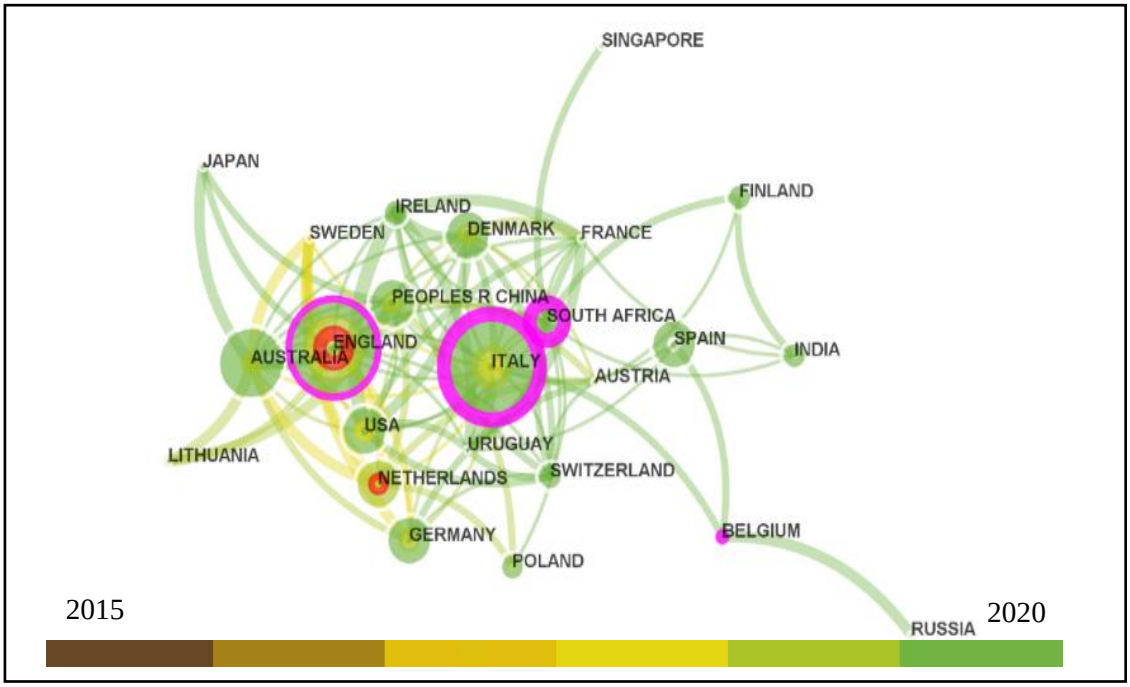
The most cited articles in the environmental sciences and technology category are: (Schroeder et al., 2019) with 136 citations and (Nosratabadi et al.,

2019) with 55 citations. In the business and economics category, the most cited article is by (Goyal et al., 2018), with 36 citations.

4.3 Countries

The countries of the main researchers in terms of work citations inform possible sources of studies on certain topics. In addition, the relationships established between the authors regarding the levels of collaboration are able to highlight the structure of research partnerships. Figure 4 shows the network of relationships considering the country of researchers on circular economy and SDGs.

Figure 4 – Author's countries network



In view of the analysis of Figure 4, it is evident that the researchers are, for the most part, from developed countries, such as the United States, England, Germany, Holland, Denmark, among others. The countries with the greatest centrality of intermediation, that is, those with the purple ring, are Italy, England and South Africa, which demonstrates that their researchers are the ones that most

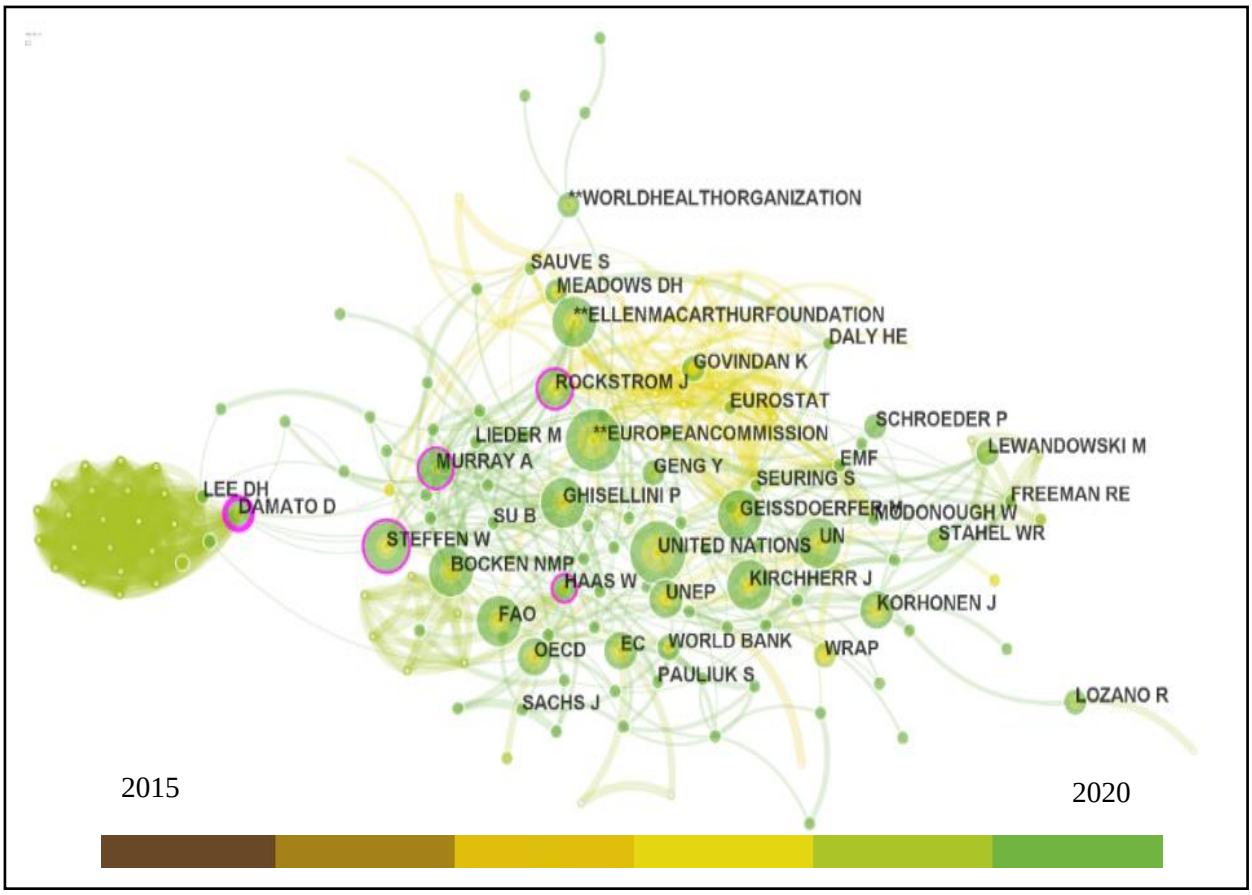
establish connections with researchers from different countries, and that they would not be connected with others. network nodes, were it not for the performance of these specific actors.

The article by authors of Italian origin with the highest number of citations deals with food waste (Corrado & Sala, 2018); the article with the highest number of citations with at least one English author (Schroeder, Patrick) addresses the intersection between circular economy for sustainable development goals (Schroeder et al., 2019) and finally, the article whose one of the authors is South Africa (Dhir & Amandeep) addresses discussions on bibliometrics and content analysis about sustainable manufacturing practices (Bhatt et al., 2020). In general, we evidenced the tendency of authors from several countries, mainly developed, to participate in the study of the theme. In addition, all continents are represented. In addition to being a topic of interest to researchers from several countries, there is funding from several agencies, such as the European Commission and the UK Innovation Center, which financed the research of 8 works, followed by the National Natural Science Foundation of China (5 works).

4.4 Authors co-citation analysis

Author co-citation analysis (ACA) aims to connect important authors in a given field, connecting them via the number of citations (Zupic & Čater, 2015). This analysis is intended to verify the intellectual structure of the field of studies in circular economy and SDGs, and they differ from co-authored maps insofar as the ACA has as its object of analysis the works present in the references of the surveyed works, and not the authors of the survey. our sample of work. Figure 5 addresses the analysis of authors' co-citation.

Figure 5 – Author's co-citation network



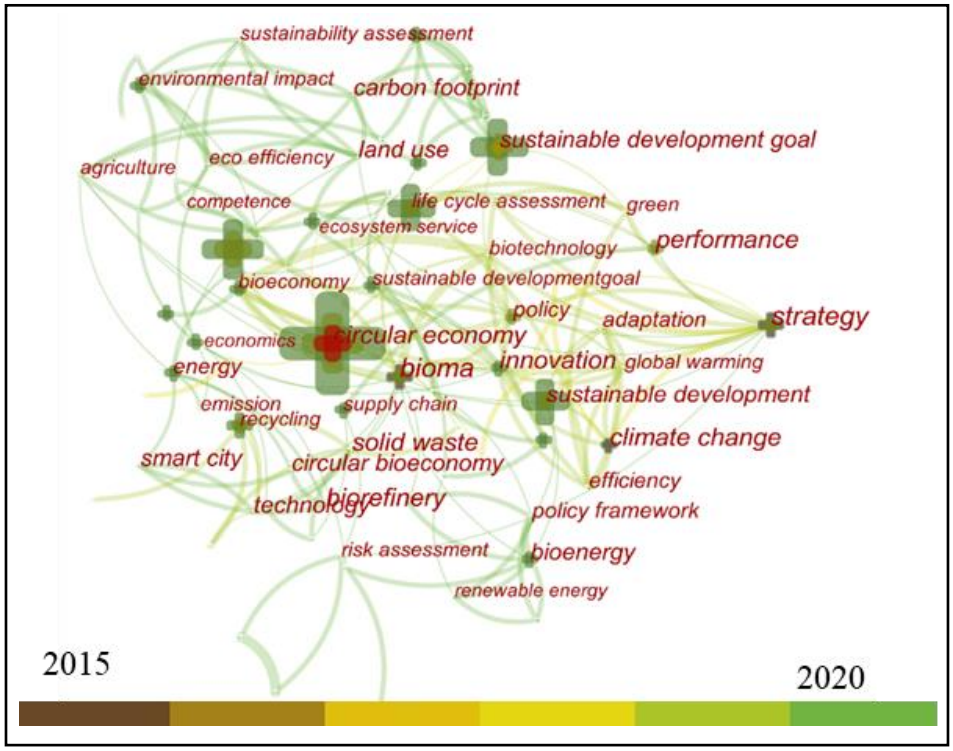
As for the authors presented, the European Commission, the World Bank, LEE DH and the United Nations stand out as the main author organizations. These organizations are very important and promote the main areas of development in the world context (Zupic & Čater, 2015). As for the individual authors, several are recognized and highlighted in the literature: Sachs, J; Lozano, R; Steffen, W; Bocken, NMP; Murray, A, among others.

4.5 Main keywords

The network of keywords (or co-occurrence of words) in Figure 6 is based on the analysis of titles texts, author keywords, keywords plus from the Web of Science, and abstracts (Chen et al., 2016). Thus, the method is promising to unravel connections between subjects in certain fields during its development (Zupic & Čater, 2015).

According to Zupic&Čater (2015), the use of only keywords for the analysis presents two problems: 1- the analysis depends on the existence of keywords, and some publications do not have them; 2- data quality depends on adequate indexing by the database. According to the authors, one way to circumvent these problems is to use titles and abstracts for the analysis, an approach adopted in this work.

Figure 6 – Keywords nwetwork



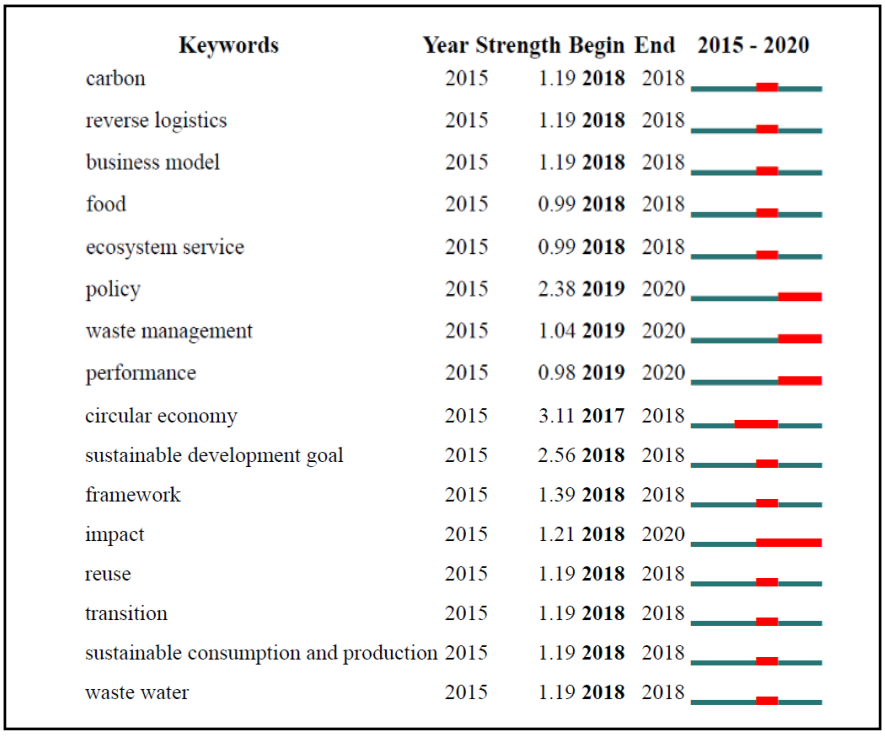
The keyword network reveals a series of insights for researchers in the field. With this, it is evident that the keyword with the greatest use in terms of citations is “circular economy”, which is relatively expected, considering that it was one of the words used in the survey. It also has the biggest citation burst, a fact reported by the center in red. Less recent relationships in the field emerge from the word strategy (strategy) due to brownish/yellow edges.

Important keywords are: bioeconomy, biome, sustainable development, competence, sustainable development objective, life cycle assessment, bioenergy, recycling, energy, renewable energy, climate change, performance, sustainability

assessment, supply chain, carbon footprint. carbon, smart cities, among others. The keywords demonstrate that sustainability is one of the aspects that support the studies, as well as topics related to innovation, technology and policies.

Another type of metric for keyword analysis is the *citation burst* of keywords. With it, it is possible to know the keywords that present a rapid and significant increase in appearances in the sample works (Chen, 2006; Huang et al., 2020), as shown in Figure 7.

Figure 7 – Fifteen keywords with citation burst



Keywords	Year	Strength	Begin	End	2015 - 2020
carbon	2015	1.19	**2018**	2018	
reverse logistics	2015	1.19	**2018**	2018	
business model	2015	1.19	**2018**	2018	
food	2015	0.99	**2018**	2018	
ecosystem service	2015	0.99	**2018**	2018	
policy	2015	2.38	**2019**	2020	
waste management	2015	1.04	**2019**	2020	
performance	2015	0.98	**2019**	2020	
circular economy	2015	3.11	**2017**	2018	
sustainable development goal	2015	2.56	**2018**	2018	
framework	2015	1.39	**2018**	2018	
impact	2015	1.21	**2018**	2020	
reuse	2015	1.19	**2018**	2018	
transition	2015	1.19	**2018**	2018	
sustainable consumption and production	2015	1.19	**2018**	2018	
waste water	2015	1.19	**2018**	2018	

The keyword with the biggest citation burst is circular economy (2.94), followed by SDGs (2.6) and politics (2.35). This demonstrates the importance of public policies for studies in the area. In addition, the keywords reuse, transition, sustainable consumption and production, water waste, carbon, reverse logistics, business model, food, and ecosystem services. To a certain extent, it is possible to perceive that the main keywords with the greatest citations burst are identical with the seventeen sustainable development goals, such as water, food, waste, policy.

Regarding the visualization of the timeline of keywords, Figure 8 shows their arrangement over three years (2017-2020). In view of it, and in line with the provisions of Table 2, which details the keywords present in each thematic line, it is possible to verify that the first timeline, in red, concentrates studies on education for sustainable development objectives. The second timeline addresses studies at the intersection of supply chain, waste management, innovation and performance ecosystems. The third timeline, in green, addresses studies related to sustainable development, economics, and climate change. The third timeline, in light blue, depicts studies that focus on reducing environmental impacts, and the concern about waste emerges. The fifth timeline, in dark blue, reveals the concern of the studies to address issues related to recycling, circular practices, and waste avoidance. Finally, the fifth line, in purple, highlights themes aimed at dealing with waste through the prism of industry 4.0, including the use of big data.

Figure 8 – Timeline of keywords and their relationship

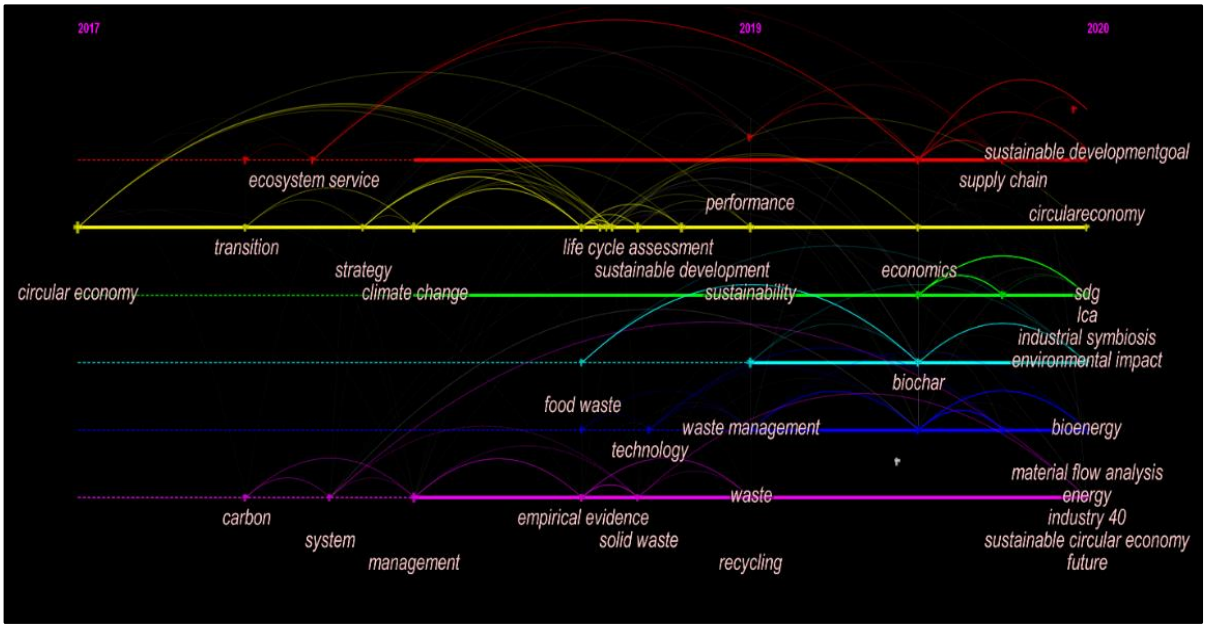


Table 2 – Keywords related to each timeline

Time line/ Cluster	Keywords
Red/ Education to SDGs	Sustainable florest handling; progresso monitoring; agenda; education; scenario analysis; modern information decision support systems; sustenability; life cycle assessment; education; educacional skills; collaborative models; project management; skills; project-based learing; design engineering; environmental education; sustainable development; material flow analysis
Yellow/ Circular economy and business models	Circular economy; sustainable developmentl; waste handling; land restoration; policy frameworks; inovation ecosystem; biothecnology; developing steps; agricutural waste; sustainability; business model; fosestry sector; lca construction; sustainable develoiping goals.
Green/ Sustainable development	Sustainable developing goals; hospitality; corporate social responsibility; environmental impact; interested party; green growth; sustainability; food consumption, circular economy; pharmaceutical products; sustainable development; environmental policy.
Light blue/ Clean Production	Circular economy; sustainability; techno-economy; biorefinary; agricultural waste; sustainable development goals; sustainable development; renewable energy; waste management plant production; soil correction; clean production; toxic metals; antibiotic resistance genes; policy frameworks; antioxidants, biochar.
Dark blue/ Recycling	Circular economy; environment; resource recovery; commercialization; techno-economy; waste; circular practices; material flow analysis; urban environment; recycling; smart cities; urbam environment; cicular pratices; urban metabolism; sustainable development; resources efficiency.
Purple/ Waste and 4.0 Industry	Circular economy; sanitation; wetlands; treatment of wet areas; resource; lifecycle management; sustainable develoment goals; electronic equipment; sustainable waste management; urban solid waste, sustainability; susatainable development goals; intelligent waste management; maturity model; sustainable circular economy; thing; internet; scanning; big data analysis; digital circular economy.

It should be noted that a keyword can be detailed in more than one timeline, due to the frequency and importance of its occurrence in the works over the years on screen. In addition, the keywords present in the thematic clusters and in the timelines represent research trends in studies on circular economy and sustainable development goals. In view of them, we perceive the intersection between basic aspects necessary for the formation of environmental and social awareness through environmental education, passing to the implementation of practices that

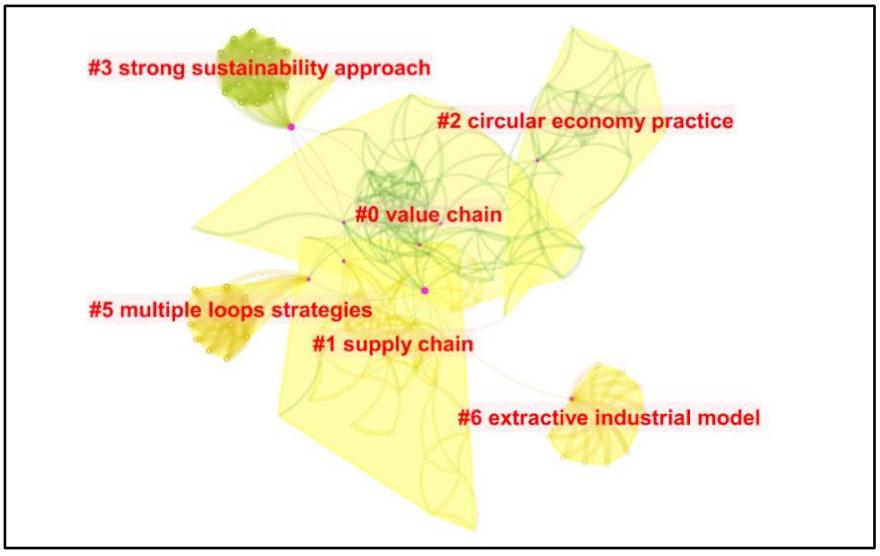
favor the reduction of waste and the use of technologies for cleaner production. To this end, the use of information and communication technology and big data tools becomes evident, culminating in industry 4.0 as an enabler of the circular economy in favor of achieving the SDGs.

4.6 Thematic clusters

The clusters represent cohesive domains in relation to themes of a certain domain of knowledge (Chen, 2016). In the field of studies on circular economy and SDGs, 43 clusters were identified, of which six are described in Figure 9 and will be discussed.

Cluster zero (0) addresses issues related to the value chain, whose most recent representative works are Modgil et al. (2020) and Jarosch et al. (2020). In the first cluster, mechanisms for creating value in the chain with a view to the SDGs are discussed. In cluster 1, the supply chain is seen as essential in reducing impacts, in enabling the functioning of the circular economy in favor of the SDGs, where one of the most recent works addresses discussions on future demand for copper, recycling and gas emissions. greenhouse effect (Ciacci et al., 2020), and circular economy in the agri-food sector (Esposito et al., 2020).

Figure 9 – Thematic clusters



Cluster 2, in turn, addresses issues related to circular economy practices. To this end, works in this cluster, the work of Priyadarshini & Abhilash (2020) deals with waste management and policies capable of promoting circular economy practices in waste and energy sectors. The work by Barros et al. (2020), maps research on circular economy practices in the context of agricultural waste, given that the reuse of agricultural waste is of great value for the circular economy.

Regarding cluster 3, sustainability is the main theme, whose most important work in terms of citations is that of Bhatt et al. (2020). Cluster 5 addresses multiple loop strategies, as discussed by Mohan et al. (2020), who discuss the perspectives of a resilient ecosystem to face the impacts arising from urban development. Finally, cluster 6 condenses studies in which the circular economy is seen as a confrontation with the current extractive industrial model based on waste, such as the work of Schroeder et al. (2019).

5 FINAL CONSIDERATIONS

This document presented an analysis of the evolution of the international literature on the SDGs and the Circular Economy. The evidence points out that it is the intersection of two areas in great growth, being represented by the production in different themes, contemplating countries from all continents. It is important to highlight that support and promotion agencies such as the European Commission and the UK Innovation Center are essential for sustainable development, both in terms of funding and technical support.

As for the research categories, engineering, sustainable sciences and green technologies, environmental sciences and ecology, public administration, urban and regional planning, social sciences and energy and fuels stand out. These areas stand out as the main research topics around the world and are the basis for meeting the 169 goals of the Sustainable Development Goals by 2030. As a driver of this process, the role of the circular economy that creates and develops a symbiosis for the production of science,

development of sustainable practices for organizations, for the promotion and integration of technologies, innovation and technical and economic capabilities for the success of the business market. The analysis of keywords and clusters reveals that the intersection between environmental education, practices that favor the reduction of waste and the use of technologies for cleaner production are central to studies on circular economy and SDGs.

This work achieves the purpose of presenting an overview and characteristics of this field in the international context, allowing researchers to examine trends in new themes and opportunities. This study is the first one that we are aware of to perform a scientometric and bibliometric analysis aligning the two themes, SDG and CE. Thus, we contribute to the literature as we uncover the main research trends, identifying research potential. Although this paper contains advances, it also has limitations, among which the use of a smaller amount of pure bibliometric indicators stands out, since the analysis of social networks was prioritized. in addition, there is the short temporal delimitation of the research, since the SDGs were created in 2015, therefore, it is not feasible to carry out the research prior to that period.

With the process of the pandemic, future studies will emerge, and for the next years, important results can be published in the main journals, in particular, topics related to: 'SDG 3 - Health and well-being' as the coronavirus pandemic has impacted the health and quality of life of the world's population; ‘SDG 4 - Quality education’ could be addressed in light of the impacts of the pandemic on formal education; ‘SDG 9 - Industry, innovation and infrastructure’ and ‘SDG 17 - Partnerships and means of implementation’ could represent a field in which innovation processes and cooperation for vaccines are investigated.

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1. Definition of research problem	√	√			
2. Development of hypotheses or research questions (empirical studies)	√	√			
3. Development of theoretical propositions (theoretical work)	√	√		√	
4. Theoretical foundation / Literature review	√	√	√		
5. Definition of methodological procedures				√	√
6. Data collection	√				
7. Statistical analysis			√		√
8. Analysis and interpretation of data			√		√
9. Critical revision of the manuscript		√			
10. Manuscript writing	√	√	√	√	√

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The authors have stated that there is no conflict of interest.

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