



Analysis in circular economy research in Latin America: A bibliometric review

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ABSTRACT

Circular Economy (CE) plays a crucial role in Latin America, where the transition to new economic development models poses significant challenges. This study conducts a bibliometric analysis of CE research in the region to identify critical areas of development, influential authors, organizations, and future research trends. This analysis aims to highlight the progress made in the CE field in Latin America and identify areas for improvement to promote sustainable development. Using the Scopus database, we analyzed 632 research papers, and the rising number of CE publications in Latin America suggests a continuous growth trajectory, expected to reach over 2500 studies by 2026. The analysis reveals that Brazil leads CE research with 274 publications, Waste Management being the most studied topic. The study highlights the region's growing trend towards implementing innovative and sustainable solutions for waste management and resource utilization, such as bioengineering and biochemistry processes, which could positively impact the region's economy and environment. The findings of this study provide valuable insights for policymakers and researchers aiming to promote sustainable development in Latin America.

1. Introduction

Bibliometric analysis is essential for evaluating research output and impact within a field, facilitating informed decision-making, and identifying collaboration opportunities and research gaps [1]. In addition, capturing the trends and development of a particular topic allows for a clear establishment of its evolution and prospects [2]. A bibliometric analysis helps identify the thematic evolution over time, authors, research cooperation, citations, journals, institutions, and key terms [3]. Hence, this research article aims to analyze and review the literature on the progress made in the Circular Economy (CE) field in Latin America (LAT). As a result, this study contributes by identifying the most significant areas of development, researchers, research networks, and the countries making academic advancements.

Notably, the deleterious effects of the prevailing economic model on the environment and natural ecosystems have raised growing

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concerns in the region. Currently, the linear 'extract, transform, and dispose' model poses a threat to sustainability and economic stability [3]. While the Circular Economy (CE) offers an alternative to this unsustainable model, its integration is essential to maintain equilibrium across economic, environmental, technological, and social aspects of an economy, sector, or industrial process [4]. The CE stands as a cornerstone for attaining sustainable development, presenting the capability to concurrently propel economic advancement, safeguard finite resources, and curtail waste generation [5]. A comprehensive notion proposed by MacArthur [6] delineates the CE as a regenerative framework where resources are maximally utilized during their active lifespan, their value is optimized through extraction, and subsequent restoration and renewal occur after their functional cycle.

The global Sustainable Development Goals agenda, along with its target 12.5, presents a substantial objective of diminishing waste generation through preventive, reductionist, recycling, and reutilization endeavors. The initial assessment of global circularity disclosed a rate of 9.1%, exhibiting an annual decline and recently descending to 7.2%. This phenomenon stems from the heightened global extraction and material utilization, which notably serves as a robust gauge of environmental harm, given their contribution to over 90% of the comprehensive global depletion of biodiversity and the exacerbation of water stress [7]. Only a few countries have implemented structured systems for categorizing and reprocessing such refuse, with the unregulated sector predominantly assuming the role of recuperating reusable materials.

Multiple studies have substantially enhanced our comprehension of the circular economy's crucial facets through thorough literature reviews and bibliometric analyses. Particularly, Ranjbari, Saidani [8] undertook an investigation that provided an all-encompassing outline of waste management (WM) within the context of the CE from 2001 to 2020. The study discerns seven prominent research themes: bio-based waste management, the transition to CE, electronic waste, and plastic waste. These discoveries offer valuable perspectives for forthcoming research initiatives and aid policymakers and practitioners in facilitating waste abatement and CE adoption.

In a recent investigation, Ranjbari, Esfandabadi [9] examined the management of healthcare waste and its associated environmental and health hazards. The study illuminates the underappreciated involvement of the healthcare sector in CE dialogues, providing significant perspectives for forthcoming waste management research endeavors. In other research, Ranjbari, Esfandabadi [10] provide a comprehensive map of biomass and organic waste research in the circular bio-economy. Principal topics encompass conversion methodologies, CE integration, environmental analysis, and food waste and bio-waste management. Ultimately, Ranjbari, Esfandabadi [11] conducted a bibliometric examination within the CE framework and proposed a research agenda addressing the COVID-19 pandemic. The analysis unveiled suggestions for enhancing waste management methodologies considering the pandemic and backing sustainable initiatives.

The bibliometric analyses demonstrate a literature review's capacity to discern and suggest scientific advancement agendas. This study delves into the difficulties and prospects of enacting the CE in Latin America, a region characterized by environmental contamination, meager recycling percentages, and substantial depletion of natural assets, especially in developing countries. In relation to recycling, Grau, Terraza [12] calculated that a mere 2.2% of urban solid waste in Latin America undergoes recycling within structured systems. By identifying institutional, social, and economic barriers, the research analyzes the growth trends and provides guidelines for strategies for its implementation and development in the region. This inquiry adds to the comprehension of the CE within this intricate context and imparts insights for formulating efficacious policies conducive to a sustainable and circular model in Latin America.

The CE presents an auspicious strategy for addressing economic and environmental challenges by optimizing resource utilization and mitigating waste. In the Latin American context, the CE concept has primarily centered on waste management as a viable economic alternative [13]. In this context, the efficacy of CE initiatives is constrained by the lack of assessment and regulatory frameworks for waste-generating processes. Conversely, numerous advanced nations have integrated CE principles into their developmental agendas, emphasizing resource reduction, reuse, and recycling. These nations seek to align with domestic strategies that foster sustainable development. Global Circular Economy (CE) strategies encompass a range of approaches, including zero-waste directives, financial incentives such as taxes and subsidies to drive the adoption of sustainable products, design criteria for durable and recyclable goods, extended producer responsibility initiatives, and policies for environmentally-conscious public procurement. Examples of these strategies are explored in the work by Govindan and Hasanagic [14].

Zero-waste policies, taxes and subsidies to stimulate the adoption of sustainable products, design norms for sturdy and recyclable goods, extended producer responsibility initiatives, and policies for sustainable public procurement exemplify worldwide CE strategies [14]. Nevertheless, the Latin American region encounters notable obstacles in its shift towards novel economic paradigms, given the scarcity of environmental safeguarding and management policies and their limited adherence [15].

Regrettably, endeavors to surmount poverty and inequality in Latin America have strained the region's substantial natural resources [16]. Thus, the CE holds the potential to wield substantial influence over Latin America, yielding effects encompassing the environmental and economic domains [17]. Embracing sustainable methods and technologies across sectors like waste management, agriculture, energy, and water stands to instigate avenues for innovation and economic advancement while concurrently diminishing environmental repercussions.

Nonetheless, the CE literature lacks a comprehensive overview of academia's role in tackling the challenges of the Latin American region, despite the necessity for pragmatic research endeavors to address these urgent issues. Specifically, the 2022 comparative report on SDG performance by region indicates that Latin America and the Caribbean are experiencing stagnation in SDG 12, in contrast to other regions that are making moderate progress, such as the East and South Asia region, which is currently leading in these related indicators. Furthermore, the studies on CE in Latin America correspond to 2.4% of the Scopus-indexed literature. This paper contends that an increased focus on applied research within Latin America and the Caribbean is imperative to effectively confront these challenges and enhance the region's advancement towards SDG 12 attainment. Therefore, a distinct demarcation between regional

scholarly output and the global literature is warranted, owing to Latin America's distinctive theoretical outlooks and empirical contexts. Specifically, the confluence of variables encompassing demand size and complexity, production capabilities, population diversity, poverty, inequality, biodiversity abundance, and energy potential presents a unique milieu, potentially necessitating customized research methodologies and a plurality of objectives and solutions tailored to regional intricacies.

Hence, this study seeks to perform a bibliometric analysis of the Latin American literature in the realm of CE to unveil pertinent contributions spanning diverse domains, including bioeconomy, bioengineering, business models, technology, innovation, process design, optimization, waste management, recycling, energy, and other related fields. The forthcoming bibliometric analysis will also disclose research projections, pertinent thematic dimensions, influential authors, journals, institutes, articles, and organizations within the domain of CE in the Latin American context. Moreover, the document will discuss important aspects of the subject's progression and prospective research trajectories aligned with sustainable development goals. A bibliometric examination of CE in Latin America boasts multiple merits. It provides a platform for scrutinizing thematic domains cultivated by individual countries. This investigation facilitates a holistic comprehension of the research landscape, identifying key topics and trends within specific countries in the region. Ultimately, the outcomes engender a basis for proposing an agenda.

2. Data and methods

The data for this research was extracted from Scopus databases until December 3rd, 2022. The Scopus database was chosen as the search engine due to its comprehensive coverage of scientific literature across various thematic areas and its widespread acceptance and frequent use in the analysis of scientific publications. The main term employed was "Circular Economy," and key terms closely associated with the topic were identified. These terms were input into the Scopus database to generate a compilation of publications, searching within document titles, abstracts, and keywords. Moreover, the search terms encompassed each Latin American country and other relevant variations to ensure comprehensive coverage of the term "Latin America." The fundamental factors that guided the selection of search terms are detailed in Table 1.

The research resulted in scientific articles, books, reports, chapters, and conference proceedings. The search was not restricted to a specific period, thereby enabling the identification of all existing publications within the repository. A total of 849 relevant publications were retrieved from the database. In terms of document type, the majority consisted of articles (n: 698), followed by conference proceedings (n: 95) and books (n: 52). Specific inclusion and exclusion criteria were applied to ensure a focused and pertinent selection of publications. Initially, duplicate articles retracted articles, corrected articles, and publications lacking identifiable authors were omitted from the analysis. This preliminary filtering process led to the exclusion of 19 documents.

In the second filtering stage, a detailed analysis of titles, abstracts, and keywords was undertaken to assess the relevance and coherence of the identified studies within the bibliometric analysis. Within the dataset, numerous articles with titles pertaining to events, conferences, or proceedings were observed and subsequently excluded (total number of studies = 29). Additionally, studies in the fields of biology, agriculture, and environment were identified, discussing potentials or projections related to green business or sustainability that could be linked to the CE (total number of studies = 64). It was also noted that certain studies contrasted their findings or conclusions with Latin America, indicating a lack of direct relevance to the region. Other articles comprised global literature reviews or bibliometric analyses, highlighting specific interconnected findings with the CE in Latin America (total number of studies = 11).

Furthermore, studies in the social and political sciences have delved into economic policies and their intersections with innovation, circularity, entrepreneurship, and employability, albeit with differing approaches to the CE (total number of studies = 45). Lastly, bioengineering, biomass, and chemistry research has concentrated on technical advancements in industrial processes or transformations (total number of studies = 49). With these considerations and a thorough content evaluation, the inclusion criteria were employed to select studies that exhibit direct relevance and contribute substantially to comprehending the CE in Latin America.

In the end, 217 research papers were excluded from the analysis after thoroughly examining each document. Consequently, 632 research papers on CE in Latin America were acquired. The overall search process, the devised filters, and the categorization of the

Table 1

List of keywords used for the literature search.

Key Terms Group 1	circular economy, circular bioeconomy, circular business, environmental business, circularity, green business, industrial symbiosis, eco-innovation, industrial ecology, circular agriculture, circular corporation, circular ecology, circular industry, circular management, circular product, circular supply chain, circular technology innovation, circular transition, circular value chain, circulatory economy.
Key Terms Group 2	Argentina, Bolivia, Brasil, Brazil, Chile, Colombia, Costa Rica, Cuba, Ecuador, El Salvador, Guatemala, Honduras, México, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Republica Dominicana, Dominican Republic, Uruguay, Venezuela, LATAM, America Latina, Sur America, Centro America, Paises Latinos, Latin America, Latinamerica, South America, Central America, Latin countries.
Search Period	All (1997–2023) until December 3rd, 2022
Search in Scopus	(TITLE-ABS-KEY ("circular econom*" OR "circular bioeconomy" OR "circular business" OR "environmental business" OR "circularity" OR "green business" OR "industrial Symbiosis" OR "eco-innovation" OR "industrial ecology" OR "circular agriculture" OR "circular corporation" OR "circular ecology" OR "circular industr*" OR "circular management" OR "circular product*" OR "circular supply chain" OR "circular technology innovation" OR "circular transition" OR "circular value chain*" OR "circulatory econom*") AND TITLE-ABS-KEY (argentina OR bolivia OR brasil OR brazil OR chile OR colombia OR "Costa Rica" OR cuba OR ecuador OR "El Salvador" OR guatemala OR honduras OR méxico OR nicaragua OR panama OR paraguay OR peru OR "Puerto Rico" OR "Republica Dominicana" OR "Dominican Republic" OR uruguay OR venezuela OR latam OR "America Latina" OR americalatina OR "Sur america" OR suramerica OR centroamerica OR "centro america" OR "Paises latinos" OR "Latin America" OR latinamerica OR "South America" OR "Central America" OR "latin countries"))

excluded elements are illustrated in Fig. 1.

Upon acquiring the collection of pertinent publications, the information extracted from the Scopus database, encompassing publication date, authorship, affiliations, titles, abstracts, journals, keywords, and other significant elements, underwent analysis using Microsoft Excel. Furthermore, the VOSviewer software [18] was employed to examine the interconnections among publications with respect to authors, countries, citations, co-citations, and keywords. These analyses facilitated the visualization of concurrent relationships, distances, and affinities among the identified publications, achieved through color coding, grouping, and distance metrics. Additionally, a thematic analysis was conducted for each study, organized based on the diverse impact domains encompassed by CE. Subsequently, the acquired data was leveraged to conduct analyses on the following facets: (1) scientific production and trends, (2) author profiles and their contributions, (3) journals dedicated to the subject, (4) geographic distribution of authors and institutions, (5) citation analysis, (6) citation and co-citation networks, (7) thematic categorization, (8) term analysis, and (9) alignment with the Sustainable Development Goals.

3. Results

3.1. Publication output and growth trend

In the evolution of CE studies in Latin America, the initial study was identified in 1997. From 1997 to 2017, around 100 research studies were conducted. Subsequently, there was a notable increase of approximately 200 publications between 2018 and 2020. The most productive period was between 2021 and 2022, exhibiting a substantial surge of approximately 300 research studies. The considerable volume of publications indicates the burgeoning nature of the topic, which is still distant from reaching maturity, and suggests an expected further increase in the publication volume in the upcoming years. Based on the publication volume and developed using the ARIMA (2,1,0) model, a forecast for the next four years predicts 292, 346, 538, and 639 publications, respectively, for 2023 to 2026. These projections anticipate a cumulative growth of more than 2500 research studies in the forthcoming years. Fig. 2 illustrates the progression of CE publications in Latin America and their distribution by subject.

The subject of industrial ecology experienced the highest growth within the field of CE in Latin America between 2000 and 2015. However, over the last seven years, there has been a notable shift in research focus toward waste management, recycling, energy, and sustainable development. These topics have emerged as prominent areas of study, each garnering more than 100 publications, highlighting their growing relevance and significance in the region's discourse on the CE.

The heightened intellectual production and research on CE in Latin America between 2018 and 2019 can be attributed to various factors influenced by the geopolitical and economic context. On a global scale, initiatives such as the Paris Agreement and the Sustainable Development Goals increased awareness of the imperative for sustainable development. Within Latin America, governments and institutions acknowledged the potential of the CE to address environmental challenges and stimulate economic growth. Regional initiatives and networks like the ECLAC facilitated cooperation and knowledge exchange. Moreover, augmented funding from international organizations and private sector entities further incentivized research endeavors.

The notable upsurge in publications on the CE from 2020 to 2022 can be attributed to several potential hypotheses. This surge could stem from an increasing recognition of the urgency to address environmental challenges, including the impact of the COVID-19 pandemic that unveiled vulnerabilities in conventional linear economic models. Furthermore, implementing policies and initiatives

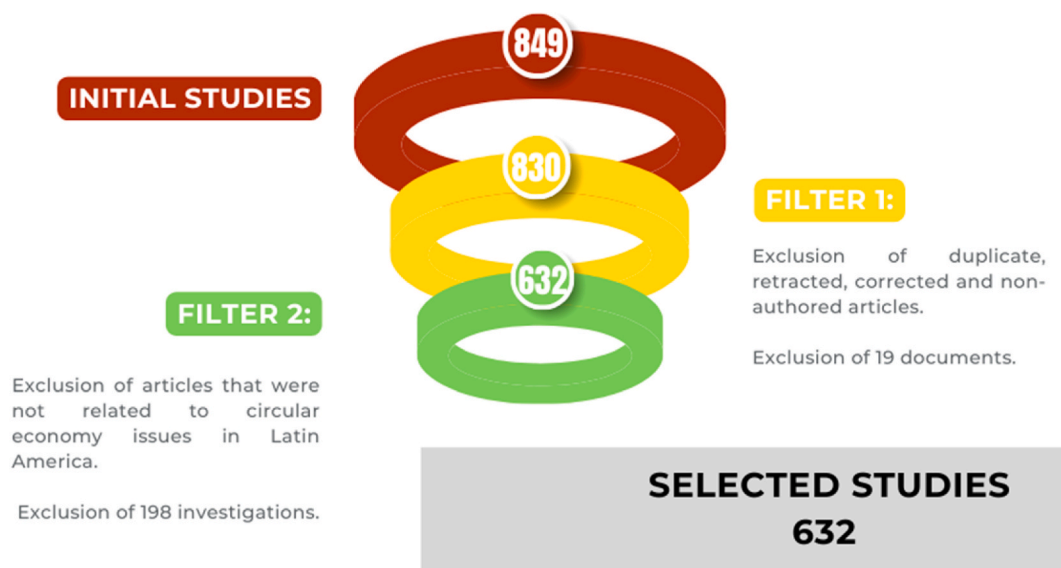


Fig. 1. Process of selection of studies for inclusion in the review.

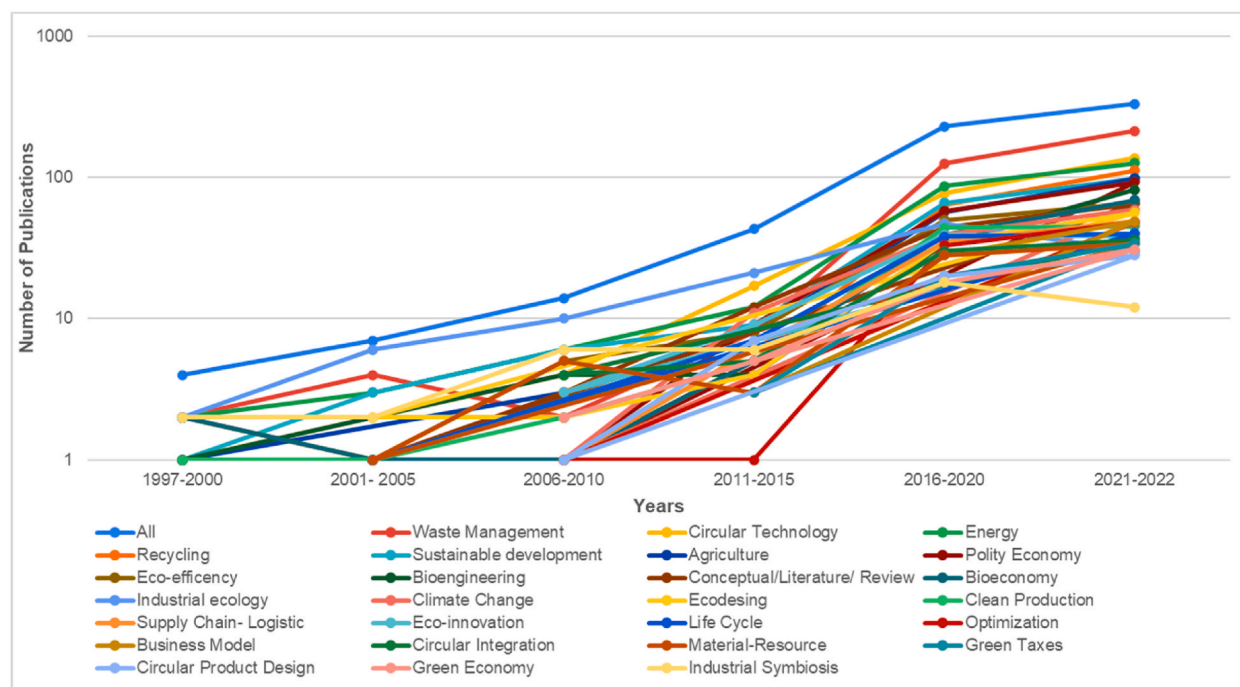


Fig. 2. The volume of publications on the Circular Economy in Latin America and their distribution by subject.

by governments and institutions in the region and heightened collaboration between academia, industry, and government sectors have invigorated research endeavors. Moreover, the awareness of economic opportunities linked to the CE, such as job creation and enhanced resource efficiency, has motivated researchers to explore and contribute to the field.

Table 2
Top-7 of most productive authors in CE in Latin America.

No	Name Author	Affiliation -Country of Author	Number of Publications	Total, Citations	Average Citation per Publication	Number of Publications as First Author	Years
1	Vázquez-Rowe I.	Pontificia Universidad Catolica del Peru, Lima, Peru	14	280	20,0	3	2017–2022
2	Ferronato N.	Università degli Studi dell’Insubria, Varese, Italy	13	279	21,5	12	2018–2022
3	Torretta V.	Università degli Studi dell’Insubria, Varese, Italy	12	275	22,9	0	2018–2022
3	Chiappetta Jabbour C.J.	Montpellier Recherche en Management MRM, Montpellier, France	12	457	38,1	5	2011–2022
4	Lopes de Sousa Jabbour A.B.	Montpellier Business School, Montpellier, France	11	453	41,2	2	2013–2022
5	Sehnm S.	Universidade do Sul de Santa Catarina, Tubarao, Brazil	9	141	15,7	7	2019–2022
5	Guisbert Lizarazu E.G.	Universidad Mayor de San Andres Bolivia, La Paz, Bolivia	9	126	14,0	0	2018–2022
6	Gorritty Portillo M.A.	Universidad Mayor de San Andres Bolivia, La Paz, Bolivia	8	248	31,0	0	2018–2022
7	Jugend D.	Universidade Estadual Paulista Júlio de Mesquita Filho, Sao Paulo, Brazil	7	190	27,1	0	2018–2022
7	Kahhat R.	Pontificia Universidad Catolica del Peru, Lima, Peru	7	191	27,3	0	2017–2022
7	Larrea-Gallegos G.	Pontificia Universidad Catolica del Peru, Lima, Peru	7	134	19,1	4	2017–2022

3.2. Authors and their cooperation

A total of 2196 distinct authors were involved in 632 publications. The most significant proportion of authors (90%; $n = 1972/2196$) was involved in only one publication. 7% ($n = 159/2196$) were credited in two publications, while 2% ($n = 41/2196$) were credited in three. 1.1% ($n = 24/2196$) of the authors were credited in more than four publications. These findings align with previous studies [19], indicating that a select group of prolific authors significantly contribute to the discourse on a particular subject. Table 2 presents the seven most prolific authors in Latin America regarding CE publications. The ranking is based on the overall number of publications.

Ian Vázquez-Rowe is the most prolific author with 14 publications, closely followed by Navarro Ferronato with 13 publications. A substantial range of citations per document is observed among the Top authors, spanning from 14 to 41 citations per publication. The number of publications as the first author displays variation, with five authors having no publications credited to them as the first author. The range varies from 0 to 12 publications. The most productive authors have demonstrated their intellectual output over the past six years.

The collated data indicates extensive collaboration in research development, as evidenced by 92.9% of publications featuring two or more authors. Many co-authored publications indicate a closer relationship between authors in the same domain and greater opportunities for future collaboration [20]. VOSviewer software was employed to scrutinize authorship relationships within the publications on this topic. Authors with a minimum of five publications were incorporated into the author network, encompassing those not linked to other authors.

The co-authorship network analysis revealed the formation of three distinct collaborative clusters. Charbel Jose Chiappetta Jabbour and Ana Beatriz Lopes de Sousa Jabbour are predominantly associated with the first cluster, with affiliations primarily from France and the United Kingdom. Their research predominantly centers on Brazil, as is the case with the works of Simone Sehnem and Daniel Jugend. The second cluster highlights a noteworthy dynamic of cooperation involving Navarro Ferronato and Vincenzo Torretta, who hold main affiliations with Italy and focus their research on Bolivia. These authors also collaborate with Marcelo Antonio Gorritty Portillo and Gabriela Edith Guisbert Lizarazu. In the third cluster, significant contributions arise from Ian Vázquez-Rowe, who collaborates with Gustavo Larrea-Gallegos and Ramzy Kahhat, primarily conducting research in Peru.

The linkages between Peru, Brazil, and Bolivia with developed nations such as Italy, France, and the United Kingdom within the context of CE can be attributed to several pivotal factors. Firstly, the progressive policies and frameworks these developed countries adopt serve as inspirational models, spurring them to initiate research collaborations. For instance, Italy has made considerable strides in promoting the recycling industry, waste management, and sustainable food supply chains. Similarly, France has enacted regulations and policies encouraging extended producer responsibility and circular practices, particularly within the construction sector. Renowned for its national CE strategy, the United Kingdom advocates for resource maximization, waste reduction, and innovation, particularly in domains such as recycling, waste management, and renewable energy.

3.3. Journal publishing in CE in Latin America

A total of 632 research articles were published across 308 different journals. Of the 308 journals, 215 (70%) published only a single article, 52 (17%) released two articles, 35 (11%) presented a range of three to 10 articles, and six (2%) published more than 10 articles on the topic (with the articles per journal spanning a range from 1 to 52 publications). Table 3 furnishes information regarding the 10

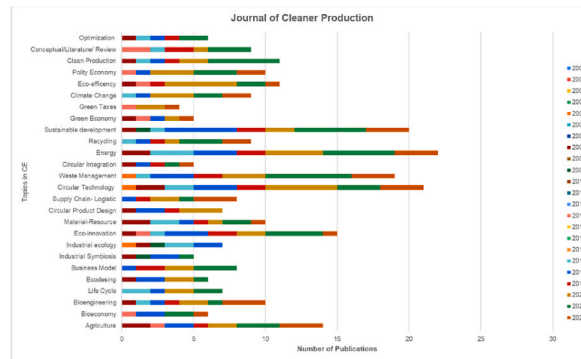
Table 3
Top-10 most active journals in CE in Latin America.

No	Journal title (ISSN)	Number of publications	Publication Type	SJR-2021	Citation	Period	Publisher
1	Sustainability/Switzerland (20,711,050)	52 (50 Articles + 2 Reviews)	Journal	Q1 (0,664)	344	2017–2022	MDPI
2	Journal of Cleaner Production (9596526)	42 (41 Articles + 1 Reviews)	Journal	Q1 (1733)	1011	2004–2022	Elsevier Ltd
3	Journal of Industrial Ecology (10881980)	30 Articles	Journal	Q2 (0,751)	867	2008–2022	John Wiley and Sons Inc
4	Waste Management and Research (0734242X)	14 (13 Articles + 1 Review)	Journal	Q1 (1921)	90	2017–2022	SAGE Publications Ltd
5	Waste Management (0956053X)	13 Articles	Journal	Q1 (1806)	136	2018–2022	Elsevier Ltd
6	Science of the Total Environment (489697)	11 (9 articles + 2 Reviews)	Journal	Q1 (1481)	153	2017–2022	Elsevier BV.
7	Journal of Environmental Management (3014797)	10 Articles	Journal	Q1 (2589)	331	2014–2023	Academic Press
8	Resources, Conservation and Recycling (9213449)	9 Articles	Journal	Q1 (0,831)	292	2018–2021	Elsevier BV.
9	Environmental Science and Pollution Research (9441344)	8 Articles	Journal	Q1 (1741)	79	2017–2022	Springer Verlag
10	IOP Conference Series: Earth and Environmental Science (17551307)	7 Conference Paper	Conference	0,202	16	2019–2022	Institute of Physics Publishing

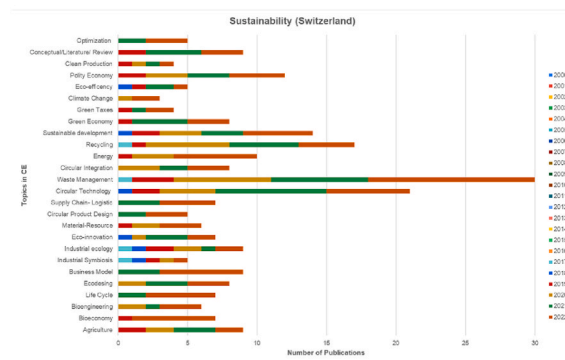
most active journals in terms of publishing. These journals, constituting 3% of the entire pool of journals, have contributed to 31% of all publications (n: 196/632). The preminent journals in this field include Sustainability (Switzerland), Journal of Cleaner Production, Journal of Industrial Ecology, Waste Management and Research, Waste Management, Science of the Total Environment, Journal of Environmental Management, Resources, Conservation and Recycling, Environmental Science and Pollution Research, as well as IOP Conference Series: Earth and Environmental Science."

All of the most prolific journals publishing works related to CE in Latin America are positioned within the first quartile of SJR, except for the Journal of Industrial Ecology. The Journal of Cleaner Production holds the highest count of citations. Among the top journals, Elsevier Ltd emerges as the most frequent publisher. These journals encompass a range of themes, including sustainability, cleaner production, waste management, industrial ecology, conservation, and recycling. Fig. 3 shows the volumes of publications of the three most influential journals, categorized based on the prevailing thematic emphasis over the past decade."

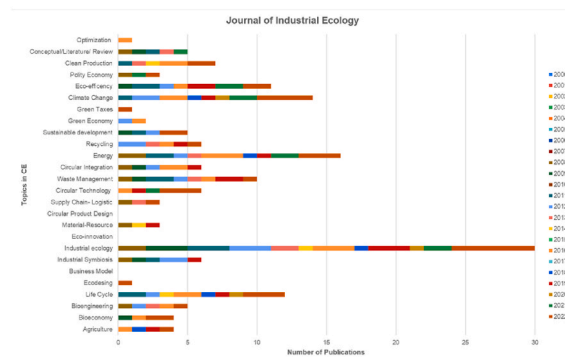
The Journal of Cleaner Production demonstrates a noteworthy shift in publication trends. From 2004 to 2010, publications covered various themes without a clear sense of intentionality. However, publications have been significantly diversified, with a recent focus on waste management, energy, sustainability, technology, and agriculture. The journal's content also exhibits an emerging influence on



a) Journal of Cleaner Production



b) Journal - Sustainability



c) Journal of Industrial Ecology

Fig. 3. Top-3 of the most active journals in CE in Latin America in recent years and its thematic participation in time with the number of publications. a) Journal of Cleaner Production; b) Journal – Sustainability; c) Journal of Industrial Ecology.

recycling, eco-innovation, and eco-efficiency topics. Meanwhile, the journal Sustainability has exhibited a notable concentration on waste management publications in the past three years. Furthermore, there is an emerging presence of technology and recycling-related subjects gaining traction within the journal's thematic coverage. Finally, the Journal of Industrial Ecology predominantly publishes technology, agriculture, eco-efficiency, and eco-innovation articles.

Publishing research on CE within sustainability and cleaner production journals is well-founded, given their alignment with resource efficiency and waste reduction principles. Such journals draw a focused readership actively in pursuit of advancements in sustainable practices, thereby amplifying the visibility and impact of the research. Researchers can significantly contribute to developing and implementing CE strategies by disseminating findings in these journals, concurrently fostering tangible real-world impact.

3.4. Geographical, institutional distribution and cooperation

3.4.1. Countries and territories

Each publication was attributed to a specific Latin American country based on the available information within the title and abstract. Approximately 8% of the publications (n: 51) are broadly connected to Latin America, with 1.45% involving at least two countries collaborating. CE publications in the Latin American context encompass 18 countries, excluding El Salvador and Paraguay, which are not represented. Fig. 4 illustrates the distribution of contributions across different Latin American countries.

Brazil emerges as the predominant research leader in CE, boasting 274 publications, constituting 43% of the total articles retrieved. Meanwhile, Mexico, Colombia, and Chile showcase substantial contributions, each having yielded over 50 publications, collectively accounting for 30% of the documented output.

Fig. 5 illustrates the cooperative network (co-authorship) within countries and regions concerning research in CE. The analysis was conducted using VOSviewer software. This network accentuates countries and territories that have produced at least five publications while omitting those that lack connections to others. The circles' sizes correlate with the publication volume, and the links represent collaborative authorship between countries.

The research cooperative network in the field of CE reveals the existence of five prominent clusters. The initial cluster, depicted by the red group, is affiliated with Mexico. The subsequent cluster, represented by the green group, is correlated with Brazil. The third



Fig. 4. Number of publications distributed by country or territory in CE in Latin America.

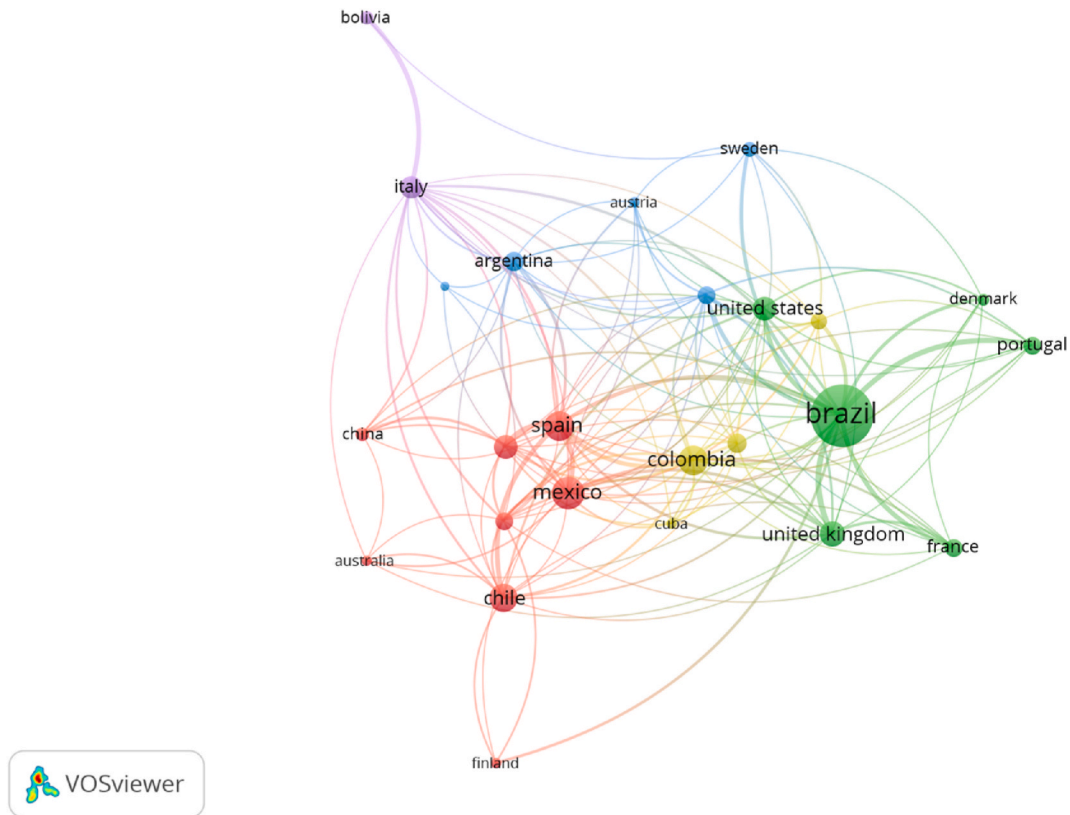


Fig. 5. Cooperation network in CE among countries and territories of Latin America.

cluster, portrayed by the blue group, is interconnected with Argentina, and the fourth cluster, represented by the yellow group, is associated with Colombia. Lastly, the fifth cluster, represented by the purple group, demonstrates connections to Italy.

The initial cluster exhibits a pronounced collaboration among researchers from Mexico, Spain, Ecuador, and Chile. Similarly, the Brazil cluster underscores substantial cooperation with the United Kingdom, France, and the United States. Likewise, the Colombia cluster showcases a robust interconnection with the prominent nations in the remaining clusters. Lastly, the Italy cluster predominantly maintains ties with Bolivia, indicating a notable publication relationship between these countries.

The relationship between technology and agriculture propels Brazil’s engagement with CE. Once a net importer, Brazil has risen as a global leader in research and innovation, particularly in Agriculture 4.0. Their progressions are geared toward resource optimization, waste reduction, and promoting sustainable practices [21]. This interdependent alliance drives efficiency and comprehensive resource management. Meanwhile, Mexico and Chile have achieved noteworthy progress in adopting the Extended Producer Responsibility (EPR) model, tailoring it to their specific circumstances. EPR constitutes a strategy to optimize resource utilization by reintegrating materials into the production cycle, progressively transitioning from a linear economy to a circular one [22].

Table 4
Top 10 most productive institutions publishing in CE in Latin America.

No	Institute	Documents	Country
1	Universidade de São Paulo	47	Brazil
2	Universidade Estadual Paulista Júlio de Mesquita Filho	35	Brazil
3	Universidade Federal do Rio de Janeiro	25	Brazil
4	Consejo Nacional de Investigaciones Científicas y Técnicas	23	Argentina
5	Universidade Federal do Rio Grande do Sul	19	Brazil
6	Pontificia Universidad Católica del Perú	18	Peru
7	Universidade Estadual de Campinas	16	Brazil
8	Universidade Federal de Santa Catarina	15	Brazil
8	Universidad Nacional Autónoma de México	15	Mexico
9	Universidad de Buenos Aires	14	Argentina
9	Università degli Studi dell’Insubria	14	Italia
9	Universidade Federal do Paraná	14	Brazil
10	Tecnológico de Monterrey	13	Mexico
10	Universidade Tecnológica Federal do Paraná	13	Brazil

3.4.2. Institutions

The top ten most productive institutions in terms of publications in CE in Latin America are shown in Table 4. Among the top publishing countries, Brazil stands out most frequently. The Universidade de São Paulo is the most prolific, with approximately 47 publications, followed by the Universidade Estadual Paulista Júlio de Mesquita Filho with 35 documents, and the Universidade Federal do Rio de Janeiro with 25 documents.

3.5. Citation analysis

This section presents the citation analysis of the documents in terms of their referencing in other publications (knowledge output: cited analysis). The citation analysis identifies how frequently publications on the topic have been referenced by other publications using Scopus databases. The 632 publications were cited 6632 times in various other publications. The average number of citations per publication stands at approximately 10.

Of the total, 30% (n: 192/632) of the articles have not been cited. Furthermore, 13% (n: 81/632) of the articles have received only one citation. Meanwhile, 31% (n: 194/632) of the publications have garnered between two to ten citations. Additionally, 22% (n: 137/632) of the publications have amassed citations ranging from 25 to 50. Lastly, 4% (n: 28/632) of the articles have been cited over 75 times. Table 5 provides the ten most cited publications.

The article with the highest number of citations corresponds to the documents titled "Quantifying Economic and Environmental Benefits of Co-located Firms," "Industrial Symbiosis in Puerto Rico: Environmentally related agglomeration economies," and

Table 5
Top 10 most frequently cited publications in CE in Latin America.

No	Reference-Year	Title	Country	Institution of First Author	Journal	Times Cited	Average citations per year	Main Topic
1	Chertow and Lombardi (2005)	Quantifying economic and environmental benefits of co-located firms	Puerto Rico	Yale University-USA	Environmental Science and Technology	245	14,4	Industrial symbiosis
2	Chertow, Ashton, and Espinosa (2008)	Industrial symbiosis in Puerto Rico: Environmentally related agglomeration economies	Puerto Rico	Yale University-USA	Regional Studies	165	11,8	industrial symbiosis
3	W. Ashton (2008)	Understanding the organization of industrial ecosystems: A social network approach	Puerto Rico	Yale University-USA	Journal of Industrial Ecology	164	11,7	industrial symbiosis
4	Ferronato, Rada et al. (2019)	Introduction of the circular economy within developing regions: A comparative analysis of advantages and opportunities for waste valorization	Bolivia	University of Insubria-Italy	Journal of Environmental Management	150	50,0	Waste
5	W. S. Ashton (2009)	The structure, function, and evolution of a regional industrial ecosystem	Puerto Rico	Yale University-USA	Journal of Industrial Ecology	110	8,5	Industrial ecology
6	C. J. C. Jabbour, Neto, Gobbo, Ribeiro, and De Sousa Jabbour (2015)	Eco-innovations in more sustainable supply chains for a low-carbon economy: A multiple case study of human critical success factors in Brazilian leading companies	Brazil	Sao Paulo State University-Brazil	International Journal of Production Economics	109	15,6	Eco-innovation
7	Elabras Veiga and Magrini (2009)	Eco-industrial park development in Rio de Janeiro, Brazil: a tool for sustainable development	Brazil	Federal University of Rio de Janeiro-Brazil	Journal of Cleaner Production	107	8,2	Eco-innovation
8	Chiappetta Jabbour, Seuring et al. (2020)	Stakeholders, innovative business models for the circular economy and sustainable performance of firms in an emerging economy facing institutional voids	Brazil	University of Lincoln- United Kingdom	Journal of Environmental Management	101	47,0	Business development
9	Wiebe, Bruckner, Giljum, Lutz, and Polzin (2012)	Carbon and materials embodied in the international trade of emerging economies: A multiregional input-output assessment of trends between 1995 and 2005	Argentina	Institute of Economic Structures Research-Germany	Journal of Industrial Ecology	96	9,6	Carbon emissions
10	Muñoz, Giljum, and Roca (2009)	The raw material equivalents of international trade: Empirical evidence for Latin America	Latin-American	Autonomous University of Barcelona- Spain	Journal of Industrial Ecology	81	6,2	Industrial ecology

“Understanding the Organization of industrial ecosystems: A social network approach.” These references have been cited 245, 165 and 164 times, respectively. These investigations have been conducted by researchers from Yale University and center around industrial symbiosis within the context of Puerto Rico. The top five positions in CE are held by institutions outside Latin America, including those from the United States, United Kingdom, Spain, Germany, and Italy.

The journal with the highest involvement in the most cited documents is the Journal of Industrial Ecology, making four contributions. Four authors have appeared more than twice at the top of the most cited publications: Chertow M.R, Ashton W.S, Chiappetta Jabbour C.J., and Lopes de Sousa Jabbour AB. The latest publication is “Stakeholders, innovative business models for the CE and sustainable performance of Firms in an emerging economy facing institutional voids,” published in 2020, with over 100 citations. This publication highlights business models related to CE in Brazil.

Finally, in an analysis of total citations from the 308 involved journals, the following results were obtained: 30% (n = 92/308) of journals have no citations. 11% (n = 33/308) of journals have only one citation, 33% (n: 103/308) of journals have between two to ten citations, 22% (n = 67/308) have between 11 and 100 citations, and 4% have more than 100 citations. The journal with the highest number of citations is the Journal of Cleaner Production, accounting for 15% (n = 1011/6632) of total citations. The Journal of Industrial Ecology comes second with 13% (n = 868/6632) of total citations. Lastly, the Journal of Environmental Management, Sustainability (Switzerland), Resources, Conservation and Recycling collectively contribute 15% (n = 987/6632) of total citations.

The most cited studies in Latin America related to industrial symbiosis are justified for several reasons. Industrial symbiosis is a crucial strategy for promoting efficiency and sustainability in production processes. It offers an integrated approach to managing material and energy flows between industries, addressing environmental challenges, and optimizing resource utilization. Moreover, industrial symbiosis can generate significant economic and social benefits by reducing production costs, improving competitiveness, and creating jobs [23]. Its alignment with sustainable development goals and practical solutions for waste management, emissions reduction, and resource conservation further contribute to its popularity in Latin America [24].

3.6. Citation and co-citation analysis

The citation analysis enables us to determine the number of references employed by the 632 articles. Subsequently, the co-citation relationship network is presented to quantify the connections between publications. Co-citation analysis aids in assessing the relationship between publications, given their joint citations. Fig. 6 shows the co-citation analysis, visualized through the VOSviewer software. Of the 632 articles, 57,274 authors were identified, and those surpassing 20 occurrences were incorporated into the network. Within this network, circle size indicates higher citations within publications pertaining to the subject. The distance denotes the level of relation between the two publications, illustrating their substantial similarity. Matching colors signify publications sharing thematic affinity. Notably, seven distinct groups are discernible within the network.

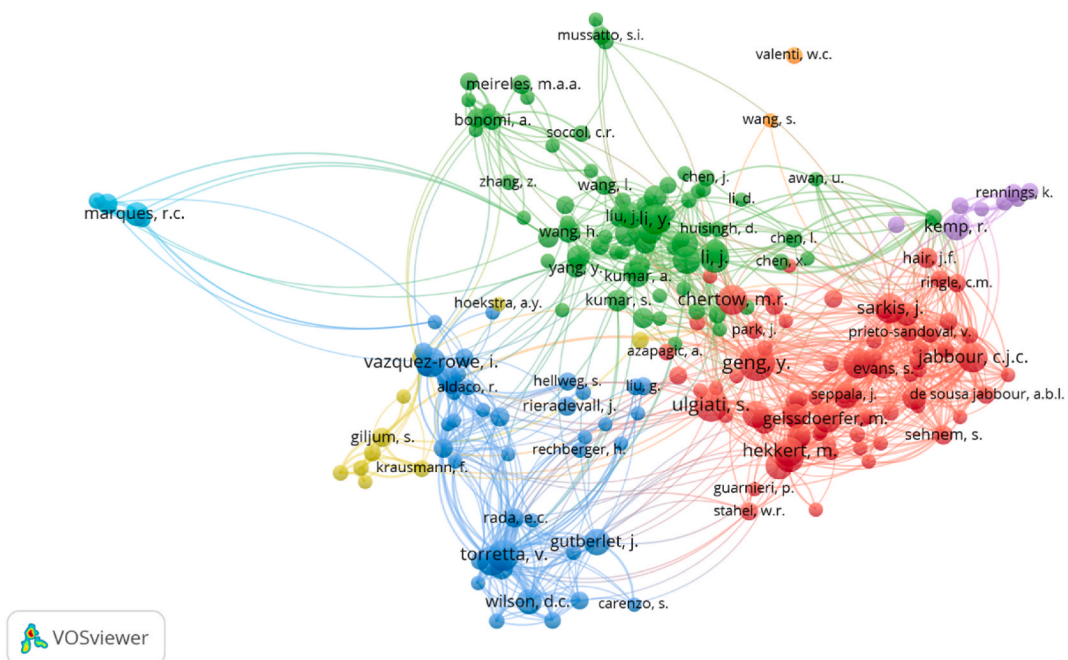


Fig. 6. Co-citation analysis of highly cited references employed in CE publications in Latin America.

3.7. Bibliographic coupling analysis: discovering emergent research areas

A bibliometric analysis using coupling was conducted to construct a map. A total of 220 articles were considered, emphasizing those with over five citations. These articles were categorized into 7 clusters, as illustrated in Fig. 7. This methodology adopts a forward-looking perspective and facilitates the identification of emerging topics within the field.

C1 - Circular economy applications in resource utilization and waste management: This cluster emphasizes optimizing resource utilization and waste management through circular economy principles. The studies within this cluster delve into areas such as utilizing agriculture for biogas production, recovering resources from wastewater, valorizing food waste, implementing sustainable solid waste management practices, and investigating the impacts of biosolids application. An illustrative example of this research type links the studies conducted by Aguiar, Milessi [25], Brenes-Peralta, Jiménez-Morales [26], and Ferreira, Buller [27].

C2 - Sustainable Assessments and Environmental Implications: This cluster encompasses a variety of studies that address sustainable assessments and environmental implications across various industries and regions. The topics explored encompass life cycle analysis, environmental impacts, policy implications, and optimization within poultry farming, waste management, cement production, agriculture, mining, and deforestation. One illustrative example connecting these research studies is demonstrated by the investigations conducted by Allegretti, Talamini [28], Gilardino, Rojas [29], and Vázquez-Rowe, Cáceres [30].

C3 - Sustainable Business Practices and Eco-innovation: This cluster encompasses studies on sustainability, circular economy, and eco-innovation within firms and industries across both developed and developing countries. Topics covered include sustainable business practices, environmental management, supply chain collaboration for sustainability, eco-innovation, circular product design, generational perceptions, and the implications of a circular economy during crises. An illustrative example of this research type links the studies conducted by Chiappetta Jabbour, Seuring [31], Severo, de Guimarães [32], and Pinheiro, Jugend [33].

C4 - Advancing Waste Management and Circular Economy: This cluster emphasizes waste management strategies, circular economy implementation, and environmental assessments in developing regions. It highlights challenges, opportunities, and policy support for sustainable development. An illustrative example of this research type is shown through the studies conducted by Ferronato, Rada [34], Margallo, Ziegler-Rodriguez [35], and Ferronato, Ragazzi [36].

C5 - Advancing Circular Economy and Sustainable Supply Chains: This research group focuses on advancing the circular economy and developing sustainable supply chains in Latin America. These studies explore strategies, practices, and case studies related to the region's circular economy implementation, sustainable supply chain management, and consumer behavior. Some investigations are linked to the studies conducted by Chiappetta Jabbour, De Camargo Fiorini [37], Cardoso de Oliveira, Machado [38], and Guarneri, Cerqueira-Streit [39].

C6 - Industrial Symbiosis and Circular Economy for Sustainable Development: This group of studies explores industrial symbiosis and circular economy approaches for sustainable development. It examines various industries and regions' case studies, strategies, and benefits. The goal is to promote integrated and sustainable practices that enhance industrial ecosystems' efficiency and environmental performance, including waste management and value recovery. An illustrative example of this research type is shown through the

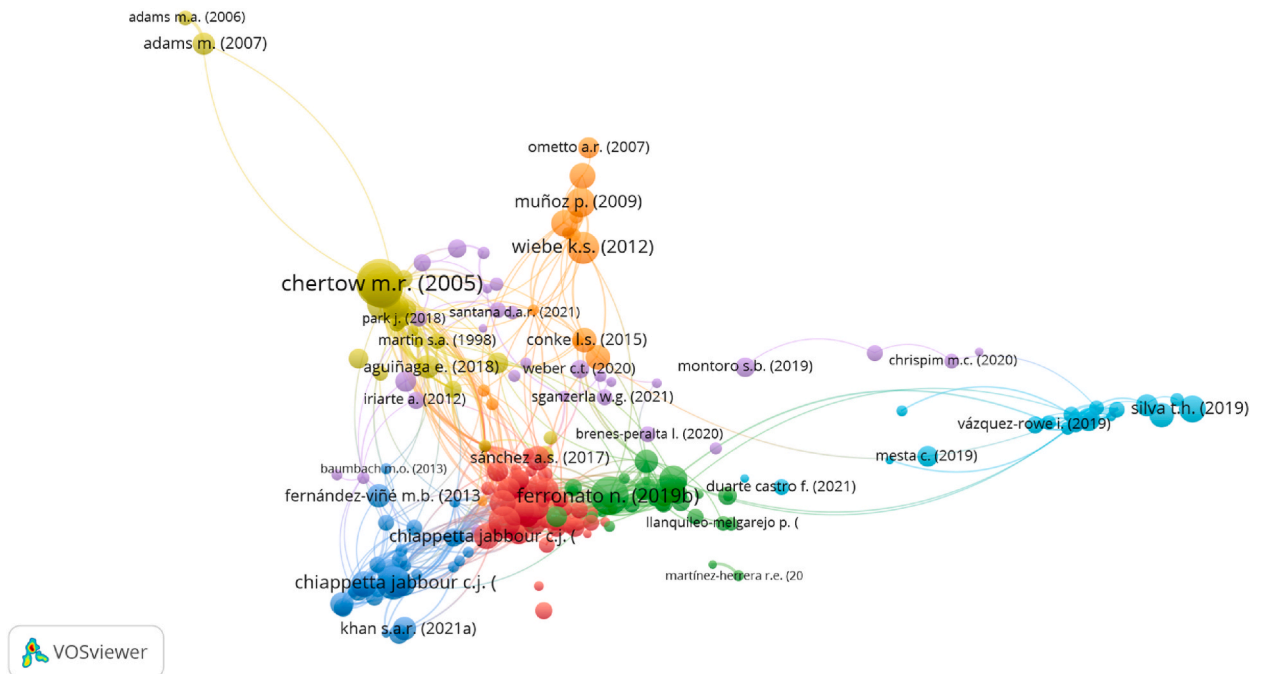


Fig. 7. Bibliographic coupling of the articles within the field of CE in Latin America.

studies conducted by Chertow, Ashton [40], Chertow and Lombardi [41], Ashton [42], Ashton [43] and Elabras Veiga and Magrini [44].

C7 - Environmental Impacts, Energy Flows, and Sustainable Development: This cluster of studies explores material flows and sustainability in emerging economies. It focuses explicitly on analyzing patterns of material flows, environmental footprints, urban metabolism, recycling, and conducting sustainability assessments. The aim is to understand these developing economies better and promote sustainable practices. Topics covered include environmental impacts, energy flows, circular economy, and sustainable development. Some examples of this relevant research were developed by Wiebe, Bruckner [45], Muñoz, Giljum [46], Russi, Gonzalez-Martinez [47], and Ingwersen [48].

3.8. Subject categories

A thematic analysis was conducted across different subareas of the CE. In this regard, each publication was classified and linked to one or more categories. A total of 25 categories were taken into consideration. Fig. 8 shows the most representative areas by percentage representation of the total number of publications in the database.

By analyzing the classification of publications, it becomes evident that a significant proportion of research, precisely 56%, pertains to Waste Management. This classification is followed by 37% of the publications that address Circular Technology and Energy. Furthermore, 29% of the articles also pertain to Recycling and Sustainable Development. Finally, the topic of agriculture obtained a participation rate of 27%. Other study areas that received less attention within the publications were Green Taxes, Green Economy, and Industrial Symbiosis, with an average occurrence of 8%.

Given the possibility of linking multiple thematic axes within the CE for each of the publications, a mapping was carried out to identify the areas of intersection between the sub-themes. The mapping process is presented as a heat map visualization, where highly intense red colors denote a strong affinity or correlation, while faded colors indicate a lack of association or relationship. The resulting map is shown in Fig. 9. The most significant thematic relationships between the publications are Waste Management with Recycling, Energy, Sustainable Development, Circular Technology, and Political Economy. Other strong relationships link Energy with Bioengineering, Circular Technology, and Agriculture. One of the areas with fewer connections to the others is the theme of optimization and industrial symbiosis.

Finally, Fig. 10 illustrates the sub-thematic relationships evident in the publications of each Latin American country. The predominant research in Brazil, Mexico, Colombia, and Ecuador was Waste Management and Circular Technology, with approximately 280 and 187 related publications, respectively. Research studies generally related to Latin America were primarily associated with literature reviews.

3.9. Terms analysis

Analyzing terms highlighted in the titles and abstracts of articles in this field can provide insights into trends for future research. The analysis was conducted using the VOSviewer software, which enables the visualization of term networks. The analysis was carried out on the 632 articles found in the field, considering their title and abstract. The terms occurring in at least ten publications were considered. 16,079 terms were selected for inclusion in the network, where 413 meet the threshold. The results are presented in Fig. 11

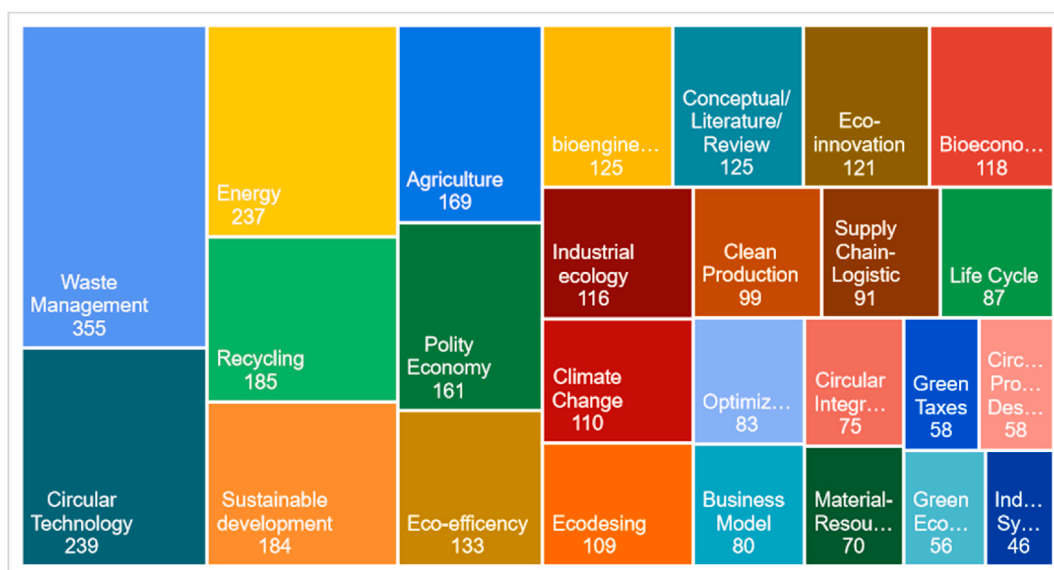


Fig. 8. Thematic participation of publications in CE in Latin America.

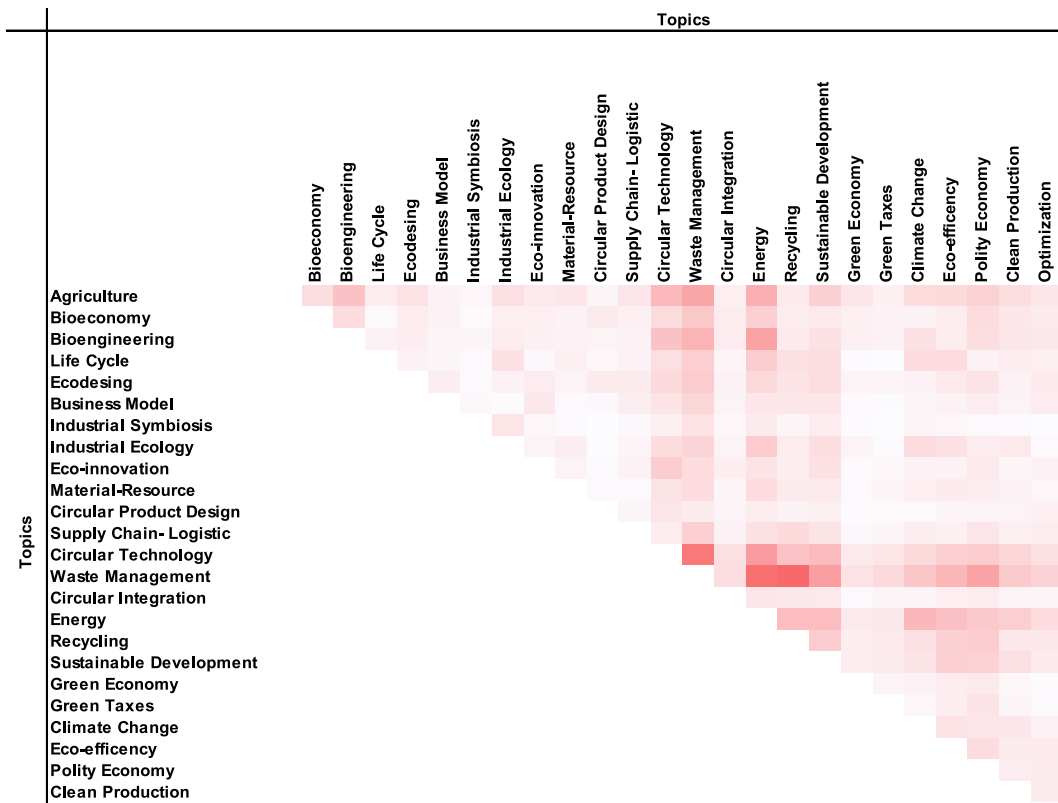


Fig. 9. Correlation of publications' topics in CE in Latin America.

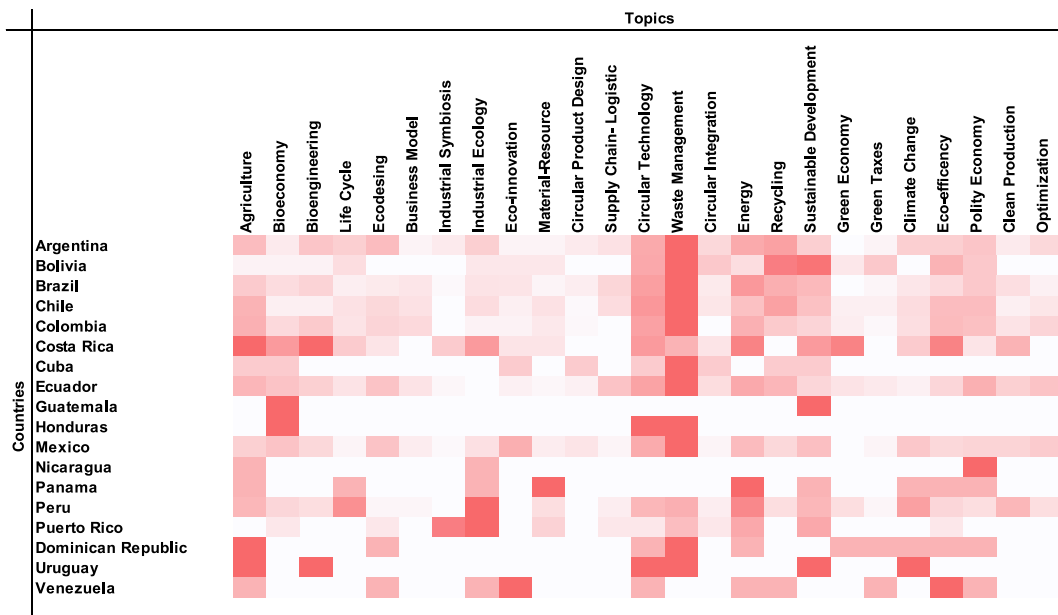


Fig. 10. Correlation of publications' topics in CE by Latin American Countries.

with 248 terms. The circles represent the occurrence of the terms. The distance between these indicates their relationship. The relationship between terms is provided by the number of times that terms co-occurrence. Five clusters were detected.

The first red cluster is related to industrial conditions. The second green cluster is linked to environmental and material resources.

The third purple cluster relates to recurring independent terms with countries (India, China) or goods. The fourth blue group is related to waste management. The fifth yellow cluster is related to the challenges facing the CE.

In addition, Fig. 12 shows the relationship between analysis terms with their temporality. The color of the terms indicates their average publication period. This value is calculated by averaging the publication years of all publications containing the terms. The most frequently used terms were found in the year 2020. The older terms tend towards yellow, while newer ones tend towards purple. According to the color range, the most recurrent terms are between 2018 and 2021. The latest terms are related to bioengineering and biochemistry processes for waste transformation and energy production.

3.10. The sustainable development goals and the circular economy in Latin America

The intersection between the Sustainable Development Goals (SDGs) and the CE in Latin America has gained significant attention in recent years. In the field of bibliometrics, a comprehensive analysis has been conducted to assess the extent to which research outputs align with each SDG. This analysis aims to identify the contributions made by various studies toward achieving sustainable development goals and sheds light on the potential synergies between the CE and the SDGs in the Latin American context. Fig. 13 illustrates the intersection between the publications' scope and the Sustainable Development Goals (SDGs) by country. The figure represents a heat map showcasing the thematic areas that have experienced significant development across different countries. This visual representation identifies pronounced intentions aligned with the Sustainable Development Goals (SDGs).

The figure depicts the prevalence of specific Sustainable Development Goals (SDGs) in the analyzed publications. The SDG with the highest frequency of connections is SDG 12 (Responsible Consumption and Production), followed by SDG 9 (Industry, Innovation, and Infrastructure), demonstrating significant engagement in approximately 360 publications. SDG 7 (Affordable and Clean Energy) and SDG 2 (Zero Hunger) are also prominently represented, with at least 160 publications related to each.

The prominence of SDG 12 in Latin America can be attributed to the region's efforts to transition away from extractive economies and promote sustainable practices such as waste management, recycling, and resource efficiency. SDG 9 reflects the region's emphasis on industrial development, technological advancement, and innovation. SDG 7 signifies Latin America's focus on exploring and expanding renewable energy sources to reduce dependence on fossil fuels. Lastly, SDG 2 highlights the region's commitment to combating poverty and hunger through agricultural development and rural empowerment.

In this context, the CE presents an opportunity to foster intra-sectoral diversification and generate added value at the national level, thereby contributing to the achievement of SDG 8 (Sustainable Economic Growth and Decent Work), SDG 9 (Sustainable Industrialization), and SDG 12 (Sustainable Consumption and Production). By embracing circular principles, such as waste reduction, resource efficiency, and innovative business models, countries in Latin America can promote sustainable economic growth, create decent

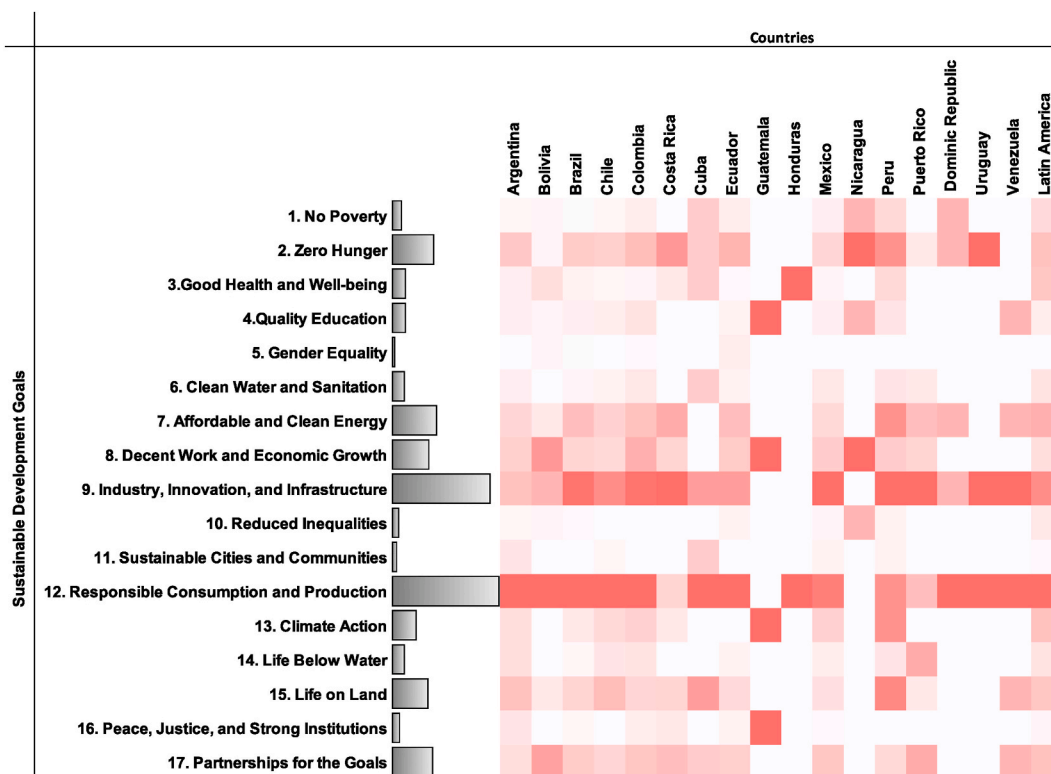


Fig. 13. Relationship in CE in Latin America with sustainable development goals.

employment opportunities, drive sustainable industrialization, and foster responsible consumption and production practices. Adopting a CE framework aligns with the objectives of these SDGs, further advancing the region's progress toward sustainable development and a more resilient future.

The analysis reveals that the Sustainable Development Goals (SDGs) with comparatively fewer research connections in the field of CE are SDG 1 (No Poverty), SDG 5 (Gender Equality), SDG 10 (Reduced Inequalities), SDG 11 (Sustainable Cities and Communities), and SDG 16 (Peace, Justice, and Strong Institutions). These goals, centered around equity, social conditions, and addressing economic and social inequality, highlight areas where further research and collaboration in the context of CE can contribute to inclusive and sustainable development in Latin America. While the current research landscape may show limited connections to these SDGs, it also presents an opportunity for thematic development and increased focus on these goals. Brazil has the highest research development across all Sustainable Development Goals (SDGs). Following closely, Mexico, Colombia, and Chile demonstrate significant advancements, particularly in SDG 9 (Industry, Innovation, and Infrastructure) and SDG 12 (Responsible Consumption and Production).

4. Discussion

This article highlights the multidisciplinary nature of CE in Latin America. The existing literature on CE in Latin America accounts for 2.4% of the literature based on Scopus data; however, since 2017, the field has witnessed its highest growth rate. Nonetheless, the concentration of research in a few countries and topics indicates that it has not fully matured and can be regarded as a field in its early developmental stages in the region. The initial interest in this field emerged among academics who recognized its potential to contribute to sustainable development for future generations [49]. However, current interest predominantly focuses on consolidating new business models that offer environmentally responsible solutions while enhancing national competitiveness [50].

Since 2015, Latin America has displayed heightened interest in the CE, primarily driven by factors like the Paris Agreement and the 2030 Agenda for Sustainable Development, raising awareness about sustainable consumption and production. Environmental challenges in the region, such as deforestation, health crises, hygiene issues, and energy supply difficulties, have further contributed to this growing concern. Consequently, the scientific literature has witnessed a surge in CE studies in Latin America, highlighting the imperative for formulating infrastructure, financing, and education policies. The Economic Commission for Latin America and the Caribbean (ECLAC) has advocated for the adoption of CE principles in its publication "Horizons 2030: Equality at the Center of Sustainable Development" [51]. This document emphasizes the significance of fostering sustainable consumption and production patterns. ECLAC proposes that in Latin America, CE practices should encompass waste management and extend to other domains such as product design, eco-design, and sustainable supply chains. A closely aligned thematic facet that garners significant attention in Latin American research pertains to Circular Product Design. Within this realm, emphasis is placed on responsible product development, and studies from Latin America exemplify the benefits of circularity, as evidenced by research conducted by Jugend, Fiorini [52], Pinheiro, Jugend [33], Aguiar, Mesa [53], and Aguiar and Jugend [54].

Many authors have made noteworthy contributions in response to this growing concern and its consequential impact on scholarly output. For example, author Ian Vázquez-Rowe, recognized for his substantial body of studies on environmental and sustainability issues in Peru, employs the life cycle assessment (LCA) methodology and related techniques to assess the environmental impacts of diverse activities and technologies. His research recommends enhancing the management and sustainability of various sectors, encompassing agriculture, energy, waste management, and transportation infrastructure. Vázquez-Rowe collaborates with Kahhat R. and Larrea-Gallegos G. Navarro Ferronato, who have extensively published on Bolivia's environmental and sustainability issues. Their studies are primarily centered on waste management practices, emphasizing CE principles, selective collection, recycling, and composting. Their research methods encompass life cycle assessment, geographic information systems, and integrated analysis. Navarro Ferronato collaborates closely with researchers such as Torretta V., Chiappetta Jabbour C.J., Guisbert Lizarazu E.G., and Gorrity Portillo MA. This collaborative network underscores the robust connection between Bolivian and Italian researchers in environmental and sustainability studies. Another prolific author in the field of sustainability is Chiappetta Jabbour C.J. These studies encompass a range of subjects, including eco-design, circular product design, and eco-innovations within Brazilian companies. The author collaborates closely with Lopes de Sousa Jabbour A.B. and Jugend D.

Conversely, Brazil is leading in CE publications in Latin America, showcasing research that underscores the benefits of adopting this model. These advantages encompass enhanced waste management, recycling, conversion of waste to energy, and utilizing renewable resources. Embracing such practices holds the potential to address environmental challenges like resource depletion, pollution, and climate change. Furthermore, several articles delve into the socio-economic factors influencing the adoption of eco-innovations, aiming to promote both environmental and economic sustainability.

In Brazil, the interest in CE emerged significantly due to unregulated development and inadequate waste management practices, resulting in environmental pollution as an externality stemming from the country's industrial expansion [44,55]. The absence of regulations and government policies for CE implementation within companies, along with insufficient adherence to proper processes under weak policies, prompted the establishment of the National Solid Waste Policy (NSWP) in 2010 [37,56,57]. Another area of interest in Brazil pertains to using biofuels derived from sugarcane, which emerged as a response to the oil crisis of the 1970s and swiftly evolved into a burgeoning market [58].

Mexico has emerged as a frontrunner in the CE field within Latin America, boasting a substantial body of CE publications. The country has made noteworthy research contributions across diverse CE domains, encompassing economic and environmental aspects of recycling, applying CE principles in the electronics sector, handling construction and demolition waste, and the production of biofuels from biomass. These research endeavors have garnered recognition from scholars such as Cordova-Pizarro, Aguilar-Barajas [59], who underscored the importance of Mexican studies in shaping new trends in electronic product management. Likewise,

Colombia has made significant contributions to the CE literature in Latin America, with studies establishing links between CE and sustainable development frameworks. These studies span a wide array of subjects, including implementing CE methodologies in rural settings, advancing CE within the construction industry, eco-innovation, and identifying pivotal factors and stakeholders in biosolids management and utilization. Other research topics encompass drivers for waste management aligned with CE principles, the promotion of entrepreneurship through a community learning model, and the utilization of agro-industrial waste.

The most cited publications in CE revolve around industrial ecology, waste management, and sustainable development in emerging economies. These articles delve into eco-innovations, corporate symbiosis, waste valorization, urban metabolism, circular supply chains, institutional frameworks, technology, and cultural influences in promoting sustainable practices. Additionally, these articles delve into nuanced case studies spanning diverse regions, including Brazil, Puerto Rico, Chile, Peru, and Colombia, offering valuable perspectives on the conceivable advantages and obstacles of embracing circular and sustainable approaches.

In the technical realm, scholarly articles investigating the convergence of the CE with waste management and energy recycling put forward a range of methodologies aimed at fostering sustainable and circular advancement across multiple sectors, encompassing waste management, agriculture, and manufacturing. These methodologies encompass technical approaches like life cycle assessment and process optimization alongside social and economic factors, such as the efficacy of informal recycling and the economic implications of recycling initiatives. The research advocates using CE strategies and tools to amplify resource efficiency, decrease waste generation, and mitigate environmental and societal repercussions.

The articles published in CE in Latin America over the last three years encompass a broader spectrum of topics. These include stakeholder engagement, pioneering business models, sustainable performance, the emergence of Industry 4.0 technologies, aquaculture, reverse logistics, open innovation, waste management, eco-innovation, life cycle assessment, governance tools, and resource retrieval. Certain studies delve into the possibilities presented by diverse waste streams for resource recovery and circularity, while others examine the contribution of renewable energy, mainly green hydrogen, in facilitating the transition toward a CE.

By embracing CE practices, Latin America encounters substantial challenges in realizing the Sustainable Development Goals (SDGs). The region's historical dependence on natural resource exports has rendered many nations susceptible to the negative impacts of commodity cycles. Although CE solutions hold the potential to foster diversification within sectors and yield added value, the absence of standardized indicators to gauge progress toward the SDGs hinders effective impact measurement and transparency. Moreover, limited access to financing and technological innovation in the region prevents the adoption of CE practices. Overcoming these obstacles necessitates collaborative endeavors between the public and private sectors and dedication to policy frameworks prioritizing sustainable economic growth and development. Notably, impediments to CE implementation in Latin America, as pointed out by Elabras Veiga and Magrini [44], include a distinct lack of governmental support. This perspective aligns with the theory outlined by Chiappetta Jabbour, Seuring [31], who incorporate this factor into their methodological approach.

Given the considerable growth in volume and diversity of literature investigating the CE in Latin America, the field of research still faces particular challenges and pending scholarly avenues. Looking ahead to the future of scholarly contributions in this domain, as underscored in the ECLAC report by Schröder, Albaladejo [21], specific issues persist, such as the insufficiency of information and data regarding regional stakeholders, companies, and civil society involvement, which continue to impede research reliability and productivity. Similarly, limited interdisciplinary connections between technical, economic, and social disciplines hinder effective research collaboration. Furthermore, the dearth of funding from private and public institutions is evident in the concentration of publications among a select group of funded authors. At the same time, numerous research outputs are generated by independent and less interconnected authors, as evidenced in the co-citation analysis.

On the flip side, concerning pending research streams, the region's progress in achieving Sustainable Development Goals (SDGs) remains a subject of concern, necessitating further scholarly production. For instance, the interplay between waste management in densely populated Latin American cities and health and hygiene concerns presents an area where the CE literature has yet to propose strategies, business models, and techniques to enhance the sanitary and economic well-being of the population through CE initiatives. These avenues could be harnessed by policymakers, businesses, and society at large. Similarly, concerning the competencies, expertise, and knowledge essential for the successful implementation of CE initiatives, research still has opportunities to contribute to cultivating and applying these proficiencies to address the specific challenges encountered in Latin America. Lastly, as indicated by the heat map in this study, research has predominantly focused on waste management in conjunction with sustainable development, recycling, and energy production. However, several thematic domains remain relatively underdeveloped, encompassing trending subjects on the global stage, such as industrial symbiosis, industrial ecology, bioeconomy, green business models, green economy, and green taxes.

Several key findings emerge when discussing the trends that the CE should follow in Latin America. Firstly, there is a clear need for increased collaborative efforts among researchers within their own countries and for establishing connections with institutions in developed countries that excel in CE practices. Prominent examples of such developed countries include Germany, the Netherlands, and Finland, which have made significant strides in this field.

Furthermore, it is crucial to stimulate research development specifically focused on CE in countries such as Paraguay and El Salvador. These countries show low participation in relevant research, underscoring the importance of promoting and supporting research initiatives within these contexts. Additionally, there is a pressing need to intentionally broaden the scope of CE research beyond the traditional focus on waste management. Exploring other areas such as technology and energy, supply chain management, eco-design, and sustainability is essential. Brazil and Mexico, with their significant contribution to over 54% of publications in the region, should serve as catalysts for research endeavors in the field.

Finally, promoting the development of the Circular Economy (CE) in Latin America encompasses several key aspects.

- a) The region's transition to a CE can be accelerated by the decreasing demand for specific raw materials and the potential regulatory limitations imposed on industries relying on linear business models. These pressures present an opportunity for businesses to shift towards circular practices and drive sustainable economic growth.
- b) The progress of major economic powers, such as the European Union and China, in adopting circular models can positively impact Latin America. Collaborative partnerships and knowledge exchange can facilitate technology transfer and inspire innovative circular initiatives in the region.
- c) Mexico, Colombia, Brazil, Chile, and Bolivia are emerging economies that show remarkable advancements in digital-driven innovation. Leveraging digital technologies can significantly enhance resource optimization, efficiency, and the adoption of circular principles, fostering sustainable development.
- d) The CE offers lucrative commercial prospects for businesses in Latin America, particularly in sectors like agriculture, renewable energy, and waste management. Embracing circular approaches can create new market opportunities, stimulate entrepreneurship, and contribute to sustainable economic growth. Seeking new energy sources can have a significant environmental impact in Latin America, reducing pollution and the carbon footprint. However, these aspects are often undervalued due to the region's natural wealth.
- e) Strengthening policies related to waste management, prevention, fiscal incentives, and Extended Producer Responsibility (EPR) systems is essential. These policies drive responsible waste management practices, encourage circularity, and foster sustainable business models throughout the value chain. For example, recycling at the source can promote new eco-innovation research.
- f) The CE can serve as a tool to address poverty and inequality in the region when implemented appropriately and considering its impact on human development. Promoting inclusive participation and ensuring equitable access to circular initiatives can create opportunities for socioeconomic advancement and improve the well-being of marginalized communities.
- g) The CE holds significant potential for stimulating and advancing development in Latin America, particularly in the agricultural sector. By embracing circularity in agriculture, urban development can be promoted while addressing social equity and poverty. Eco-innovations for agricultural waste can generate value-added products and byproducts, minimizing waste and creating economic opportunities and employment in rural communities.

By embracing these aspects and fostering collaboration between stakeholders, Latin America can unlock the full potential of the CE, drive sustainable development, and create a prosperous, equitable, and environmentally conscious future for the region.

5. Conclusions

The Circular Economy (CE) in Latin America is still in its early stages of development, but the interest and research in this field have grown since 2017. This multidisciplinary domain has garnered attention from academia, policymakers, and industry leaders who recognize its potential to promote sustainable regional development. However, fundamental challenges in funding, government engagement, and collaboration continue to impede academic production in this field. The scientific literature highlights policies, infrastructure, financing, and education's significance in advancing CE. Notably, Brazil and Mexico have emerged as leaders, contributing the highest volumes of publications in CE, encompassing topics like waste management, eco-innovations, and sustainable performance. The most cited publications revolve around industrial ecology, waste management, and sustainable development. These articles put forth a range of technical, social, and economic approaches to stimulate sustainable and circular development across various sectors, including waste management, agriculture, and manufacturing. Overall, the CE in Latin America holds the potential to foster sustainable consumption and production patterns, enhance resource efficiency, and mitigate environmental and social impacts. However, due to Latin America's stagnation in advancing SDG achievement, substantial work remains to be undertaken to implement and harness the CE in alignment with the region's sustainability needs.

The study on CE in Latin America acknowledges limitations that offer potential avenues for future enhancement. Firstly, while the investigation centered on the Scopus repository, forthcoming studies could contemplate incorporating other repositories or databases to encompass research conducted in Latin America that might be published in languages other than English. This addition would afford a more all-encompassing perspective of CE developments in the region. Additionally, although a wide array of keywords related to CE was employed, there is potential for expanding the scope to encompass emerging viewpoints from sustainability, environmental studies, ecology, and economics. By integrating these perspectives, forthcoming research can further underscore the multidisciplinary nature of the CE and capture supplementary insights and potentialities within the domain. These potential refinements will contribute to a more comprehensive and holistic comprehension of CE advancements in Latin America.

Author contribution statement

- 1 - Conceived and designed the experiments.
- 2 - Performed the experiments.
- 3 - Analyzed and interpreted the data.
- 4 - Contributed reagents, materials, analysis tools or data.
- 5 - Wrote the paper.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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