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REVIEW PAPER

Evaluation Methodologies for Circular Economy in Municipal Composting and Urban Agriculture: a Literature Review with Focus on Latin America

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Abstract

The Circular Economy (CE) offers a promising alternative to the prevailing linear economic model, yet robust evaluation methodologies are essential to assess its implementation and impact. This literature review examines methodologies applicable to municipal composting systems linked to urban agricultural production, with a specific focus on the Latin American context. The study reveals that despite numerous methodologies developed to evaluate circularity, there is a lack of structured methodologies to assess the circularity of municipal organic waste management systems through composting and its connection with urban agriculture, particularly in heterogeneous and multivariate contexts like Latin American cities. The review indicates that Life Cycle Assessment (LCA) is commonly used, but often with a primary focus on environmental impacts, neglecting social, economic, and circularity dimensions. The findings emphasize the necessity of developing methodological models tailored to the conditions of Global South regions, acknowledging the challenges in implementing CE and the importance of reviewing ongoing efforts toward circularity.

Extended author information available on the last page of the article

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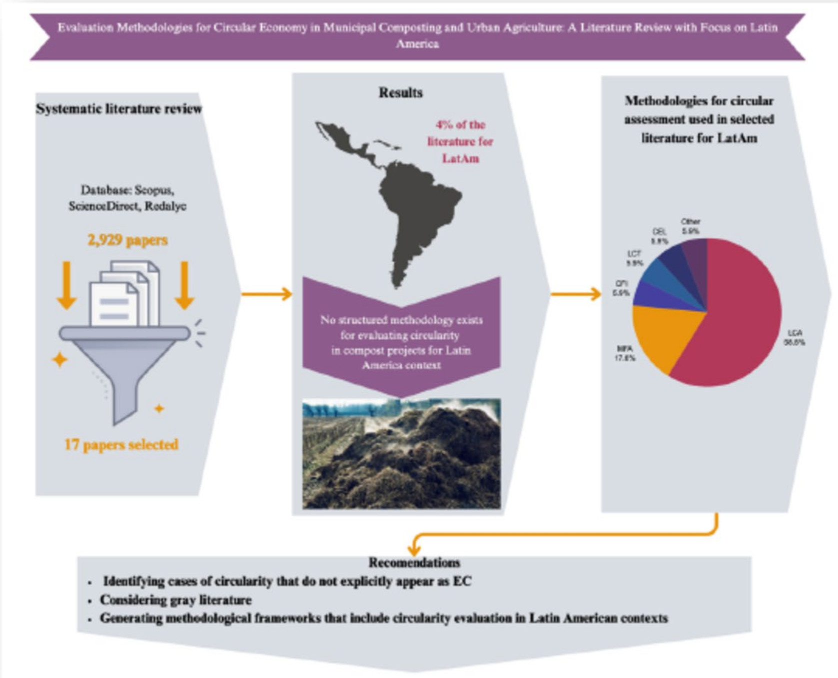
Graphical Abstract



Keywords Circular Economy · Evaluation Methodologies · Composting · Agriculture · Life Cycle Analysis · Latin America

Introduction

The global socio-ecological crisis is fundamentally rooted in the linear economic model of extraction, use, and disposal, which contradicts the cyclical nature of ecological systems. This model drives resource depletion, waste generation, and environmental degradation, exacerbating challenges such as fossil fuel dependency, growing socio-economic inequality, and increasing greenhouse gas (GHG) emissions, all of which accelerate climate change. In contrast, the Circular Economy (CE) presents a promising alternative by decoupling economic growth from resource extraction and prioritizing resource minimization, reuse, and recirculation (Ellen MacArthur Foundation, 2019) [1]. Circular Economy is viewed as a condition for sustainability, a beneficial relation, or a trade-off. A transition towards a more circular economy entails extending the value and utility of products while repurposing production and consumption waste as secondary resources, offering solutions and co-benefits to various economic and environmental challenges (Geissdoerfer et al., 2017; Kirchherr et al., 2017; Mayer et al., 2019) [2–4].

There is a recognized urgency to move towards a circular economy, due to the effects of resource and biodiversity depletion, climate change and growing inequalities between countries related to the world's production and consumption patterns (ISO 2020) [5]. This is particularly true in developing countries, who have tended to bear the brunt of inequalities of wealth and waste in the developed world.

CE aligns with the United Nations Sustainable Development Goals (SDGs), strongly related to the achievement of SDGs 12, 9, 13, 12 and 15 with potential synergies with SDGs 1, 2 and 14 (Belmonte-Ureña, et al., 2021) [6]. Notably will have a direct relation in the promotion of a responsible consumption, economic growth, and climate action (Korhonen et al., 2018) [7], as it includes production and post-consumer strategies designed to close, slow down, or narrow resource cycles. The maximization or extension of the resource's utility directly implies the aggregation of continuous value to materials, which remain active in the production system for a longer time (Deshpande & Haskins, 2021) [8]. The realization of these benefits hinges on overcoming obstacles related to resource efficiency, waste management, and socio-economic equity—challenges that are particularly pronounced in regions such as Latin America. Despite CE's recognition as a potential solution to sustainability challenges, significant theoretical and practical barriers persist, particularly regarding the gap between conceptual frameworks and real-world applications.

The development and implementation of CE policies are shaped by the societal and institutional contexts in which they emerge. Consequently, even when countries face similar sustainability challenges—such as waste reduction or resource efficiency—their responses may vary significantly due to differences in political, economic, and social landscapes (Haswell et al., 2024) [9]. Recognizing and adapting to these regional differences is crucial when applying sustainability frameworks like CE in Global South contexts. Governance structures, political priorities, stakeholder networks, and institutional capacities in these regions often diverge considerably from those in the Global North, necessitating tailored approaches to CE implementation.

In megacities—defined as urban areas with populations exceeding 10 million—CE strategies become even more critical. As global population growth and urbanization accelerate, these densely populated, human-centered ecosystems are set to become pivotal drivers of environmental and socio-economic transformations (IDB, 2014) [10]. Current projections indicate that the global population will continue to rise, reaching 8.5 billion by 2030 and 11 billion by 2100 (Jones, 2024) [11]. Simultaneously, urbanization is intensifying, with more than 4 billion people residing in urban areas, including over 600 million in megacities (Ding, He, & Zhu, 2022) [12]. By 2030, approximately 60% of the global population is expected to be urbanized, increasing to nearly 70% by 2050 (Mackay & Shaker, 2024) [13]. Cities and megacities account for the majority of global energy consumption and GHG emissions (Taylor et al., 2012) [14], underscoring the urgent need for sustainable urban interventions. Notably, organic waste mismanagement remains a pressing issue, yet it also presents an opportunity for CE solutions to mitigate urban environmental challenges.

Latin America is the most urbanized developing region in the world, home to some of its largest cities, including Buenos Aires, Lima, Mexico City, Rio de Janeiro, and São Paulo, each with populations approaching or exceeding 10 million. Currently, 80% of the region's 505 million inhabitants reside in urban areas, a figure expected to reach 87% (685 million people) by 2050—significantly higher than the global urbanization rate of approximately 54% (UNDDR, 2025) [15]. These urban centers play a crucial role in fostering innovation, concentrating skilled labor, stimulating economic activity, and providing essential public services. However, rapid urban expansion also exacerbates socio-environmental challenges, including inequality, insecurity, pollution, inadequate public infrastructure (Mackay & Shaker, 2024) [13], and food sovereignty concerns (Artmann & Sartison, 2018) [16]. Additionally, the increasing frequency of extreme climate events heightens urban vulnerabilities, particularly for marginalized populations. Urban areas significantly contribute to climate change, accounting for over 75% of global energy consumption and generating between 75% and 80% of global GHG emissions. Addressing these challenges is imperative to safeguarding and enhancing the quality of urban life in both the present and future (Mackay & Shaker, 2024) [13].

Latin America presents unique challenges, such as high levels of socio-economic inequality, weak institutional frameworks, and a predominance of informal waste management systems. Additionally, regional agricultural and urban composting systems operate under different governance structures, financial constraints, and cultural perceptions compared to those in highly industrialized economies. These differences affect the applicability and effectiveness of CE evaluation methodologies, necessitating an approach tailored to Latin America's specific conditions.

Urban agriculture is a sector that, while contributing to environmental pressures such as water consumption, GHG emissions, and land-use changes, stands to benefit substantially from CE principles. Composting, for instance, exemplifies CE by closing the loop between consumption, waste generation, and resource regeneration (Rashid, M. 2021) [17]. However, integrating CE into agriculture faces unique hurdles in the Global South, where socio-political, economic, and environmental conditions complicate implementation. Context-specific evaluation methodologies are essential to accurately assess CE's potential in these regions.

Despite the global recognition of CE as a key strategy for sustainable development, its adoption and implementation in Latin America remain limited and underexplored. Many methodologies used to evaluate CE in other regions fail to fully account for Latin America's unique socio-economic, regulatory, and infrastructural conditions. While CE has advanced significantly in the Global North, Latin America faces distinctive challenges, including pronounced socio-economic inequality, weak institutional frameworks, and a reliance on informal waste management systems, all of which influence the feasibility and effectiveness of CE initiatives. Furthermore, regional agricultural and urban composting systems operate under governance structures, financial constraints, and cultural perceptions that differ markedly from those in industrialized economies.

Methodological frameworks for evaluating CE strategies have been developed and refined from various approaches, and currently, there is an abundance of indicators to measure resource efficiency and sustainability performance (environmental, economic, and/or social) (Pauliuk, 2018) [18]. Iacovidou et al., [19] identified over 60 environmental, economic, social, and technical metrics that can be used solely to assess waste management and resource recovery systems from a CE perspective. In 2016, the European Academies' Science Advisory Council (EASAC) [20] provided a list with over 300 indicators that could be used to measure progress in CE. However, guidance on monitoring the implementation of CE strategy remains vague. The standard stipulates that organizations are solely responsible for choosing appropriate CE indicators, and often these metrics present contradictions in both form and content, contributing to confusion and misunderstandings in public and academic debates (Corona et al., 2019) [21].

This study is of paramount importance as it aims to bridge this critical knowledge gap by developing evaluation frameworks that align with Latin America's specific challenges and opportunities. While global experiences provide valuable insights, methodologies must be adapted to Latin American realities to ensure practical and actionable recommendations. Understanding how circularity can be effectively measured and applied to municipal composting and urban agriculture in these conditions is essential for facilitating a sustainable transition to CE in the region.

By identifying key research gaps and proposing a nuanced approach to evaluating CE in agriculture—particularly composting in the Global South—this research contributes to the refinement of evaluation methodologies, ensuring their applicability to diverse socio-economic and environmental contexts. The findings of this study will support the advancement of sustainable CE initiatives, addressing pressing concerns related to sustainability, climate action, and socio-economic equity, ultimately fostering more resilient and sustainable urban systems in Latin America.

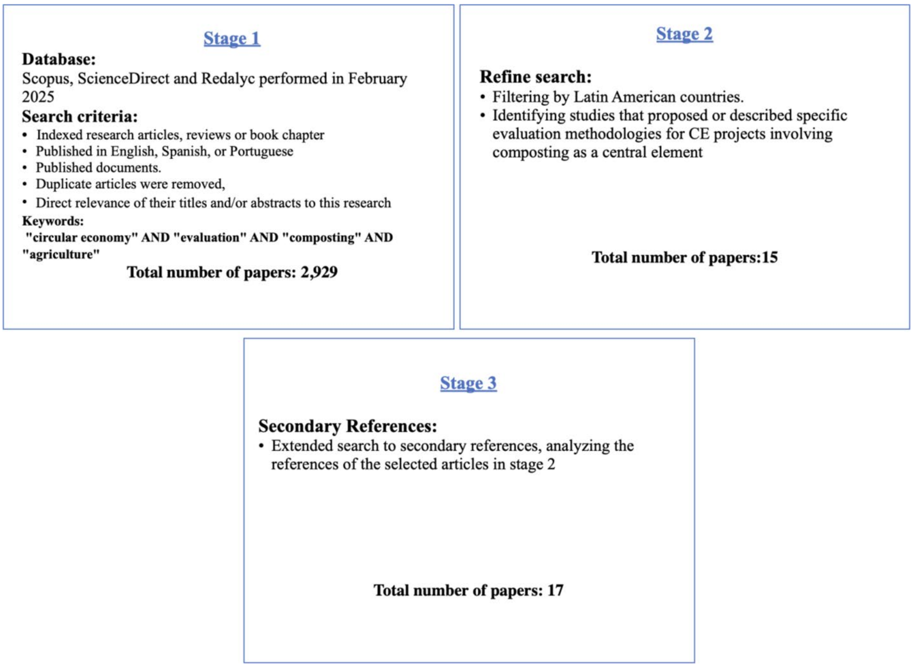


Fig. 1 Process for literature selection, based on PRISMA methodology

Methodology

Literature Search

For the systematic literature analysis, a selection of information was conducted based on the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) methodology (2020) [22], whose process is described in Fig. 1. The databases used were Scopus, ScienceDirect, and Redalyc, as they contain the highest number of journals and literature related to the topic of CE. This review included defining the search, identifying keywords, and available sources of information.

The search focused on scientific research articles using the following protocol: (i) years of publication between 2000 and 2024; (ii) titles or abstracts must include the keywords "compost" or "organic waste" and "Circular Economy" and "assessment" or "evaluation"; (iii) only indexed scientific articles; (iv) keywords must contain at least one of the following: "compost," "circular economy," "assessment," "agriculture," "circularity." From the result of this search, we filtered according to selection criteria, resulting in 17 articles that met the characteristics of this research for analysis.

Selection Criteria

The criterion for these searches is shown in Fig. 1, We used the selecting indexed research articles, reviews, and literature compilations in English, Spanish or Portuguese, limited to already published documents. Duplicate articles were removed, and articles were chosen based on the direct relevance of their titles and/or abstracts to this research.

As shown in the Fig. 1, the database search process was conducted in three stages, starting from general to specific, with the results detailed in Table 1.

Stage 1 In the selected databases (Scopus, ScienceDirect and Redalyc), a first gross searched was carried out to find articles related to the topic of this review. The search keywords were "circular economy" AND "evaluation" AND "composting" AND "agriculture." Articles were selected based on the filters and selection criteria. In the case of Redalyc, being a database for Latin American literature, the search was also carried out in Spanish.

Stage 2 Once general results were identified, a filtering was performed on those coming from Latin American country using the same databases and parameters, resulting in a considerably smaller amount of available literature. Subsequently, the research focused on identifying studies that proposed or described specific evaluation methodologies for CE projects involving composting or organic waste management as a central element. Special attention was paid to the evaluation criteria used for circularity, the implementation of the methodologies, and their relevance to the stakeholders involved.

Stage 3 The search was extended to secondary references by analyzing the bibliographies of the initially selected articles. This allowed the identification of a small number of significant works cited within the primary literature, especially those addressing the CE in the context of Latin American countries. This step was crucial to ensure a comprehensive and updated understanding of the topic and to incorporate perspectives and findings from

Table 1 Results obtained from keyword search

Search Database[1]	Applied Filters	Search 1	Results	Search 2	Results Filtered by Relevance and Pertinence to the Objective of This Study
		Key words		Filtering of Studies Conducted in Latin American Countries	
Scopus	Limited to Article Limited to review Peer Reviewed Published Language: English, Spanish, Portuguese	"Circular economy" AND "evaluation" AND "composting" AND "agriculture"	1,313	28	6
ScienceDirect	Limited to Article Limited to review Peer Reviewed Published Language: English, Spanish, Portuguese Open Access	"Circular economy" AND "evaluation" AND "composting" AND "agriculture"	1,567	57	5
Redalyc	Limited to Full text Peer Reviewed Language: English and Spanish	"Circular economy" AND "evaluation" AND "composting" AND "agriculture"	14	10	1
	Limited to Full text Peer Reviewed Language: English and Spanish	**"economía circular" Y "evaluación" Y "compostaje" Y "agricultura"**	35	12	3
Secondary references				2	
Total Number of Articles to Include in the Review				**17**	

[1]Last Access Date: Feb 2025

research conducted specifically in Latin American contexts, which have socioeconomic and environmental particularities that can influence the applicability and success of CE projects.

It is important to clarify that, for this literature review, the conceptual reference was taken from the definition of circularity evaluation methodologies described by Corona et al. (2019) [21], in which they analyze that circularity metrics aimed at measuring the contribution of circular strategies to sustainable development, should be comprehensive enough to prevent a shift from reduced material consumption to increased environmental, economic, or social impacts. Such a metric should clearly indicate how the benefits of recycling are allocated to recyclers and users of recycled materials and should include measurements of added economic value. Therefore, the identification of literature was based on selecting works that meet or closely align with this description when discussing CE evaluation methodologies, or where their objectives include measuring circularity, to analyze how measurement is approached.

Results Analysis

Description of Circularity Assessment Methodologies

The results revealed a significant information gap regarding how to assess circularity in composting projects linked to agriculture in Latin American regions. A total of 2,929 articles were found in the first search, but only 4% of them are from Latin American regions, as shown in Fig. 2. Of the latter, only 17 articles were directly related to the objective of this review. It is important to clarify that none of the articles found proposed a methodology to evaluate the circularity of urban organic waste composting and its contribution to urban or peri-urban agricultural systems in any Latin American region. Therefore, the results obtained will be used to identify the most used methodologies in similar cases or those with some relevance or applicability.

Of all the papers not included in this literature review, many focus on industrial ecology, waste management, and sustainable development in general. These articles explore topics such as eco-innovations, corporate symbiosis, waste valorization, urban metabolism, circular supply chains, institutional frameworks, technology, and cultural influences in promoting sustainable practices. However, very few specifically address the assessment of circularity and its application in composting projects.

A total of 16 articles were analyzed, including those identified through references from other authors. Of these, 8 employed the Life Cycle Assessment (LCA) methodology or its derivatives (LCC, SLCA, LCSA, and LCT), 1 combined LCA with another methodology, and 7 utilized alternative approaches, such as the Circular Economy Level (CEL) of a supply chain, Material Flow Analysis, or Multi-Criteria Analysis, as shown in Fig. 3. Notably, only one of the selected articles addressed all three dimensions of sustainability (environmental, economic, and social) while also considering or mentioning circularity evaluation in processes, as detailed in Table 2. The remaining articles primarily focused on the environmental dimension, with some providing limited coverage of social or economic aspects. Most of the articles were published within the last three years, highlighting the recency of

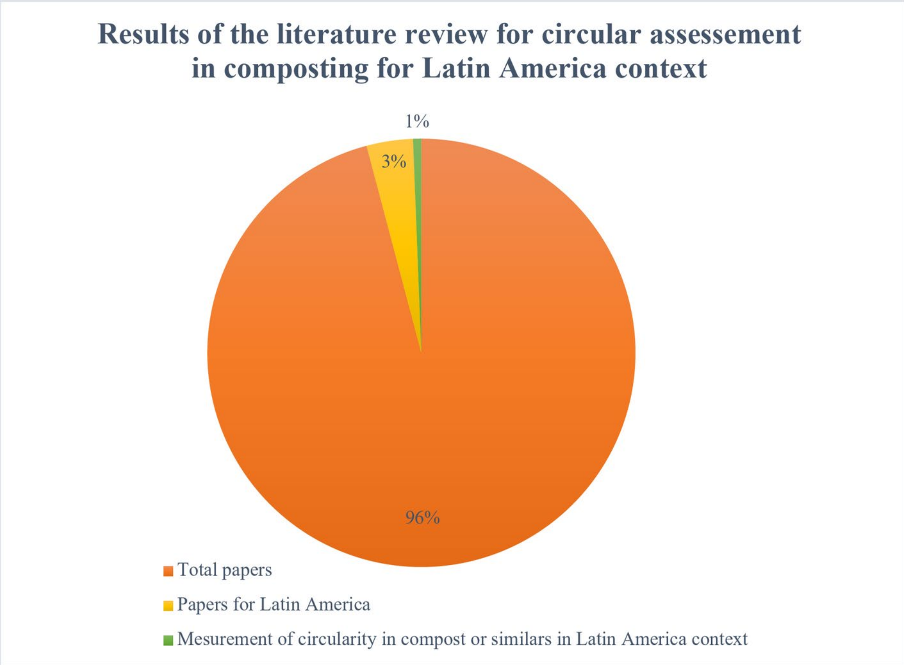


Fig. 2 Percentage of papers found in the systematic literature review

the research. In terms of geographic distribution, Brazil had the highest number of studies, followed by Colombia and Ecuador, as illustrated in Fig. 4.

Life Cycle Assessment (LCA) for Avaluation of Circularity in Composting Projects

As detailed in Table 2, most of the articles identify in this review uses LCA methodology for the evaluation of the CE perspectives. LCA is widely recognized as the primary methodological framework for assessing the environmental impacts of circular products and systems (Villanueva & Wenzel, 2007 [27]; Cooper & Gutowski, 2017 [28]; Corona, 2019 [21]). Its flexibility allows integration with other sustainability metrics, such as Life Cycle Costing (LCC) for economic evaluation and Social Life Cycle Assessment (S-LCA) for social aspects. To enhance systemic integration, the Life Cycle Sustainability Assessment (LCSA) framework was developed (Klöpffer, 2008 [29]).

However, studies applying LCA to composting often overlook social, economic, and circularity assessments. Oviedo-Ocaña et al. (2023) [30] conducted a systematic review on LCA for composting, highlighting key challenges: variability in impact categories, lack of consensus on functional units and system boundaries, and difficulties in defining emissions. They emphasize the need for primary data, regional databases, and methodologies to evaluate the environmental benefits of composting, particularly in developing countries.

De Morais Lima et al. (2021) [31] analyzed municipal waste management scenarios in Brazil using LCA, finding high uncertainty due to data scarcity in rural areas. Their results underline the importance of municipal policies, education, and behavioral change but lack a

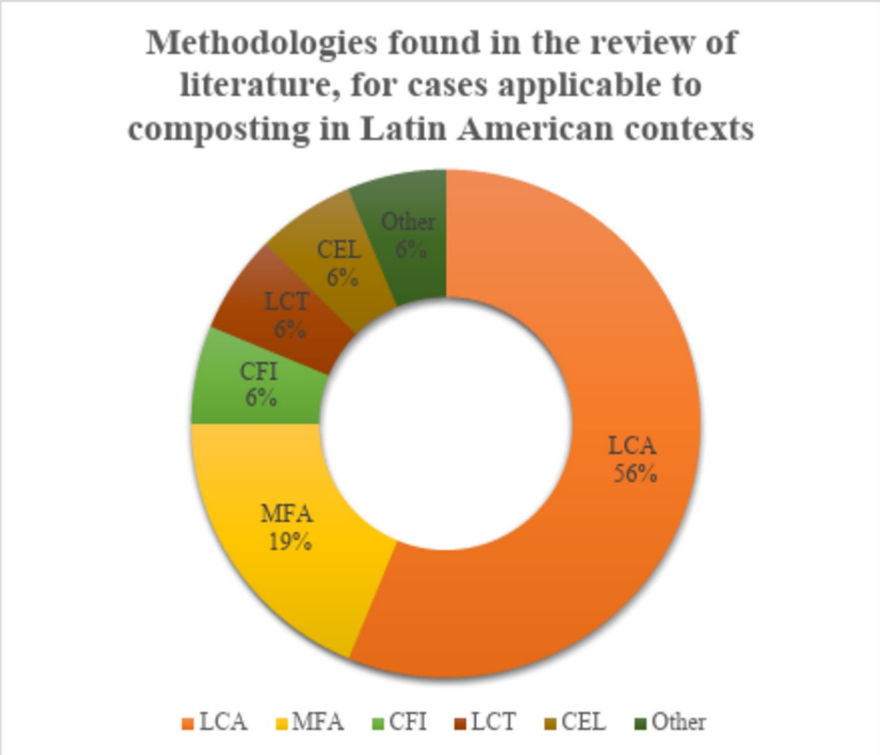


Fig. 3 Type of methodologies used in the review of literature, for cases applicable to composting in Latin American context

methodological framework for circularity assessment. Similarly, Oliveira et al. (2021) [32] applied LCA to an urban horticulture system in Belo Horizonte, Brazil, to estimate potential reductions in environmental impact through circular local production but did not assess economic or social dimensions.

Chrispim et al. (2020) [33] proposed a resource recovery framework for a wastewater treatment plant in São Paulo, favoring biogas recovery and sludge composting. Although LCA was used, circularity was not explicitly addressed. The authors acknowledge the need to refine the framework to assess composting's contribution to circular systems. Laura et al. (2020) [34] applied LCA to sludge management in Guatemala, recommending composting for pathogen reduction and soil enhancement. However, the study does not evaluate social or economic aspects.

Ibáñez-Forés et al. (2021) [35] examined urban waste management in Brazil through LCA, concluding that improving composting and selective waste separation is essential for long-term sustainability. While they propose circularity-driven scenarios, their analysis focuses solely on environmental impacts, excluding socio-economic factors and material recirculation.

Across these studies, circularity remains an underdeveloped component in LCA applications. A transition from the conventional "cradle-to-grave" approach to a circular "cradle-to-

Table 2 Summary of the reviewed evaluation methodologies on circularity

Evaluation Methodology	Envir	Econ	Soci	Circ	Object of study	Type of waste	Scale	Year	Authors	Country
Life Cycle Analysis (LCA)	x				Life cycle assessment of biowaste and green waste composting systems	AOW	Loc	2023	Oviedo-Ocaña, et al	Brazil
	x				Resource-oriented sanitation: Identifying appropriate technologies and environmental gains by coupling Santiago software and life cycle assessment in a Brazilian case study	MSW	Loc	2022	de Morias Lima	Brazil
	x				Environmental assessment of waste handling in rural Brazil: Improvements towards circular economy	AOW	Mun	2021	de Morias Lima	Brazil
	x				A sustainable approach for urban farming based on city logistics concepts for local production and consumption of vegetables	AOW	Mun	2021	Oliveira et al.,	Brazil

Table 2 (continued)

Evaluation Methodology	Envir	Econ	Soci	Circ	Object of study	Type of waste	Scale	Year	Authors	Country
	x				Selecting sustainable sewage sludge reuse options through a systematic assessment framework: Methodology and case study in Latin America	WW	Reg	2020	Laura et al.,	Guatemala
	x				Achieving waste recovery goals in the medium/long term: Eco-efficiency analysis in a Brazilian city by using the LCA approach	MSW	Mun	2021	Ibáñez-Forés et al.,	Brazil
	x		x		Applying a circular transition model focused on LCA to promote the knowledge acquired by students in compost process in a home environment containment of the COVID-19 pandemic	DOW	Loc	2022	Ramírez C.I.A. et al [23]	México

Table 2 (continued)

Evaluation Methodology	Envir	Econ	Soci	Circ	Object of study	Type of waste	Scale	Year	Authors	Country
Life Cycle Analysis (LCA)/SWOT Analysis	x	x	x		An integrated environmental assessment of MSW management in a large city of a developing country: Taking the first steps towards a circular economy model	MSW	Mun	2022	Lara-Topete, G. et a	Mexico
Life Cycle Assessment (LCA)/ Linear Programming (LP)	x				Combined application of Life Cycle Assessment and linear programming to evaluate food waste-to-food strategies: Seeking for answers in the nexus approach	AOW	Mun	2018	Laso J. et al	Spain
Life Cycle Think (LCT)	x	x	x		Life Cycle Thinking for a Circular Bio-economy: Current Development, Challenges, and Future Perspectives	MSW	Mun	2023	Ramos Huarachi et al	Brazil

Table 2 (continued)

Evaluation Methodology	Envir	Econ	Soci	Circ	Object of study	Type of waste	Scale	Year	Authors	Country
Multicriteria analysis	x	x	x		A robust multicriteria analysis for the post-treatment of digestate from low-tech digesters. Boosting the circular bioeconomy of small-scale farms in Colombia		Loc	2022	Juan-pera, M. et al	Colombia
Material Flow Analysis (MFA)	x		x	x	Assessing Nutrient Circularity Capacity in South American Metropolitan Areas	MSW	Reg	2022	Girett et al	Brazil, Argentina, Peru, Colombia, Chile, Venezuela, Ecuador, Paraguay, Uruguay y Bolivia
	x	x		x	The study assesses the potential for nutrient recycling (N, P, K) and renewable energy production through anaerobic wastewater treatment in Las Juntas de Abangares, Costa Rica. It proposes a circular management model for liquid, solid, and gaseous by-products of a treatment plant	WW	Loc	2023	Solano R. et al [24]	Costa Rica

Table 2 (continued)

Evaluation Methodology	Envir	Econ	Soci	Circ	Object of study	Type of waste	Scale	Year	Authors	Country
	x	x		x	Circular agriculture increases food production and can reduce N fertilizer use of commercial farms for tropical environments	AOW	Loc	2023	Moreira G. et al [25]	Brazil
	x				Generate an analytical tool to carry out an Environmental Balance of the City. Taking Mexico City as a case study, the article begins by analyzing the metabolic fluxes of the city from 2009–2012, then estimates the local carrying capacity	MSW	Mun	2018	Rosales-Pérez, N [26]	Mexico
Material Flow Analysis (MFA)/ Other-life-cycle-based	x			x	Economy Indicators for the Assessment of Waste and By-Products from the Palm Oil Sector. Processes/	AOW	Reg	2022	Bejarano et al	Colombia
Level of circular economy of a supply chain (CEL)	x	x	x	x	Evaluation of the Circular Economy in a Pitahaya Agri-Food Chain	AOW	Loc	2022	Diéguez-Santana et al	Ecuador

Env Environment; *Eco* = Economy; *Soc* = Society; *Circ* = Circularity

Scale is measured by Regional = Reg, Municipal = Mun and Local = Loc, depending on the size of the project or sector evaluated

Type of waste: *DOW* = Domestic Organic Waste; *MSW* = Municipal Solid Waste; *AOW* = Agricultural Organic Waste; *WW* = Waste Waters

Fig. 4 Latin American countries where the identified studies are carried out

cradle" perspective is needed. Future research should adopt systemic, multidisciplinary, and multi-criteria evaluations to align LCA more effectively with circular economy principles.

It is observed that for all the studies found using the LCA methodology, there is a need to further develop the circularity component, which should be systemic, multidisciplinary, and multicriteria. This would allow for the adaptation of CE strategy evaluations in an operational and comprehensive manner, shifting from the typical "cradle to grave" approach to a circular "cradle to cradle" vision.

Life Cycle Analysis Combined with Other Methodologies

Several authors highlight the need to extend Life Cycle Assessment (LCA) beyond environmental evaluation by integrating complementary methodologies. Life Cycle Thinking (LCT) has emerged as a broader framework incorporating LCA, Life Cycle Costing (LCC), Social Life Cycle Assessment (S-LCA), and Life Cycle Sustainability Assessment (LCSA) to comprehensively address sustainability dimensions.

Ramos Huarachi et al. (2023) [36] reviewed LCT applications in the biocircular economy (CBE)[1], noting its recent growth, particularly in Europe, with a primary focus on bio-

[1] According to the Center for International Forestry Research (2021) [59], the bio-circular economy is a nature-driven economy. This new concept stems from the circular economy (CE) and emphasizes the use of renewable, biologically sourced materials derived from agricultural, forestry, and marine waste and residues that are not used in normal production processes or are discarded. In the bio-circular economy, bio-based

waste conversion to biofuels via biorefinery processes. Despite its potential, LCT remains limited to environmental assessments, neglecting economic and social dimensions. The authors identified five key challenges: expanding system boundaries, incorporating more impact endpoints, developing regional databases, promoting CBE policies, and integrating socio-economic aspects. However, LCT is still theoretical, with no established case studies.

Lara-Topete et al. (2022) [37] analyzed urban solid waste management in Guadalajara, Mexico, using LCA, sensitivity analysis, and SWOT analysis to assess economic, sociocultural, legal, political, and infrastructural challenges in transitioning to circular waste management. Their findings reveal that LCA alone indicates eco-efficiency but does not equate to sustainability. They advocate for a comprehensive approach linking environmental and economic indicators, yet the socio-political complexities of waste management remain underexplored.

Romero-Perdomo and González-Curbelo (2023) [38] examined the integration of Multicriteria Decision Analysis (MCDA) with LCA in agro-industrial biomass waste management. They identified key gaps, particularly in social impact evaluation, where stakeholders are insufficiently considered, reducing the effectiveness of circular strategies. While LCA remains the dominant tool, independent assessment of economic and social factors is necessary, as holistic sustainability analyses rarely incorporate social implications.

Laso et al. (2018) [39] proposed a Water-Energy-Food-Climate Nexus Index (WEFCNI) combining LCA with Linear Programming (LP) to optimize waste management decisions. Their study, based on anchovy canning waste in Spain, explores alternatives such as food waste valorization, waste-to-energy incineration, and landfill biogas recovery. Although applicable to food systems, the methodology lacks economic and social assessments and does not explicitly evaluate circularity.

Across these studies, the integration of circularity into LCA remains a challenge. A shift toward systemic, multidisciplinary, and multicriteria approaches is essential to bridge the gap between environmental assessments and holistic sustainability evaluations.

Other Methodologies Assessing the Circularity

While most studies reviewed rely on Life Cycle Assessment (LCA), other methodological frameworks offer valuable insights. Girett et al. (2023) [40] assessed nutrient circularity in ten Latin American metropolitan areas using Material Flow Analysis (MFA). Their study identified local conditions influencing nutrient flow management, focusing on recovery and reuse. Although it considers environmental and policy-related indicators, economic aspects and social actors beyond public policy remain unaddressed. The study underscores the necessity of a multidisciplinary approach to enable the transition toward nutrient circularity.

Bejarano et al. (2023) [41] developed indicators to evaluate circularity within the agro-industrial palm oil sector in Casanare, Colombia. Using MFA and a life cycle-based carbon footprint approach, they quantified material incorporation and avoided CO_2 emissions. Their findings inform strategies to reduce landfill use and environmental pressure. However, while their indicators effectively measure waste incorporation and prevention, they lack clear socio-economic parameters tailored to the local context.

materials are used instead of fossil fuels and materials derived from fossil fuels. The focus is on minimizing waste, sharing resources, and keeping products "alive" as long as possible, particularly through resale or reuse.

Diéguez-Santana et al. (2021) [42] proposed a circular economy (CE) assessment tool to improve business practices in Mexico and Ecuador. Their methodology, based on a 91-item checklist and neural network analysis, evaluates CE implementation levels across nine study variables. Applied to the pitahaya agri-food chain in Ecuador (2022) [43], the tool categorized CE levels into five grades, facilitating benchmarking and strategy development. While comprehensive for business applications, its adaptability to broader sectors with complex boundaries requires further validation.

Several additional studies contribute to integrating circularity into agricultural practices. Ferronato et al. (2019) [44] explored diaper composting in Bolivia, briefly addressing circularity but omitting inorganic resource use in closing agricultural cycles. Their multivariate analysis does not incorporate sustainability dimensions. Similarly, Rego (2014) [45] and Vieira & Panagopoulos (2024) [46] analyzed urban and peri-urban agriculture in Brazil, focusing on public policies and ethnographic case studies to support sustainable production within a CE framework. In Mexico, Dielman (2017) [47] examined urban agriculture from socio-ecological and economic perspectives, identifying opportunities for circular practices. However, these studies remain largely descriptive, lacking structured evaluation methodologies.

Despite methodological advancements, circularity assessments often remain fragmented. Future research should integrate multidisciplinary approaches that encompass environmental, economic, and social dimensions to enhance circular economy evaluations.

Discussion

Circularity metrics should provide an indication of how well the CE principle is applied to a product or service. However, most published circularity metrics have been criticized for not representing the systemic and multidisciplinary nature of CE (Saidani et al., 2017) [48], and they tend to focus heavily on environmental measurements or measuring the extent to which material cycles are closed. These approaches often overlook the characteristics of circular systems (e.g., whether they are shorter or longer) and the performance of multidimensional sustainability, namely environmental, economic, and social dimensions (Corona et al., 2019) [21].

Although research on the circular economy (CE) in Latin America has increased, Ospina-Mateus et al. (2023) [49] highlight that most studies focus on stakeholder engagement, pioneering business models, sustainable performance, Industry 4.0 technologies, aquaculture, reverse logistics, open innovation, waste management, eco-innovation, life cycle assessment, governance tools, and resource recovery. However, the findings of this research reveal a significant gap in the evaluation of circularity within composting and agricultural contexts.

Based on this literature review, the first key observation is the significant disparity in research volume on circularity in Latin America compared to other regions. Even when focusing on countries with strong traditions in agroecology and composting—such as Mexico, Colombia, Brazil, Argentina, Chile, Cuba, and Ecuador—there is a notable absence of studies analyzing circularity in these areas. This aligns with Betancourt and Zartha (2020) [50], who identified a gap in CE research in Latin America compared to Europe. They found that CE remains less explored in the region due to varying interpretations and terminology, often focusing on isolated aspects like industrial ecology or recycling rather than a comprehensive approach. As a result, CE research in Latin America has yet to reach its full potential, as the concept itself continues to be redefined.

Another important factor to discuss is the time it may take for the dissemination of concepts and their methods of application and measurement. Considering that most of the identified articles are less than five years old, with the majority even published in 2023, it is possible that the adaptation mechanisms for these methodologies to specific contexts are still in progress, and the increase in the number of studies evaluating composting projects from a CE perspective is just a matter of time.

Regarding the methodologies most used to measure the circularity of composting projects in agricultural contexts, it is interesting to note that, in the systematic literature search, the use of methodologies was heavily skewed towards LCA and its derivatives (LCC, S-LCA, and LCSA). This result is consistent with the rest of the literature written for the evaluation of circularity in the world, with the most widely used methodologies in Europe, China and North America, as found by Saidani et al., 2019 [51]. In fact, is it is worth noting that, in terms of circularity indicators, among the 20 sets of indicators at the micro level of CE, identified for Saidani et al. (2019) [51], 17 of them have been developed by European contributors. And for the macro level 9 indicators for circularity have been developed by Chinese actors. Indeed, academic publications on the macro level of CE come mostly from China-related cases. For Latin America region there are no development of new indicators for circularity, and these are almost the only methodologies used in the few cases where studies related to a CE evaluation were found. And this is something to point out, because this methodology does not include ways to evaluate the closing of cycles y most of the cases.

Corona (2019) [21] asserts that current circularity metrics do not address all spheres of sustainability. One reason for this, which is consistent with what Betancourt M. and Zartha S. also pointed out in 2020 [48], is the diverse understanding of the CE concept, which in some cases is reduced to a mere recirculation of materials. Such an approach might be useful for informative purposes (e.g., to what extent materials are recirculated), but due to its limited scope, it should not be used as the sole indicator to support sustainable decision-making. Moreover, circularity metrics based solely on the degree of material recirculation are insufficient for measuring the reduction or absence of virgin resource use within a process (which should be a priority in CE) and may mask a shift towards greater energy consumption and pollutant emissions. However, the degrees of material circularity are easier to communicate to the public and are playing an important role in increasing the awareness of the concept.

As shown in Table 2, most studies focus primarily on the environmental dimension, with minimal or no consideration of social and economic aspects. Furthermore, process circularity assessments are rarely applied in real-world cases. Given that composting is a key strategy for closing material cycles in urban, peri-urban, and agricultural systems—enhancing production and productivity—its success depends not only on environmental factors but also on social and economic conditions. Therefore, comprehensive methodologies are needed to evaluate sustainability dimensions and process circularity. These methodologies must be flexible and robust enough to integrate socioeconomic factors and local conditions for a more accurate and applicable analysis.

Related to the previous, Latin American countries need to address key economic, sociocultural, and political challenges to transition to CE models. These challenges include: (1) generating local data for the development of inventories and primary databases; (2) identifying relevant stakeholders in the process and determining their level and type of involvement in the process under evaluation; (3) incorporating public policies and their short, medium-, and long-term implications; and (4) developing technically skilled human resources for the design and implementation of evaluation methodologies such as LCA and its variants.

Perspectives for Latin American Contexts

The Latin American region shares not only geographic location but also characteristics not seen in other parts of the world. For example, it is a region with significant ethnic and cultural diversity converging in urban and rural centers, each with very different worldviews, priorities, and needs. It also experiences marked economic inequality, where the wealthiest 10% hold 77% of the wealth while the poorest 50% possess only 1%. Moreover, inequality levels in this region consistently exceed those of other parts of the world (De La Mata, 2022) [52]. The region also faces high levels of climate vulnerability, which makes adaptation and damage reconstruction actions a priority in public policy. Additionally, it shares a heterogeneous agricultural production sector, including large agro-industries focused on exports and a predominantly impoverished rural and peri-urban population engaged in subsistence farming, often without generational succession. This makes the social factor one of the most complex variables to include when evaluating circular strategies in agriculture.

The real challenge for the CE model in this region is to adapt the concepts to diverse realities, and for the agricultural sector this involves addressing complex issues. If the model were to be implemented in settlements and communities of the Global South, the factors to consider would be even more diverse due to the heterogeneous social and economic contexts. An example of this is the variety of agricultural models in the rural areas of Mexico City, the capital of Mexico, where there are ejidal areas (community-based land tenure systems), chinampa farming with ancestral practices, subsistence farming that interacts with ecological conservation areas, and diverse social realities such as peasant organizations fighting for land against urban growth, organized crime flows, and illegal deforestation, among others. These variables would need to be analyzed in detail to consider implementing a CE model in agricultural production. The methodologies for doing so would need to be robust and meticulous enough to capture the local reality and determine whether we can truly speak of material and economic circularity.

These diverse realities, with very different priorities, underscore the importance of simplifying the concept to ensure its dissemination and understanding at all levels through education. This approach would facilitate a quicker and more efficient transition to CE, as society itself would then pressure industries and governments to generate new sustainable policies.

In addition to economic and social issues, there are also conceptual differences in the implementation of CE between Latin America and the Global North. Betancourt M. and Zartha S. (2020) [48] found that while Europe and Asia have been working on the transition to CE for much longer, Latin America shows a strong interest in advancing these topics. However, the region faces challenges that Europe has gradually overcome, such as cultural and political factors. Unfortunately, in its eagerness to generate change, Latin America is repeating Europe's mistakes in implementing CE, particularly by presenting it as an alternative for generating economic value through recycling and waste management. These conceptual errors have been identified by Europe and may be the reason why the concept is still being redefined [48].

There are structural cultural and economic differences between the Global North and Latin America. In the Global North, CE may be seen as an alternative model or a trendy approach to making things more sustainable. In contrast, for Latin America, CE is a necessity in a world overwhelmed by environmental, social, and economic challenges. CE can represent a path toward social equality by increasing opportunities and reducing inequalities; it embodies the need for a radical change in wealth creation, and in the production, distribution, and consumption of goods and services. This change must stem from reconnecting with the natural environment and recovering cultural values to build CE from the foundations of society as a path towards sustainability (Betancourt et al., 2022) [48].

Emerging countries face various structural challenges that directly impact the implementation of policies aimed at achieving the SDGs and aligning with circular economy practices. These challenges include weaknesses in collection logistics, the material transport chain, processing, composting, recycling, and a reliance on unsustainable waste disposal methods. To address this complex issue, a comprehensive approach is necessary to design strategies that minimize these problems and enhance the opportunities each country holds. In the environmental, economic, and social dimensions, there are numerous aspects that can be explored to create viable and actionable alternatives, supported by robust and consistent policies (Sehnem et al., 2023) [53]. The development and application of circular economy through waste management projects such as composting evaluation methodologies in Latin America are essential to guide decision-makers in tracking progress toward SDG fulfillment (Sáncez A, 2022) [54]. Such methodologies provide insights into how circular practices can be effectively implemented, ensuring that the region not only advances in waste management but also fosters sustainability in a way that contributes to the global goals.

Given this, it is essential to design methodologies that can evaluate the circularity of composting projects linked to agricultural production areas, particularly in urban zones with high food demand and large volumes of organic waste suitable for composting. In these cases, the social, economic, political, and environmental realities must be considered to clearly determine whether true circularity exists. Our research team is currently conducting a study on this topic, aiming to propose a methodology that includes the spheres of sustainability and the circularity of this process, with the intention of sharing the results soon.

Limitations and Further Investigations Possibilities

The main limitations of this literature review are related to the methodology used in the search process. By focusing solely on literature published in indexed journals, experiences and non-academic publications addressing alternative ways of assessing circularity in Latin American contexts may be overlooked. It is recommended to include grey literature in the searches to gain a broader understanding of the work conducted and the potential methodologies used to assess circularity in composting projects. Expanding the search terms is also suggested, as the term "circular economy" does not necessarily appear in all cycle-closing efforts.

As an opportunity for future research, we believe that it will be valuable to establish comparisons between methodologies applied in Latin America and those used in other regions, such as Europe or Asia. This would offer valuable insights into how contextual factors determine methodological choices. A more in-depth comparison between regions is an area of opportunity for significant knowledge contributions and progress toward the transition to a more circular economy.

That said, we strongly concur that conducting a more comprehensive and quantitative comparative analysis of the identified methodologies—particularly those offering sufficient data transparency—would be highly beneficial. Future studies could explore in greater depth the technical robustness of each approach, systematically examining their underlying assumptions, data requirements, and contextual applicability across diverse settings in the region. Such research would not only provide a clearer understanding of the comparative strengths and limitations of each methodology, but also contribute to more informed, evidence-based decision-making by stakeholders and policymakers aiming to implement the most suitable approaches for their specific objectives and conditions.

Conclusions

The results of this review highlight a significant gap in the available information on how to assess circularity in composting projects related to agriculture in Latin America. Out of 2,929 articles identified in the initial search, only 4% are from Latin American countries, with just 17 directly related to the review's focus. Most of the methodologies employed to evaluate CE projects in agriculture with composting are based on LCA. However, these approaches are primarily focused on the environmental dimension and fail to sufficiently address other sustainability factors or the circularity of processes. While complementary methodologies and evaluation frameworks were found, none of the circularity metrics fully encompass all aspects of sustainability. This may be indicative of the ongoing global debate over the CE concept and its application methods.

Life Cycle Assessment (LCA) is one of the most widely used methodologies for evaluating CE initiatives, providing quantitative indicators to assess environmental impacts, such as CO_2-equivalent emissions, mineral resource depletion, and energy consumption (Corona B., 2019). Additionally, LCA integrates economic and temporal indicators, making it a robust tool for evaluating CE interventions. However, despite its extensive use, existing LCA-based approaches often fail to fully capture circularity in waste management systems, particularly in municipal composting. This limitation emphasizes the need for a comprehensive literature review to identify relevant methodologies and highlight gaps in the assessment of CE strategies, particularly in the Global South.

This study contributes to the body of knowledge by highlighting the lack of research incorporating circularity evaluation methodologies for urban agricultural systems involved in composting within Latin American contexts. The unique circumstances and characteristics of countries in this region necessitate the development of specific methodologies that account for the socio-environmental and political heterogeneity they face. Additionally, it is important to note that the selection of keywords in systematic literature searches may not yield the most representative results, given the variability in the understanding and application of the CE concept within the region. While the Global North has made significant progress in defining and applying CE principles, consensus is still lacking in Latin America, potentially limiting the research found under this label. However, this does not imply that circular strategies are not being pursued.

The growing importance of studying and implementing CE projects worldwide is undeniable and necessary. However, the application of these principles is not uniform across all contexts. Latin America presents heterogeneous and multivariate conditions, where complex and often intertwined factors must be considered to effectively evaluate projects aimed at sustainability and CE.

Applying evaluation methodologies for projects with these characteristics, it is recommended to incorporate the three dimensions of sustainability (environmental, social, and economic), along with the circular dimension. The measurement of CE initiatives plays a crucial role in achieving the SDGs, as it helps track progress toward sustainable resource management, waste reduction, and economic resilience. Efforts should continue to evaluate CE projects with the aim of developing general methodological frameworks that are flexible enough to adapt to different contexts, rather than relying on frameworks developed in the Global North, which operate under distinct and incomparable conditions."

As part of future research, we are working on developing a methodology that includes the sustainability dimensions, as well as the circularity of the composting process carried out at the Composting Plant in Mexico City, and its relationship with peri-urban agricultural production areas in Milpa Alta. These social, economic, political, and environmental realities must be accounted for to determine whether true circularity exists.

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