



PATHWAYS TO CIRCULARITY IN AGRICULTURE: THE ROLE OF COOPERATIVES IN SUSTAINABILITY

CAMINHOS PARA A CIRCULARIDADE NA AGROPECUÁRIA: O PAPEL DAS COOPERATIVAS NA SUSTENTABILIDADE

CAMINOS HACIA LA CIRCULARIDAD EN EL AGROPECUARIA: EL PAPEL DE LAS COOPERATIVAS EN LA SOSTENIBILIDAD

ABSTRACT

Objective: This study aimed to analyze the impacts, challenges, and benefits arising from the implementation of the Circular Economy (CE) in agricultural cooperatives, considering its environmental, social, and economic dimensions in different geographical contexts.

Design/Methodology/Approach: A systematic literature review was conducted, based on 274 publications from the Scopus and Web of Science databases. Of these, 23 studies were selected for qualitative analysis. The data processing was operationalized following the systematic review framework proposed by Tranfield et al. (2003), combined with qualitative content analysis techniques, structured to identify CE practices, challenges faced, benefits perceived, the role of cooperatives, and existing gaps in the literature.

Results: The results indicate that agricultural cooperatives have the potential to promote CE. However, these organizations face limitations such as insufficient infrastructure, financial constraints, lack of training, and the absence of adequate public policies. CE enables the adoption of practices such as industrial symbiosis, the development of biorefineries, and the valorization of waste, contributing to local development and the achievement of the goals of the 2030 Agenda.

Limitations/Implications of the Research: The study is limited to the theoretical-conceptual scope of articles indexed in two specific databases (Scopus and Web of Science), which restricts the inclusion of non-indexed gray or regional literature. Furthermore, the external validity of the discussions is constrained by the historical scarcity of robust empirical data regarding circularity within the context of rural cooperatives in developing nations.

Theoretical/Practical Implications: This study contributes to CE by expanding its analysis in agricultural cooperatives, offering a comprehensive review of challenges and opportunities in this sector. Theoretically, it encourages exploring the interaction between circular models, cooperatives, and sustainable development. Practically, it supports policies and strategies for CE in cooperatives, highlighting their potential for practices such as industrial symbiosis and waste valorization, strengthening rural sustainability.

Originality: The study presents originality by focusing on the Circular Economy in agricultural cooperatives, filling a theoretical and practical gap. The research encourages future investigations on sustainability in the rural sector, circular business models, and the strategic role of cooperatives in this specific context.

Keywords: Circular Economy. Agricultural Cooperatives. Cooperative Governance. Local Development. Systematic Review.

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RESUMO

Objetivo: O presente estudo objetivou analisar os impactos, desafios e benefícios decorrentes da implementação da Economia Circular (EC) em cooperativas agropecuárias, considerando suas dimensões ambiental, social e econômica em distintos contextos geográficos.

Design/Metodologia/Abordagem: Foi realizada uma revisão bibliográfica sistematizada, fundamentada em 274 publicações das bases Scopus e Web of Science. Destas, 23 estudos foram selecionados para análise qualitativa. A operacionalização do tratamento dos dados seguiu o modelo de revisão sistemática proposto por Tranfield et al. (2003), associado à técnica de análise de conteúdo qualitativa, estruturada para identificar práticas de EC, desafios enfrentados, benefícios percebidos, o papel das cooperativas e lacunas existentes na literatura.

Resultados: Os resultados indicam que as cooperativas agropecuárias apresentam potencial para promover a EC. No entanto, essas organizações enfrentam limitações como insuficiência de infraestrutura, restrições financeiras, carência de capacitação e ausência de políticas públicas adequadas. A EC possibilita a adoção de práticas, como simbiose industrial, desenvolvimento de biorrefinarias e valorização de resíduos, contribuindo para o desenvolvimento local e o cumprimento dos objetivos da Agenda 2030.

Limitações/Implicações da Pesquisa: O estudo limita-se ao escopo teórico-conceitual de artigos indexados em duas bases de dados específicas (Scopus e Web of Science), o que restringe a inclusão de literaturas cinzentas ou regionais não indexadas. Além disso, a validade externa das discussões é balizada pela escassez histórica de dados empíricos robustos sobre circularidade no contexto de cooperativas rurais de nações em desenvolvimento.

Implicações Teóricas/Práticas: Este estudo contribui para a EC ao expandir sua análise em cooperativas agropecuárias, oferecendo uma revisão abrangente de desafios e oportunidades nesse setor. Teoricamente, incentiva a explorar a interação entre modelos circulares, cooperativas e desenvolvimento sustentável. Praticamente, subsidia políticas e estratégias para a EC em

cooperativas, evidenciando seu potencial para práticas como simbiose industrial e valorização de resíduos, fortalecendo a sustentabilidade rural.

Originalidade: O estudo apresenta originalidade ao focalizar a Economia Circular em cooperativas agropecuárias, preenchendo uma lacuna teórica e prática. A pesquisa incentiva futuras investigações sobre sustentabilidade no setor rural, modelos de negócios circulares e o papel estratégico das cooperativas nesse contexto específico.

Palavras-chave: Economia Circular. Cooperativas Agropecuárias. Governança Cooperativa. Desenvolvimento Local. Revisão Sistemática.

RESUMEN

Objetivo: El presente estudio tuvo como objetivo analizar los impactos, desafíos y beneficios derivados de la implementación de la Economía Circular (EC) en cooperativas agropecuarias, considerando sus dimensiones ambiental, social y económica en distintos contextos geográficos.

Diseño/Metodología/Enfoque: Se realizó una revisión bibliográfica sistematizada, basada en 274 publicaciones de las bases de datos Scopus y Web of Science. De estos, se seleccionaron 23 estudios para análisis cualitativo. La operacionalización del tratamiento de los datos siguió el modelo de revisión sistemática propuesto por Tranfield et al. (2003), asociado a la técnica de análisis de contenido cualitativo, estructurado para identificar prácticas de EC, desafíos enfrentados, beneficios percibidos, el papel de las cooperativas y las lagunas existentes en la literatura.

Resultados: Los resultados indican que las cooperativas agropecuarias tienen el potencial de promover la EC. Sin embargo, estas organizaciones enfrentan limitaciones como infraestructura insuficiente, restricciones financieras, falta de capacitación y la ausencia de políticas públicas adecuadas. La EC permite la adopción de prácticas como la simbiosis industrial, el desarrollo de biorrefinerías y la valorización de residuos, contribuyendo al desarrollo local y al cumplimiento de los objetivos de la Agenda 2030.

Limitaciones/Implicaciones de la Investigación: El estudio se limita al alcance teórico-conceptual de los artículos indexados en dos bases de datos específicas (Scopus y Web of Science), lo que restringe la inclusión de literatura gris o regional



no indexada. Además, la validez externa de las discusiones se ve limitada por la escasez histórica de datos empíricos sólidos sobre la circularidad en el contexto de las cooperativas rurales en naciones en desarrollo.

Implicaciones Teóricas/Prácticas: Este estudio contribuye a la EC al expandir su análisis en las cooperativas agropecuarias, ofreciendo una revisión exhaustiva de los desafíos y oportunidades en este sector. Teóricamente, fomenta la exploración de la interacción entre modelos circulares, cooperativas y desarrollo sostenible. En la práctica, apoya las políticas y estrategias para la EC en las cooperativas, destacando su potencial para prácticas como la simbiosis industrial y la valorización de residuos, fortaleciendo la sostenibilidad rural.

Originalidad: El estudio presenta originalidad al centrarse en la Economía Circular en las cooperativas agropecuarias, llenando un vacío teórico y práctico. La investigación alienta futuras investigaciones sobre la sostenibilidad en el sector rural, los modelos de negocio circulares y el papel estratégico de las cooperativas en este contexto específico.

Palabras clave: Economía Circular. Cooperativas Agropecuarias. Gobernanza Cooperativa. Desarrollo Local. Revisión Sistemática.

INTRODUCTION

The Circular Economy (CE) presents itself as an alternative to the traditional linear economic model, which is based on the logic of “extract, produce, consume, and dispose” (Ghisellini, Cialani, & Ulgiati, 2016). In contrast to this approach, the CE aims to maximize the utilization of natural resources, extending their lifespan through strategies such as reuse, remanufacturing, recycling, and revalorization of waste (Ellen MacArthur Foundation, 2013; Sehnem & Pereira, 2019). It is a regenerative economic model that seeks to decouple economic growth from dependence on finite resources, while promoting more sustainable and efficient production cycles. Furthermore, the CE aims to preserve and enhance natural capital, optimize resource yields, and foster systemic effectiveness through the redesign of material flows and business models (Ellen MacArthur Foundation,

2015b; Geissdoerfer et al., 2017).

The theoretical foundation of the CE is structured around fields such as ecological economics, thermodynamics, and industrial ecology (Korhonen, Honkasalo, & Seppälä, 2018). Pearce and Turner were pioneers in conceiving the economy as a system of circular flows, based on the principles of thermodynamics, which highlight the physical limits of the planet. Industrial ecology, in turn, offers a systemic approach by proposing industrial symbiosis, where waste from one process becomes input for others (Lieder & Rashid, 2016; Mello & Silva, 2022). Although this theoretical-conceptual framework has emerged as a consolidated theme globally, in Brazil, this movement still lacks academic investigations that systematically and practically analyze specific sectors with high economic and ecological impact, such as agriculture and livestock. The contemporary dissemination of the CE concept is largely due to the contributions of the Ellen MacArthur Foundation (2013, 2015a), which defines the circular economy as a system based on technical and biological cycles, whose purpose is to maintain the value of products and resources for as long as possible. The foundation also attributes to the CE the potential to foster innovation, generate jobs, boost economic growth, and mitigate environmental impacts. Studies by the foundation indicate that the adoption of CE can generate annual savings exceeding USD 600 billion in sectors such as manufacturing and consumer goods, in addition to significantly reducing carbon emissions and dependence on virgin resources (Ellen MacArthur Foundation, 2013, 2015a).

Despite the conceptual consolidation of the CE, there is a limited articulation with the social dimension of sustainability. Geissdoerfer et al. (2017) highlight that, although the CE aligns with the principles of sustainable development, its implementation often neglects social aspects, compromising its effectiveness. Ghisellini, Cialani, and Ulgiati (2016) add that the practical application of the CE is still in its initial stages, requiring greater integration among the public, private sectors, and civil society. Bocken et al. (2014) propose archetypes of sustainable business models that integrate social concerns



from design to product use, demonstrating the need for holistic approaches.

The implementation of the CE faces several challenges, especially in emerging economies and sectors with structural constraints. Among the main obstacles are the absence of adequate infrastructure, the high costs of transitioning to circular models, and the lack of specific public policies (Sehnem & Pereira, 2019). Additionally, there is cultural resistance from producers and consumers, evidenced by the low acceptance of sustainable packaging in the agri-food sector (Valle, Guarnieri, & Filippi, 2023). Lewandowski (2016) observes that structuring circular business models also requires overcoming technological and institutional uncertainties, especially in contexts of low institutional maturity.

Another limiting factor is the scarcity of educational actions and the reduced perception of the economic and environmental value of waste, which hinders the adoption of circular practices (Almeida, Aguiar e Jugend, 2021). Schoefs et al. (2024) advocate for the need to adapt circular models to regional specificities, considering geographical, social, and economic variations. In developing countries, such differences can compromise the viability of standardized models. Antikainen and Valkokari (2016) suggest that innovation in circular business models should be guided by collaborative frameworks, involving multiple stakeholders from the outset of the process.

In the case of agricultural cooperatives, additional challenges are observed, such as lack of financing, deficiency in technical training, and the absence of public policies aimed at promoting circularity. The transition to the CE in this context requires not only the introduction of technological innovations but also institutional and cultural transformations, with an emphasis on strengthening governance and trust among cooperative members (Ada et al., 2022; Musson & Rousselière, 2020). Mikielawicz et al. (2020) highlight that, in rural contexts, the transition to the circular bioeconomy requires specific institutional arrangements that enable intersectoral partnerships and the cascading use of agricultural waste.

The interaction between the CE and agricultural cooperatives presents itself as a strategic opportunity for promoting sustainable practices in rural areas. Due to their collaborative organizational structure and territorial insertion, these cooperatives are in a favorable position to establish industrial symbiosis networks, optimize input use, and implement circular initiatives (Castro et al., 2019; Donner, Gohier, & de Vries, 2020). The adoption of CE allows for the conversion of agricultural waste into value-added products, such as organic fertilizers, biofuels, and energy, contributing to income diversification and the strengthening of local economies (Dubina et al., 2024; Esfandiari Bahraseman et al., 2024).

The role of cooperatives as agents of environmental innovation is illustrated by Musson and Rousselière (2020), who highlight their capacity to foster the use of recycled inputs and integrate the various links of the production chain. Such organizations are capable of adopting practices such as composting, packaging reuse, precision technologies, and energy recovery from waste (Almeida, Aguiar, & Jugend, 2021). Donner, Gohier, and de Vries (2020) demonstrate the viability of implementing agricultural biorefineries in the cooperative context, promoting the transformation of by-products into new goods and energy, in accordance with circular principles. Shen et al. (2024) emphasize the positive effects of returning organic waste to the soil, contributing to ecosystem regeneration and increased agricultural productivity.

The efficient management of these processes can be improved through the use of integrated accounting, which considers financial, environmental, and social indicators, supporting sustainable decision-making (Dubina et al., 2024). Ada et al. (2022) also highlight the role of cooperatives in the digitalization of the agricultural sector and in mediating between technological innovation and productive practices.

Despite the identified potential, the adoption of CE by agricultural cooperatives still faces significant obstacles. Among the main challenges are the lack of infrastructure, the absence of technical training, the limitation of financial resources, and the fragility of



public support policies (Cavicchi & Vagnoni, 2022; García-Agüero et al., 2024). Perdana and Kusnandar (2023) also observe the disarticulation among the links of the agricultural chain, which harms the effectiveness of circular strategies. Prieto-Sandoval et al. (2022) point to the absence of governance mechanisms and coordination structures among the actors involved as limiting factors for creating synergies. In certain regions, such as Romania, resistance to innovation and low levels of investment in cooperatives persist, hindering their transition to the CE (Zlati et al., 2023). Muriuki et al. (2024) and Preprame et al. (2023) argue that overcoming these obstacles requires the formulation of structured public policies, adequate financing, access to technology, technical training, and strengthening of participatory governance. The adoption of CE in the cooperative sector therefore depends on the integrated articulation of these elements to enable a just and regenerative circular transition.

Although the theoretical foundations of the CE are consolidated, there is a significant gap regarding its application in specific sectors, such as agriculture, particularly in the context of rural cooperatives. Existing literature tends to focus on urban and industrial environments, neglecting the challenges and opportunities associated with CE in cooperative agriculture (Ghisellini, Cialani, & Ulgiati, 2016; Elia, Gnoni, & Tornese, 2017). Velasco-Muñoz et al. (2021) identify the scarcity of studies focused on adapting the CE to the agricultural sector, which hinders the formulation of applicable strategies. Furthermore, the measurement of the environmental, social, and economic impacts of CE in agricultural cooperatives is underdeveloped, compromising the formulation of effective public policies (De Boer & van Ittersum, 2018) and restricting the decision-making capacity of managers and policymakers.

The lack of comprehensive empirical studies makes it difficult to replicate solutions in different contexts. Mikielewicz et al. (2020), Elia, Gnoni, and Tornese (2017) highlight that the effects of CE on rural sustainability are not yet fully understood, especially concerning the social dimension and the creation of shared value. Thus, it becomes fundamental to understand

local dynamics to enable the circular transition in agricultural cooperatives. The absence of comparative approaches between regions, types of cooperatives, and adoption strategies reinforces the need for new research focused on these variables.

This gap becomes even more critical given the increasing pressure for the agricultural sector to align with the sustainability goals of the United Nations 2030 Agenda. Kirchherr, Reike, and Hekkert (2017) state that, although the CE is widely promoted as a systemic solution to environmental challenges, its effectiveness depends on contextualized, integrated, and participatory implementation, a condition still far from rural reality. In the Brazilian scenario, this need for academic advancement is even more pressing, given that investigations applied to the reality of national infrastructure and agricultural chains are scarce. This observation underpins the problem and delimits the research question that guides the present study: how do global scientific publications characterize the impacts, challenges, and benefits of integrating the circular economy into the ecosystem of rural agricultural cooperatives?

The investigation of CE in agricultural cooperatives is justified by the convergence of multiple global challenges: the need to decouple economic growth from intensive natural resource use, the urgency of regenerating degraded ecosystems, and the demand for resilient and inclusive production models in rural areas. The CE proposes a restorative alternative, based on closed material and energy flows, with an emphasis on redesigning processes, reusing resources, and minimizing losses (Ellen MacArthur Foundation, 2015a).

Given the intensity of environmental impacts associated with agricultural activity, the principles of CE are particularly suitable. Strategies such as composting, biorefineries, agroforestry systems, and the reuse of agro-industrial waste contribute to mitigating negative effects, regenerating natural resources, and promoting the resilience of production chains in the face of climate change.



Agricultural cooperatives, due to their democratic structure and territorial capillarity, have high potential to mobilize farmers around sustainable practices. They play a strategic role in disseminating innovations, building short marketing chains, and sharing resources and knowledge among producers (Musson & Rousselière, 2020). Kirchherr, Reike, and Hekkert (2017) emphasize that collaboration is an essential factor for the success of CE, especially in contexts with resource scarcity, requiring locally adapted solutions.

In addition to environmental benefits, CE can foster social inclusion by valuing agricultural by-products, strengthening family farming, and promoting business models based on shared services, such as cooperative machinery systems, collective waste management, and joint marketing of recycled inputs (Dubina et al., 2024; Ada et al., 2022). This multifunctionality enhances the relevance of CE as an instrument for sustainable rural development, with the potential to generate integrated impacts across economic, social, and environmental dimensions.

Considering the strategic importance of agricultural cooperatives for food security and environmental sustainability, deepening the study of their circular practices responds not only to academic gaps but also to concrete demands of the global ecological transition. The expected results can support public policies, technical support programs, and more effective cooperative governance models, in addition to fostering the replication of good practices in different territories.

In view of the above, the general objective of this study is to analyze the impacts, challenges, and benefits of implementing the circular economy in agricultural cooperatives, considering their environmental, social, and economic dimensions in different geographical contexts. The aim is to fill existing theoretical and empirical gaps, as well as to offer practical subsidies for building a just, regenerative, and economically viable circular transition in the rural cooperative sector.

To achieve this objective, a qualitative methodological approach was operationalized through a systematic literature review. The study design was based on the methodological guidelines of Tranfield, Denyer, and Smart (2003) and incorporated screening criteria inspired by the PRISMA protocol. Data collection was performed in the international databases Scopus and Web of Science, resulting in a final corpus of 23 articles qualitatively analyzed using content analysis technique.

This article is structured into six fundamental chapters, including this introduction. Section 2 is dedicated to the Theoretical Review, detailing the integrated axes of circular economy, cooperatives, and sustainability. Section 3 focuses on the detailed description of Materials and Methods. Results and Discussion are presented in an articulated manner in Section 4. Finally, Section 5 establishes the Final Considerations, limitations, and suggestions for future investigations.

THEORETICAL FRAMEWORK

The global transition from the linear economic model to the Circular Economy (CE) establishes a new paradigm focused on closing material loops, preserving finite resources, and transforming waste into valuable inputs (Alves et al., 2022; Andreatta et al., 2024; Silva & Sauka, 2024). In territorial practice, this dynamic unfolds across three integrated governance scales: the micro scale, focused on ecodesign and changes in citizen consumption behavior and sorting; the meso scale, concentrated on industrial symbiosis networks and eco-innovation among companies, under the precepts of Industrial Ecology; and the macro scale, consolidated through public policies and regulatory frameworks, such as the Política Nacional de Resíduos Sólidos (PNRS) in Brazil, which structure the legal and institutional support for sustainable development (Alves et al., 2022; Almeida et al., 2021; Silva et al., 2021; Melo & Silva, 2022).

In the field of bio-waste and municipal solid waste (MSW) management, the choice of processing technologies defines the commercial value of co-products and their absorption in regional markets (Schoefs et al., 2024). Biological



solutions such as anaerobic digestion convert organic matter into biogas and digestate, directly connecting circularity to the expansion of renewable energies in the industrial sector (Schoefs et al., 2024; Alves et al., 2022). Although the reuse of industrial by-products for local generation of biomass, solar, or wind energy boosts eco-efficiency, the implementation of these structures faces severe economic barriers, represented by high initial transaction costs, complex investments, and unequal competition with traditional fossil fuels (Alves et al., 2022; Almeida et al., 2021).

Furthermore, demographic characteristics and technological specificities generate territorial tensions between different management scenarios (Schoefs et al., 2024). The decentralized model prioritizes actions in local micro-units, eliminating logistical costs and retaining nutrients within the territory itself, although it presents lower commercial standardization (Schoefs et al., 2024). On the other hand, the centralized model is based on large recovery plants with strict quality control and economies of scale, but it requires complex transport systems and poses the risk of nutrient evasion to global markets (Schoefs et al., 2024). To balance these local socioeconomic realities, the modeling of hybrid scenarios, evaluated by tools such as Life Cycle Assessment (LCA), emerges as the most suitable alternative for each locality (Schoefs et al., 2024; Almeida et al., 2021).

This transition to circular flows reveals transversal challenges and particularities according to the market sector studied (Almeida et al., 2021; Andreatta et al., 2024). The agri-food segment frequently deals with operational conservatism and sorting costs that burden micro and small businesses (Almeida et al., 2021). In parallel, the fashion industry faces the ecological impacts of the fast fashion model, characterized by textile waste and intensive water consumption, which demands strategies for circular design, fabric recycling, enzymatic fiber separation, and supply chain tracking through blockchain technologies (Andreatta et al., 2024). In both contexts, cultural barriers related to consumer acceptance require greater transparency and alignment between sustainability, quality, and financial viability (Almeida et al., 2021; Andreatta

et al., 2024).

In the Brazilian scenario, the practical application of these concepts in urban centers takes on an essentially human dimension through the work of cooperatives and associations of recyclable material collectors (Silva & Sauka, 2024). Faced with social vulnerabilities and unemployment, these workers act as central ecological agents, responsible for collecting and sorting about 90% of the recyclables processed in the country (Silva & Sauka, 2024). Adhering to the shared responsibility guidelines of the PNRS, the strengthening of these organizations depends on the consolidation of local cooperation networks that harmoniously integrate public authorities, universities, neighboring companies, and civil society (Silva & Sauka, 2024).

Finally, to enable initial investments and mitigate the financial risks of this technological transition, whether in the automation of sorting cooperatives, the energy adaptation of industries, or the reverse logistics of clothing, credit cooperativism and green finance act as indispensable strategic levers (Queiroz et al., 2024; Silva & Sauka, 2024). Through regional proximity and management models oriented by ESG principles, financial cooperatives offer sustainable credit lines and green bonds that reduce economic entry barriers, promoting productive inclusion, local income generation, and environmental integrity in communities (Alves et al., 2022; Queiroz et al., 2024; Silva & Sauka, 2024).

MATERIALS AND METHODS

This investigation was conducted through a systematic literature review, based on the systematic review model outlined by Tranfield et al. (2003), which is structured into three main phases: (i) planning, (ii) execution, and (iii) analysis and dissemination of findings. Additionally, the adopted methodology incorporated elements from the contributions of Canto, Grunert, and Barcellos (2021), being duly adapted to the specific context of the Circular Economy (CE) within agricultural cooperatives. The choice of a systematic approach is justified by the need to provide transparency, reproducibility, and



scientific rigor to the mapping of the state of the art, minimizing selection biases by the researchers.

Stage I – Review Planning

The initial phase of the systematic review consisted of formulating research questions and delimiting the thematic scope, with the purpose of conducting a critical analysis of the impacts, benefits, and challenges associated with the implementation of the Circular Economy (CE) in agricultural cooperatives. The choice of this focus stems from the growing importance attributed to CE as an alternative to the linear model of production and consumption, especially in sectors with high dependence on natural resources, such as agriculture (Ghisellini, Cialani, & Ulgiati, 2016; Ellen MacArthur Foundation, 2013). Given the strategic role of agricultural cooperatives in promoting sustainable practices, this investigation aims to answer the following research questions:

1. What are the main environmental, social, and economic impacts resulting from the adoption of Circular Economy practices in agricultural cooperatives?
2. What challenges limit the effective

implementation of the Circular Economy in these organizations, and how do these challenges vary according to the regional context?

The definition of these questions aimed to address theoretical and empirical gaps identified in the literature, with an emphasis on the scarcity of studies focused on rural areas and the need to adapt circular strategies to territorial specificities (Velasco-Muñoz et al., 2021; Schoefs et al., 2024).

To ensure methodological rigor and comprehensiveness in data collection, the Web of Science and Scopus databases were selected, widely recognized for their credibility and international coverage (Canto, Grunert, & Barcellos, 2021; Geissdoerfer et al., 2017; Snyder, 2019). The search strategy employed consisted of using the terms “circular economy” AND cooperative*, applied to the title, abstract, and keywords fields, aiming to identify studies with conceptual adherence to the research object. No initial restrictive time frame was applied in the inventory to capture the entire historical evolution of the phenomenon, mitigating the exclusion of seminal rural studies.

The review protocol presented below synthesizes the criteria and procedures adopted in the planning stage.

Table 1
Review Protocol

Stage	Description
Research Questions	1. What are the main environmental, social, and economic impacts resulting from the adoption of CE practices in agricultural cooperatives? 2. What challenges limit the effective implementation of CE in these organizations, and how do these challenges vary according to the regional context?
Target Population	Scientific articles addressing CE in the context of agricultural cooperatives.
Databases	Web of Science and Scopus.
Search Strategy	Terms: “circular economy” AND cooperative* applied to title, abstract, and keywords fields.
Document Type	Peer-reviewed articles published in scientific journals (excluding book chapters, conference abstracts, and gray literature).
Inclusion Criteria	Studies with an explicit focus on CE practices within agricultural or agro-industrial cooperatives.
Exclusion Criteria	Duplicate articles; studies unrelated to cooperatives or without a direct relation to CE; articles not addressing the agricultural sector; studies unavailable for full reading.
Screening Procedure	Three-step filtering process: (i) elimination of duplicates; (ii) analysis of title, abstract, and keywords; (iii) specific selection of agricultural cooperatives via full reading.
Data Analysis	Descriptive analysis and qualitative content analysis, structured from thematic categories defined in the protocol.

Source: author’s.

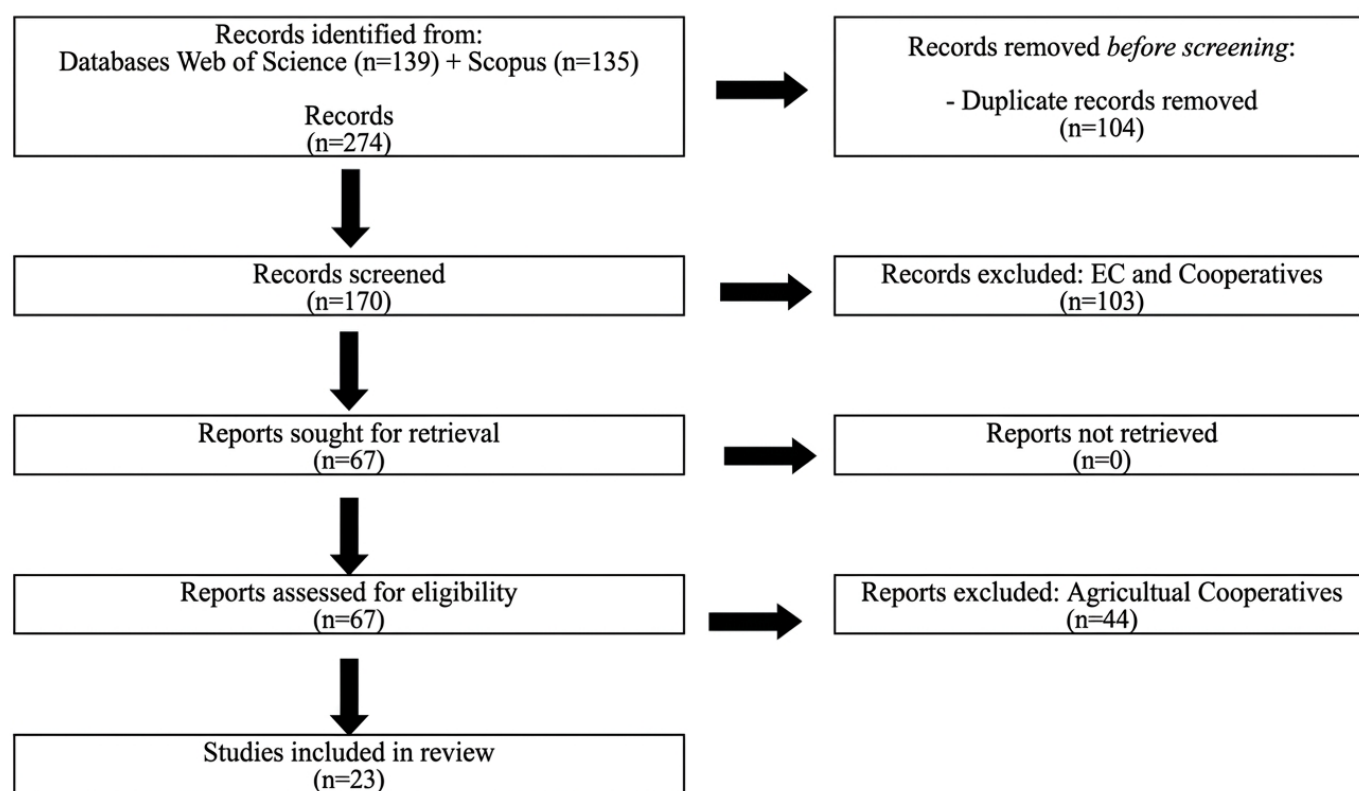


The planning stage ensured a consistent methodological basis for the review, enabling the systematic and critical mapping of scientific production related to the Circular Economy in agricultural cooperatives. In addition to establishing a replicable procedure, the adopted methodological structure contributed to identifying recurrent patterns, theoretical gaps, and relevant opportunities for both the advancement of academic knowledge and the improvement of sustainable practices in the sector.

Stage II – Review Conduct

The initial search resulted in the identification of 274 articles, with 139 from the Web of Science database and 135 from Scopus. According to the guidelines proposed by Tranfield et al. (2003) and Snyder (2019), the selection of studies followed multiple screening steps, based on the PRISMA model (Figure 1), and was carried out independently by different researchers, with the aim of ensuring objectivity, resolving inconsistencies through consensus, and guaranteeing consistency in the inclusion of the analyzed materials.

Figure 1
PRISMA Flow Diagram for Study Selection



Source: adapted from PRISMA. PRISMA Statement. Retrieved from: <http://www.prisma-statement.org/>

The final sample, after full reading and application of predefined inclusion and exclusion criteria, resulted in 23 articles considered suitable for qualitative analysis.

Stage III – Analysis and Synthesis of Studies

The third stage of the review consisted of a qualitative analysis of the 23 selected articles, guided by a systematic content analysis approach, according to the guidelines established by Tranfield et al. (2003) and reinforced by

Snyder (2019). The analytical categories were previously defined in the review protocol, with the objective of directly answering the research questions, focusing on identifying the impacts, challenges, and benefits related to the adoption of CE in agricultural cooperatives. The content analysis technique followed systematic thematic coding, allowing complex qualitative data to be embedded into standardized conceptual blocks for cross-analysis across the geographical realities found.

The analysis enabled the identification of recurrent patterns in implemented circular practices, as well as important regional, structural, and institutional asymmetries that affect the viability of CE in the context of rural cooperatives.

By integrating environmental, social, and economic dimensions, the investigation highlighted the strategic role of these organizations in consolidating more regenerative and resilient agro-industrial systems.

Table 2
Elements for Analysis of Selected Articles

Analysis Category	Description
CE Practices	Include actions such as recycling, composting, remanufacturing, the use of biorefineries, the reuse of organic waste, and technologies for closing production cycles. Common practices include the production of biofertilizers, renewable energy, and systems such as compost bedded-pack, which integrate waste management and agricultural fertilization (Ellen MacArthur Foundation, 2013; Donner, Gohier, & de Vries, 2020; Kuipers et al., 2022; Garcia-Garcia et al., 2024).
Challenges and Barriers	Include legal, institutional, technological, cultural, financial, and infrastructure obstacles. Observed issues include the absence of effective regulation, sociocultural resistance, lack of incentives, technical limitations, scarcity of funding, and low environmental awareness (Ghisellini, Cialani, & Ulgiati, 2016; Sehnem & Pereira, 2019; Ada et al., 2022; Perdana & Kusnandar, 2023; Kim et al., 2023; Zlati et al., 2023; Castilla-Polo & Sánchez-Hernández, 2022; García-Agüero et al., 2024).
Benefits and Impacts	The CE contributes to environmental regeneration (reduction of emissions, pollution, and waste), the generation of economic value (waste valorization, cost reduction, creation of new markets), and positive social impacts (jobs, inclusion, innovation, food security, animal welfare, and cooperative reputation). It also promotes synergies among rural actors and strengthens economic resilience (Shen et al., 2024; Dubina et al., 2024; Ada et al., 2022; Kuipers et al., 2022; Castilla-Polo & Sánchez-Hernández, 2022; Garcia-Garcia et al., 2024).
Role of Cooperatives	Cooperatives are viewed as strategic agents in the implementation of the CE, especially due to their democratic structure, territorial capillarity, and capacity for articulation among small producers. They facilitate resource sharing, adaptive innovation, and the construction of industrial symbiosis networks (Musson & Rousselière, 2020; Castro et al., 2019; Dubina et al., 2024).
Gaps in the Literature	There remains a scarcity of empirical studies on CE in agricultural cooperatives, especially in rural contexts and developing countries. There is a lack of comparative approaches between regions, long-term impact assessments, and integrated performance indicators (Ghisellini, Cialani, & Ulgiati, 2016; Velasco-Muñoz et al., 2021; De Boer & van Ittersum, 2018). The diversity of geographical and social contexts is still poorly considered, limiting the replicability of solutions.

Source: author's.



The analysis showed that, although promising initiatives exist, the transition of agricultural cooperatives to models based on the Circular Economy still faces significant obstacles. Among the main impediments identified are the precariousness of available infrastructure, the limited technical training of those involved, and the insufficiency of financial resources specifically directed towards circular initiatives. Furthermore, deficiencies in governance are observed, which compromise coordination among various actors and hinder the formation of synergies capable of sustaining more effective circular strategies (Prieto-Sandoval et al., 2022; Zlati et al., 2023).

In contrast, it was found that agricultural cooperatives possess institutional and organizational attributes that qualify them as central agents in promoting the Circular Economy. Their territorial insertion, combined with their capacity for community mobilization and collaborative structure, constitutes a differential for the implementation of practices adapted to local realities. The introduction of technologies such as biorefineries, composting systems, and energy recovery from waste, combined with the use of integrated sustainability indicators, can strengthen the role of these organizations as catalysts for innovation and environmental regeneration (Donner, Gohier, & de Vries, 2020; Dubina et al., 2024). Finally, this stage of the review highlighted the urgent need for further empirical studies that encompass the geographical, economic, and sociocultural diversity characterizing agricultural cooperatives. As argued by Kirchherr, Reike, and Hekkert (2017), the full transformative potential of the Circular Economy can only be achieved through its contextualized, participatory, and evidence-based application. Thus, the results systematized here offer relevant subsidies for the formulation of more effective public policies, the development of technical training strategies, and the guidance of future research agendas aimed at building a circular, equitable, and sustainable agricultural model.

Research and Validation Procedures

To ensure the methodological robustness and reliability of the obtained results, this review incorporated a set of systematic validation

procedures, based on the qualitative analysis protocols recommended by Tranfield et al. (2003), Snyder (2019), Canto, Grunert, and Barcellos (2021). The analytical and selection process was conducted independently by two researchers, which provided greater impartiality and rigor to the interpretation of the data. Any analytical divergences were resolved through consensus, allowing for the refinement of the categories used and the mitigation of possible individual biases.

The categorization of findings was guided by the theoretical dimensions associated with the Circular Economy, as well as by the specific challenges of the agricultural sector identified in contemporary literature (Ghisellini, Cialani, & Ulgiati, 2016; Schoefs et al., 2024). This methodological orientation ensured coherence between the objectives of the investigation and the procedures adopted in data analysis.

The qualitative approach employed enabled the identification of significant contextual nuances, as well as the detection of recurrent patterns in the examined studies. Particularly highlighted were the structural barriers to the implementation of the Circular Economy, the regional diversity of reported experiences, and the role of agricultural cooperatives as strategic agents in the transition to more sustainable production models (Musson & Rousselière, 2020; Dubina et al., 2024).

Intended Theoretical-Practical Contributions

This systematic review aims to broaden the understanding of the application of Circular Economy principles in agricultural cooperatives, a topic still incipiently addressed in scientific literature. Based on the analysis of selected studies, a critical synthesis was developed that addresses both the benefits and challenges faced by these organizations in implementing circular practices.

In addition to offering an updated overview of the state of the art, the research intends to contribute to managers, public policy makers, and academics by providing subsidies that enable the development of more effective and contextualized strategies, consistent with the socio-economic specificities of rural areas. The theoretical propositions derived from this study aim to fill gaps in territorial and cooperative integration.



Table 4
Theoretical-Practical Contributions and Deliverables

Delivery Dimension	Objective
Critical synthesis of existing literature	To map and systematize empirical evidence on the implementation of the Circular Economy in agricultural cooperatives, focusing on their sectoral and territorial specificities.
Identification of barriers and challenges	To understand the institutional, regulatory, cultural, financial, and technological obstacles that limit the adoption of CE in different territorial realities and levels of cooperative maturity.
Mapping of impacts and benefits	To evaluate the environmental (emission reduction, waste management), social (job creation, inclusion, public health), and economic (waste valorization, cost reduction, increased profitability) effects resulting from the application of circular practices in agricultural cooperatives.
Strategic role of cooperatives	To highlight the leading role of cooperatives as catalysts for the transition to sustainable and regenerative models, through social innovation, territorial articulation, and the dissemination of practices adapted to the rural context.
Subsidies for public policy and cooperative management	To support managers, policymakers, and technical support entities with evidence on effective practices, recurrent challenges, and opportunities for replicating successful CE models in the cooperative agricultural sector.
Direction for future research agendas	To identify theoretical and methodological gaps, such as the scarcity of empirical studies in developing countries, the absence of comparative approaches between regions, and the lack of specific indicators for measuring the impacts of CE in cooperative contexts.

Source: author's.

The systematic mapping executed in this review contributes to strengthening the scientific debate on sustainability in the agricultural sector, promoting the advancement of the Circular Economy as an effective instrument for ecological regeneration, social inclusion, and economic viability in rural areas. As argued by Kirchherr, Reike, and Hekkert (2017), the effectiveness of the Circular Economy depends on its application in specific contexts, which underscores the relevance of understanding the role of agricultural cooperatives in building a circular transition that is just, territorially adapted, and guided by the principle of shared value.

RESULTS AND DISCUSSION

Environmental, social, and economic impacts of the circular economy in agricultural cooperatives

The circular economy emerges as an essential paradigm for promoting sustainability in the agricultural sector, with particular relevance in the context of cooperatives. This approach focuses on restructuring production systems with the aim of minimizing waste and optimizing resource utilization (Ellen MacArthur Foundation, 2013; Donner, Gohier, & de Vries, 2020). Diverse practices and technologies are encompassed to close production cycles and add value to materials

previously considered waste (Garcia-Garcia et al., 2024). The main practices observed in agricultural cooperatives include organic waste management through recycling and composting, the reuse and valorization of agricultural by-products, remanufacturing, and the implementation of biorefineries for transforming biomass into bioproducts (Donner, Gohier, & de Vries, 2020; García-Agüero et al., 2024; Laili et al., 2024). The production of biofertilizers from animal manure and crop residues, the generation of renewable energy such as biogas and biomethane, and the adoption of integrated waste management and fertilization systems, such as compost bedded-pack, exemplify the application of these principles (Bluemling & Wang, 2018; Donner, Gohier, & de Vries, 2020; Kuipers et al., 2022). Other relevant practices involve the sustainable management of plastic waste and packaging, as well as the safe use of treated wastewater for irrigation, adapted to local conditions and ensuring sanitary safety (Esfandiari Bahraseman et al., 2024; García-Agüero et al., 2024; Kim et al., 2023; Castro et al., 2019). Initiatives such as returning rice straw to the soil illustrate the closing of nutrient cycles at the farm level (Shen et al., 2024). Cooperatives, guided by collaboration, play a fundamental role in facilitating the implementation of these practices and disseminating eco-innovations in rural areas (Ada et al., 2022; Castilla-Polo &



Sánchez-Hernández, 2022; Musson & Rousselière, 2020; Prieto-Sandoval et al., 2022; Shebanin et al., 2024).

Under a deep analytical perspective, the introduction of these practices into the rural-urban cooperative environment denotes a structural break with the linear logic of systemic disposal. When the evidence collected in the literature is confronted with the classic theoretical foundations of the Circular Economy, it becomes evident that the conversion of agricultural by-products into new sources of raw material and energy goes beyond the mere mitigation of superficial ecological damage. It is, fundamentally, an ontological reconfiguration of the concept of waste in agro-industrial organizations. Complex technological systems such as decentralized biorefineries and integrated organic fertilization arrangements act directly on the reconfiguration of the production functions of partner rural properties. By coupling the dynamics of plant biomass and animal waste reuse to the cooperatives' asset portfolio, these arrangements reduce the material entropy of regional productive ecosystems. This transition operates a rearrangement in supply chains, in which open and dissipative nutrient flows are replaced by closed cycles of economic reiteration, generating eco-efficient advantages that shield family agribusiness against external volatility, as discussed in the resource optimization models of Donner, Gohier, and de Vries (2020) and García-García et al. (2024).

The environmental impacts of the circular economy in agricultural cooperatives are extensive and contribute significantly to the sector's sustainability. The management and reuse of organic waste and agricultural by-products result in the reduction of soil, water, and air pollution, preventing the uncontrolled release of nutrients and contaminants (Bluemling & Wang, 2018; Gusukuma et al., 2024; García-Agüero et al., 2024). The local production of biofertilizers reduces dependence on chemical fertilizers, whose production chains and usage patterns are associated with considerable environmental impacts, including greenhouse gas emissions and eutrophication (Gusukuma et al., 2024). Bioenergy generation from waste offers a renewable

alternative to fossil fuels, aiding in climate change mitigation (Donner, Gohier, & de Vries, 2020; Gusukuma et al., 2024). Proper management and recycling of agricultural plastics are crucial for minimizing environmental contamination (Kim et al., 2023). Safe wastewater reuse contributes to water resource conservation, particularly in water-scarce regions (Esfandiari Bahraseman et al., 2024; Castro et al., 2019). Integrating circular metrics into cooperative performance evaluation allows for more precise accounting of environmental costs and the identification of opportunities to optimize resource use (Cavicchi & Vagnoni, 2022; Dubinina et al., 2024).

By deepening the theoretical tension of this environmental panorama, it becomes evident that the replacement of synthetic inputs with endogenous biofertilizers deactivates the most severe degradation vector of agricultural watersheds: the diffuse surface runoff of industrial nitrogen and phosphorus. Closing the local biological cycle on cooperative properties prevents anthropogenic eutrophication episodes that typify the conventional linear agrochemical model. However, the academic debate needs to move beyond celebrating these isolated biophysical indicators. The true analytical leap provided by qualitative evidence resides in the fact that collective management executed by cooperatives equalizes the operational asymmetries of small rural properties. Individually, farmers lack the technical scale or economic stability to structure pathogen-rich wastewater purification processes or to manage stable thermophilic composting systems in compliance with current strict sanitary regulations. Therefore, the systemic internalization promoted by the cooperative arrangement transforms environmental compliance from a prohibitive regulatory cost into a natural byproduct of territorialized ecosystemic cooperation, converting diffuse liabilities into vectors of rural-urban biodiversity conservation, in line with the findings of Castro et al. (2019) and García-Agüero et al. (2024) regarding the safe reuse of effluents and biomass.

Economically, the circular economy provides substantial opportunities for agricultural cooperatives, promoting efficiency and



profitability. The valorization of waste and by-products into new products or energy sources generates new revenue streams and reduces the operational costs associated with disposal (Donner, Gohier, & de Vries, 2020; Prieto-Sandoval et al., 2022). The endogenous production of biofertilizers and bioenergy decreases the need for purchasing external inputs, increasing economic efficiency and member resilience (Dubinina et al., 2024; Perdana & Kusnandar, 2023). Optimizing resource use, such as water, also translates into direct financial benefits (Esfandiari Bahraseman et al., 2024; Castro et al., 2019). Adopting circular practices can enhance the reputation of the cooperative and its products in the market, facilitating access to new niches and investments aligned with sustainability (Castilla-Polo & Sánchez-Hernández, 2022; Cavicchi & Vagnoni, 2022; Zlati et al., 2023).

From the analytical perspective of financial governance and applied microeconomics, the disconnection of dependency in the face of transnational synthetic mineral fertilizer supply chains represents a profound structural change in the cooperative's capital balance. The costs associated with traditional fertilization are usually the main liquidity drain for family producers, operating under a price dynamic pegged to foreign currencies that ignores local income realities. By internalizing the manufacture of complex organomineral biofertilizers and decentralizing energy supply through agro-industrial biogas, the cooperative neutralizes these severe currency and macroeconomic risks. Furthermore, the examined literature demonstrates that the reputational increase resulting from explicit alignment with ESG corporate guidelines strategically repositions the cooperative's portfolio in more demanding consumer markets, a dynamic that Castilla-Polo and Sánchez-Hernández (2022), as well as Zlati et al. (2023), associate with the ability to attract new commercial niches and improve institutional legitimacy indicators in the eyes of green investors.

Socially, the circular economy in agricultural cooperatives contributes to rural development in multiple ways. The creation of new activities related to waste management and valorization can generate jobs and income

opportunities in the countryside (Muriuki et al., 2024; Shebanin et al., 2024). Implementing safe practices in waste management and resource reuse, such as treated wastewater, is fundamental to protecting the health of farmers, rural workers, and consumers, ensuring the production of safe food (Esfandiari Bahraseman et al., 2024; García-Agüero et al., 2024). Cooperatives play a vital role in promoting education, training, and knowledge sharing regarding sustainable practices among their members, strengthening social capital, collaboration, and the capacity for innovation in the rural community (Ada et al., 2022; Bluemling & Wang, 2018; Musson & Rousselière, 2020). The improvement in environmental quality resulting from circular practices positively impacts the overall well-being of the community (Shebanin et al., 2024).

The deepening of the human dimension indicates that circular activities generate new occupational dynamics in the field, corroborating the findings of Muriuki et al. (2024) and Shebanin et al. (2024) regarding the retention of qualified jobs in rural areas. The increased complexity of agricultural reverse chains, with the operation of biomethane plants, automation of industrial composting, and internal biochemical nutrient monitoring laboratories, generates qualified jobs with high technical compensation within the rural territory itself. This dynamic anchors the young human capital in their original rural communities, offering professional trajectories aligned with contemporary technological innovation and socio-environmental sustainability. Furthermore, the educational processes conducted by cooperatives, highlighted by Ada et al. (2022) and Musson and Rousselière (2020), act in deconstructing the historical technical dependency of small producers on commercial external inputs. By decentralizing access to knowledge about agricultural biotechnology and ecological metrics, the cooperative arrangement dismantles the historical dependency on closed technological packages supplied by oligopolistic corporations, returning to local communities the intellectual autonomy for decision-making regarding the management of their own territorial agro-ecosystems.



Challenges for the implementation of the circular economy in agricultural cooperatives

The implementation of the circular economy in agricultural cooperatives, despite its recognized benefits in environmental, social, and economic spheres, faces a complex set of challenges and barriers that limit its adoption and large-scale expansion (Ada et al., 2022; Batlles-Delafuente et al., 2024; Castro et al., 2019; Esfandiari Bahraseman et al., 2024; García-Agüero et al., 2024; Kim et al., 2023; Muriuki et al., 2024; Musson & Rousselière, 2020; Perdana & Kusnandar, 2023; Prieto-Sandoval et al., 2022; Shen et al., 2024; Zlati et al., 2023). These obstacles manifest in several dimensions, including legal, institutional, technological, cultural, financial, and infrastructure factors.

Barriers of a legal and institutional nature represent a significant hurdle. The absence of clear and effective regulation, along with the lack of coherent and targeted public policies for the circular economy in the agricultural sector, constitutes one of the main obstacles to its implementation by cooperatives (Ada et al., 2022; Batlles-Delafuente et al., 2024). The inadequacy or insufficiency in implementing existing waste management policies in certain contexts is also observed (Ada et al., 2022; García-Agüero et al., 2024). The lack of government incentives and financial and technical support programs specifically aimed at circular initiatives in cooperatives limits progress (Batlles-Delafuente et al., 2024; Zlati et al., 2023). Issues related to governance and coordination among multiple actors and different levels of government equally impose challenges to the integration of circular practices into broader value chains (Batlles-Delafuente et al., 2024; Perdana & Kusnandar, 2023). The bureaucratic complexity of obtaining licenses and accessing public resources can discourage cooperatives (Zlati et al., 2023).

From an institutional analytical standpoint, this regulatory entanglement evidences that current state normative structures were entirely designed to serve and legitimize the linear flow of production. There is a profound bureaucratic inadequacy in regulatory agencies, which tend to categorize reusable biological by-products under the same punitive and prohibitive criteria

applied to hazardous toxic industrial waste. This inflexible regulatory treatment, mapped empirically by Ada et al. (2022) and Batlles-Delafuente et al. (2024), generates excessive transaction costs that paralyze the dynamism of cooperatives. The transaction costs for the approval and sanitary homologation of an organomineral biofertilizer or for the injection of biomethane into local distribution grids often exceed the market value of the generated asset itself. Excessive bureaucracy acts, in practice, as a hidden barrier to entry that perpetuates the monopoly of conventional energy and chemical sources, discouraging cooperative-based rural-urban socio-environmental entrepreneurship due to the lack of an agile, contextualized, and multi-level regulatory framework.

Regarding technological challenges, the limitations in adopting and operating new circular economy technologies, such as small-scale biorefineries or advanced composting systems, can be considerable for cooperatives and their members (Donner, Gohier, & de Vries, 2020; Kuipers et al., 2022). The difficulty in accessing appropriate technologies or the high initial investment cost in equipment and infrastructure constitute interconnected financial and technological barriers (Kim et al., 2023; Zlati et al., 2023). The management of specific waste streams, such as agricultural plastics, still faces challenges related to the lack of efficient technological solutions and adequate infrastructure for collection and processing in various regions (Kim et al., 2023; García-Agüero et al., 2024). Insufficient logistics infrastructure for the collection, transport, and centralized processing of organic waste and other by-products at a cooperative scale can hinder the implementation of efficient circular models (Bluemling & Wang, 2018; Perdana & Kusnandar, 2023). These logistical bottlenecks demonstrate that, without macro-structural planning of transport networks, frictional costs render the territorial closing of material cycles unfeasible.

The analysis of these operational impediments validates the restrictions pointed out by Bluemling and Wang (2018), as well as by Perdana and Kusnandar (2023), regarding diseconomies of scale and the complexity of



transporting agricultural waste. Most of the biorefining and advanced effluent treatment solutions available in the global market were designed for large-scale centralized agricultural mega-enterprises, requiring continuous volumetric inputs of raw material that individual family cooperative properties cannot supply. When a cooperative attempts to mimic these systems at a meso-level without deep logistical redesign, it faces prohibitive transport costs, since moving raw, wet bio-waste, characterized by low energy density and high water weight, consumes more fossil fuel in trucks than the clean energy generated in the final plant. This ecological and operational paradox requires cooperatives to develop endogenous innovations in organizational and logistics micro-collection and dynamic routing, lest they see the thermodynamic and financial efficiency of their circular projects totally neutralized by transport distances in extensive rural territories.

Cultural and social barriers are also significant. Resistance to change from farmers and cooperative members, which is often rooted in traditional practices or the perception of risk associated with new approaches, can constitute a significant obstacle to the adoption of circular practices (Ada et al., 2022; Esfandiari Bahraseman et al., 2024; Musson & Rousselière, 2020). Low awareness of the principles and benefits of the circular economy, or the lack of technical and managerial knowledge to implement circular business models, likewise limits member engagement (Ada et al., 2022; Esfandiari Bahraseman et al., 2024; García-Agüero et al., 2024; Muriuki et al., 2024). Issues related to food security and consumer perception of products derived from circular practices, such as the use of biofertilizers or treated wastewater, demand communication and trust-building strategies (Esfandiari Bahraseman et al., 2024).

Sociologically, peasant resistance to new circular technologies does not stem from irrational underdevelopment-related conservatism but constitutes a rational historical strategy for minimizing risks in contexts of extreme socio-economic vulnerability. Family-based producers operate with narrow financial margins and, understandably, hesitate to replace

synthetic chemical fertilizers of predictable and standardized performance with local recycled organic compounds whose nutrient release behavior can vary according to seasonal conditions. Breaking this paradigm of socio-cultural distrust, as argued by Esfandiari Bahraseman et al. (2024) and Musson and Rousselière (2020), depends on coordinated actions for the transfer and empirical validation of technology in the field. Breaking this perception barrier requires the cooperative to assume the role of scientific guarantor of rural eco-innovations, which demands the structuring of local demonstrative experimental units and the introduction of transparent traceability certifications that transform cultural distrust into a legitimate reputational advantage in consumer markets.

Financially, the scarcity of access to adequate funding is a critical barrier to the implementation of the circular economy in agricultural cooperatives (Ada et al., 2022; Zlati et al., 2023). The initial investment required for the acquisition of new technologies, adaptation of infrastructure, and the development of circular business models can be substantial, exceeding the individual investment capacity of members and even the cooperative itself (Zlati et al., 2023). The perception of risk associated with innovative circular ventures and the difficulty in demonstrating long-term economic viability can hinder access to credit and deter investor interest (Dubinina et al., 2024; Donner, Gohier, & de Vries, 2020). Volatility in the prices of by-products and circular products can also generate economic uncertainty for cooperatives that invest in these chains (Donner, Gohier, & de Vries, 2020).

The isolation of rural sustainable financing reflects the inadequacy of traditional risk matrix criteria, as pointed out by Zlati et al. (2023) and Dubinina et al. (2024). Standard financing lines operate with risk matrices designed strictly for the linear model of chemical monoculture and large-scale heavy mechanization. When a cooperative seeks resources to implement an integrated network of rural biodigesters, it faces the absence of tangible real guarantees suitable for conventional banking models and repayment periods incompatible with the biological and logistical maturation time of these projects.



Market price volatility for ecological assets aggravates this financial isolation. Without the consolidation of public or mutual mechanisms for guaranteeing minimum prices for circular co-products and locally generated energy, private investment remains inhibited. This gap, under the analysis of Donner, Gohier, and de Vries (2020), requires innovative designs for inter-organizational economic risk-sharing, delegating to credit cooperatives the role of architecting financial incentives contextualized for regional agro-ecological transition.

Finally, the transition to the circular economy within agricultural cooperatives constitutes a complex process that requires the coordinated overcoming of challenges of various natures. Effectively addressing these barriers, through the creation of a favorable regulatory environment, the development of targeted financing mechanisms and technical support, investment in infrastructure and technology, and the continuous promotion of training and awareness, is fundamental to catalyzing the transformative potential of the circular economy in this vital sector (Ada et al., 2022; Batlles-Delafuente et al., 2024; Musson & Rousselière, 2020).

The role of Agricultural Cooperatives

Agricultural cooperatives are widely recognized as essential strategic agents for the implementation of the circular economy in the agricultural sector. Their organizational structure, characterized by democratic management, vast territorial capillarity, and a remarkable capacity for articulation among a large number of small and medium-sized producers, positions them in a privileged manner to foster the circular transition (Ada et al., 2022; Castilla-Polo & Sánchez-Hernández, 2022; Musson & Rousselière, 2020; Prieto-Sandoval et al., 2022). These entities facilitate collective action, a crucial factor for achieving the scale and efficiency required in circular economy initiatives in rural areas, such as the centralized management of waste flows and the development of shared infrastructure (Bluemling & Wang, 2018; Perdana & Kusnandar, 2023). From an analytical standpoint, the

cooperative acts as the institutional hub that fills the logistic and technical gap between the isolated individual producer and the meso-scale buyer market.

The unifying role of the cooperative confirms the institutional propositions of Castilla-Polo and Sánchez-Hernández (2022), as well as Prieto-Sandoval et al. (2022), regarding the mitigation of rural fragmentation through associativism. The ecological transition imposes challenges that exceed the atomized agency capacity of isolated producers at the end of the supply chain. When analyzed through the lens of the New Institutional Economics, the cooperative emerges as a hybrid governance arrangement that drastically reduces transaction costs associated with rural symbiosis contracts. By establishing democratic channels of internal deliberation based on mutual transparency, the cooperative replaces market distrust with an ecosystem of mutual trust grounded in common territorial identity. This established social capital network is converted into a valuable intangible institutional infrastructure, allowing for the safe sharing of residual biological assets, the standardization of ecological operational routines, and the collective dilution of risks inherent in the introduction of pioneering biotechnological routes in the rural environment.

The practical contributions of cooperatives to the circular economy are multifaceted and encompass various aspects of the agricultural value chain. They promote the efficient sharing of resources, including machinery, equipment, and technical knowledge, optimizing their use and extending their service life. Cooperatives act as catalysts for adaptive innovation, fostering the adoption of new technologies and circular practices among their members through demonstrations, training programs, and specialized technical assistance (Musson & Rousselière, 2020; Ada et al., 2022). Additionally, they play a central role in building and managing industrial and agricultural symbiosis networks, establishing connections between producers and other entities in the chain to enable the large-scale reuse of waste and by-products (Bluemling & Wang, 2018; Prieto-Sandoval et al., 2022).



The organization of the collection, processing, and distribution of secondary materials, such as manure for the production of biofertilizers and biogas, or harvest by-products for other purposes, demonstrates the closing of nutrient and material cycles facilitated by cooperatives (Bluemling & Wang, 2018; Donner, Gohier, & de Vries, 2020). Their activity also extends to the management of products that do not meet conventional commercial standards, seeking routes for their valorization and minimizing waste (Perdana & Kusnandar, 2023). By establishing and promoting compliance with standards and certifications, such as Good Agricultural Practices, cooperatives encourage the adoption of more sustainable methods aligned with circular economy principles (Preprame & Buncha, 2023).

This practical support in the reverse chain validates the structural analyses of Donner, Gohier, and de Vries (2020) and Preprame and Buncha (2023), by demonstrating how cooperative operational standardization legitimizes the commercialization of organic co-products. By assuming responsibility for the sorting, refining, and distribution of secondary materials and bioproducts, cooperatives resolve the historical problem of information asymmetry that renders secondary circular markets unviable. The buyer of a cooperative-based biofertilizer possesses technical guarantees of microbiological stability provided by the institution, which would not happen in unregulated informal bilateral transactions between farmers. Similarly, by finding sustainable economic routes for "imperfect" food falling outside the traditional aesthetic standards demanded by urban retail, cooperatives transform systemic food waste into secondary value-added chains via local industrial processing. This strategic redirection acts on territorial food security and promotes the retention of economic wealth generated within the borders of the rural communities themselves.

The role of agricultural cooperatives in these processes is, therefore, distinctive and comprehensive. They serve as coordination platforms that overcome the fragmentation inherent in individual agricultural production (Bluemling & Wang, 2018). The mutual trust

and social capital intrinsic to the cooperative structure facilitate collaboration and the overcoming of barriers to the adoption of new practices, including resistance to change and lack of information (Ada et al., 2022; Musson & Rousselière, 2020). Cooperatives possess the capacity to aggregate the volume of waste or by-products from multiple members, making the investment in processing and valorization technologies economically viable, which would be prohibitive for a single producer (Donner, Gohier, & de Vries, 2020; Prieto-Sandoval et al., 2022). Additionally, their orientation toward collective benefit and sustainable development positions them as natural promoters of a more circular economy that equitably benefits members, the community, and the environment (Castilla-Polo & Sánchez-Hernández, 2022). They can articulate the demand for circular inputs among members and negotiate more favorable conditions for the acquisition of technologies or the commercialization of circular products in markets (Perdana & Kusnandar, 2023; Zlati et al., 2023).

The collective appropriation of the value added generated by rural waste corroborates the thesis of solidarity governance by Castilla-Polo and Sánchez-Hernández (2022), opposing the concentration tendencies of ordinary vertical capitalist supply chains. In the conventional concentrated corporate model, the introduction of advanced biorefineries tends to marginalize small family rural producers, integrating them in a subordinate way only as suppliers of cheap raw biomass with low added value. The cooperative arrangement inverts this correlation of operational forces. As the family rural producers themselves exercise collective ownership over the processing and waste refining plants of the cooperative, the surplus profits and dividends generated by the sale of biogas, renewable electricity, and organomineral biofertilizers return directly to the associated productive base. This mechanism guarantees local development and ensures a transition to the circular economy that is socially just, territorially balanced, and truly oriented by the principle of permanent shared value. Despite their strategic position, the activity of agricultural cooperatives in promoting the circular economy is not without limitations, as evidenced in the



analyzed studies. Institutional and legal barriers, such as the lack of clear regulation and the insufficiency of incentives directed toward circular business models in cooperatives, restrict their capacity for action (Ada et al., 2022; Batlles-Delafuente et al., 2024). Financial limitations, including difficulty in accessing adequate funding and the high initial cost of circular technologies, represent significant obstacles, even in the context of collective action (Ada et al., 2022; Zlati et al., 2023). Technological and infrastructure barriers, such as limited access to appropriate technologies or inadequate infrastructure for centralized collection and processing in certain regions, may constrain the scale and efficiency of cooperative circular initiatives (Kim et al., 2023; García-Agüero et al., 2024; Perdana & Kusnandar, 2023). Finally, cultural and social challenges, such as resistance to change and low environmental awareness among some members, may hinder full adherence and engagement in circular practices, despite the cooperative's promotion efforts (Ada et al., 2022; Esfandiari Bahraseman et al., 2024). Overcoming these limitations requires the support of effective public policies, the development of adapted financing mechanisms, and the implementation of continuous training and awareness programs (Ada et al., 2022; Zlati et al., 2023).

This chronic dependence on external macro-structural factors is sustained by the logistical barriers identified by García-Agüero et al. (2024) and Kim et al. (2023), by demonstrating that local associativism does not autonomously eliminate state infrastructural deficits. If the regional territory suffers from the precariousness of paved rural roads or suffers from the instability of public electrical transmission networks to export the surplus of clean energy generated in farm biodigesters, the cooperative's internal efforts remain severely restricted. This scenario reinforces the urgency of coordinated multi-level intersectoral articulation, in which cooperatives cease to act in isolation and begin to co-design rural public policies in direct partnership with universities, sustainable financial promotion agencies, and government regulatory bodies, building a robust transition governance.

FINAL CONSIDERATIONS

A presente revisão sistemática possibilitou a consThis systematic review enabled the consolidation of the current state of knowledge regarding the application of Circular Economy (CE) principles in agricultural cooperatives, focusing on identifying adopted practices, generated impacts, challenges faced, and benefits observed in the transition process to circular models in rural contexts. The analyzed evidence indicates the strategic potential of agricultural cooperatives as facilitators of CE, due to their collaborative organizational structure, broad territorial insertion, and capacity for articulation among small producers.

The academic originality of this analysis resides precisely in filling a critical gap in national and international literature by moving away from purely industrial or urban approaches to circularity to shed light on the specificities of the rural-urban and cooperative environment. The study advances existing literature by demonstrating that the cooperative is not a mere user of ecological technologies, but rather the essential institutional hub for diluting financial risks and enabling the logistical scale required for closing material cycles that family farming properties could never achieve in isolation.

It was verified that the implementation of CE in agricultural cooperatives provides significant benefits in environmental, economic, and social dimensions. Among the positive environmental impacts, the reduction of pollution through the valorization of organic waste, the production of bioenergy and biofertilizers, the reuse of packaging, and the safe reuse of wastewater stand out. From an economic perspective, there is an increase in profitability, a diversification of revenue streams, and a strengthening of the financial resilience of these organizations. In the social sphere, CE contributes to productive inclusion, job creation, the strengthening of rural social capital, and the dissemination of technical knowledge among cooperative members. Beyond the descriptive character of these impacts, the study offers practical contributions and systematized guidelines for the management of agricultural cooperatives: it is recommended to structure internal technical



committees for eco-innovation, co-invest in decentralized modular plants for biodigestion and automated composting, and create traceability seals for generated biofertilizers, transforming environmental compliance into a high-value-added commercial asset for market differentiation.

However, the adoption of CE by agricultural cooperatives is hindered by a set of structural barriers. Among the main bottlenecks are the lack of specific public policies, the absence of adequate regulations, limited access to financing lines, technical infrastructure weaknesses, and cultural resistance to adopting innovations. These factors compromise the effectiveness and scalability of circular practices, especially in regions with low institutional capacity. Such challenges evidence the need for integrated actions between public authorities, the productive sector, and civil society, grounded in territorial planning, incentives for innovation, and the strengthening of cooperative governance. As intrinsic limitations to this research, we recognize the predominantly qualitative and literature-mapping character, which lacks econometric field validation of the exact financial return of these ecological investments in different Brazilian regions, in addition to the fact that the Scopus and Web of Science databases may omit relevant local technical reports produced outside the global indexed journal circuit.

The analysis of the literature also revealed relevant gaps, particularly the scarcity of in-depth empirical studies on CE in the context of agricultural cooperatives, the limited number of comparative approaches between different regions and typologies of cooperatives, and the absence of specific metrics for evaluating the impacts of CE in these contexts. These gaps hinder the replication of good practices and the formulation of public policies based on robust evidence. Furthermore, there is a need for a greater understanding of the processes of technological adaptation, social innovation, and the construction of collaborative networks, aspects that constitute potential agendas for future research. Reinforcing this future direction and integrating the research debates, we highlight the pressing need for empirical studies focused

on developing countries, whose institutional contexts differ radically from the realities of the northern hemisphere. Methodologically, the construction of standardized rural eco-efficiency indicators and the investigation into how the democratic cooperative structure can foster the co-creation of ecological patents emerge as fertile paths for upcoming scientific agendas.

Thus, the contributions of this study are not restricted to a critical systematization of existing literature but also include providing practical subsidies to cooperative managers, public policymakers, and researchers. We emphasize the urgency of formulating structured public policies, investing in infrastructure and technical training, and creating financing mechanisms adapted to the reality of cooperatives. The Circular Economy presents itself as a promising approach to promoting ecological regeneration, social inclusion, and economic sustainability in rural areas. However, its effective implementation requires coordinated, sustainable efforts that are sensitive to territorial specificities, guided by principles of equity, participation, and shared value.

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