# Circular Transitions in Agri-Food Systems: Business Models, Sustainability and International Cooperation

# Transições Circulares em Sistemas Agroalimentares: Modelo de Negócio, Sustentabilidade e Cooperação Internacional

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## Justificativa

The main objective of the session is to guide the transition from a linear economy to a circular economy within agri-food supply chains, exploring the role of circular economy approaches in promoting sustainability and innovation. The transition toward circular production models is increasingly recognized as a key strategy for achieving the sustainability of the agri-food system. The reduction and valorization of production waste can bring potential benefits: reducing environmental impacts, enhancing resource efficiency, and creating new economic opportunities. The session will include contributions from researchers involved in circular agri-food systems, which explore opportunities for knowledge exchange and joint innovation between the two countries. The session aims to bring together scholars working on circular economy, sustainable agri-food systems, and innovation in agriculture. Contributions may address theoretical frameworks, empirical analyses, business model innovation, policy instruments, and consumer perspectives related to circular transitions in the agri-food sector. Particular attention will be given to international research collaborations and comparative perspectives. These contributions will serve as a starting point for a broader discussion involving scholars working on similar themes in different geographical and institutional contexts. The session welcomes interdisciplinary perspectives from agricultural economics, sustainability studies, innovation management, and food system research.

**Resumos Expandidos:**

1. **Bridging Italy and Brazil for Circular Agri-Food Economy (Circular Agri-Food Bridge)**[1]

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## Introduction and Objectives

The project's central focus will be on developing circular business models that are adapted to the distinct and strategic agri-food sectors of both countries. Pilot projects will showcase scalable, reproducible solutions to critical issues in both regions. Finally, this project aims to position Italy and Brazil as worldwide leaders in the circular economy for the agri-food supply chain, encouraging long-term collaboration, innovation, and sustainable growth for a greener future. The primary objective of the project is to drive the transition from a linear to a circular economy within strategic agri-food sectors of Italy and Brazil by developing innovative circular business models that enhance sustainability, economic resilience, and environmental responsibility. The project aims to minimize loss and waste, optimize resource use and by-products recovery by rethinking traditional value chains and implementing circular business models. By reducing reliance on non-renewable resources and implementing regenerative practices, the project will also contribute to the mitigation of the environmental impacts of the agri-food sectors. In addition, circular models will unlock new economic opportunities for farmers, producers, and businesses by creating value from waste, fostering innovation, and improving supply chain efficiency. This will increase competitiveness and economic growth in the agri-food sectors of both Italy and Brazil. Lastly, to foster international cooperation, the collaboration between Italy and Brazil will create a starting point for knowledge exchange, technology transfer, and joint innovation, positioning both countries as global leaders in sustainable agri-food practices. This will help, based on the results, the development of valid managerial practices guidelines and policy recommendations. Those would be valuable and applicable to both partners. By addressing these objectives, the project will play a pivotal role in building resilient, resource-efficient, and sustainable agri-food sectors in Italy and Brazil, aligning with global sustainability goals.

## Theoretical Framework

Circular economy has emerged as a key paradigm for promoting more sustainable patterns of production and consumption (Chiaraluce, 2021; Gómez-García *et al.*, 2021). By emphasizing resource efficiency, waste reduction, and the regeneration of natural systems, the circular economy aims to replace the traditional linear model of “take-make-dispose” with closed-loop production systems. This transition is particularly relevant for the agri-food sector, which generates large volumes of by-products and organic waste throughout its value chains, posing significant environmental and economic challenges for producers and food industries (Chiaraluce; Bentivoglio; Finco, 2023; Marrucci; Daddi; Iraldo, 2019). Within this context, circular business models have gained increasing attention as mechanisms capable of translating circular economy principles into practical strategies for firms and supply chains (Donner;

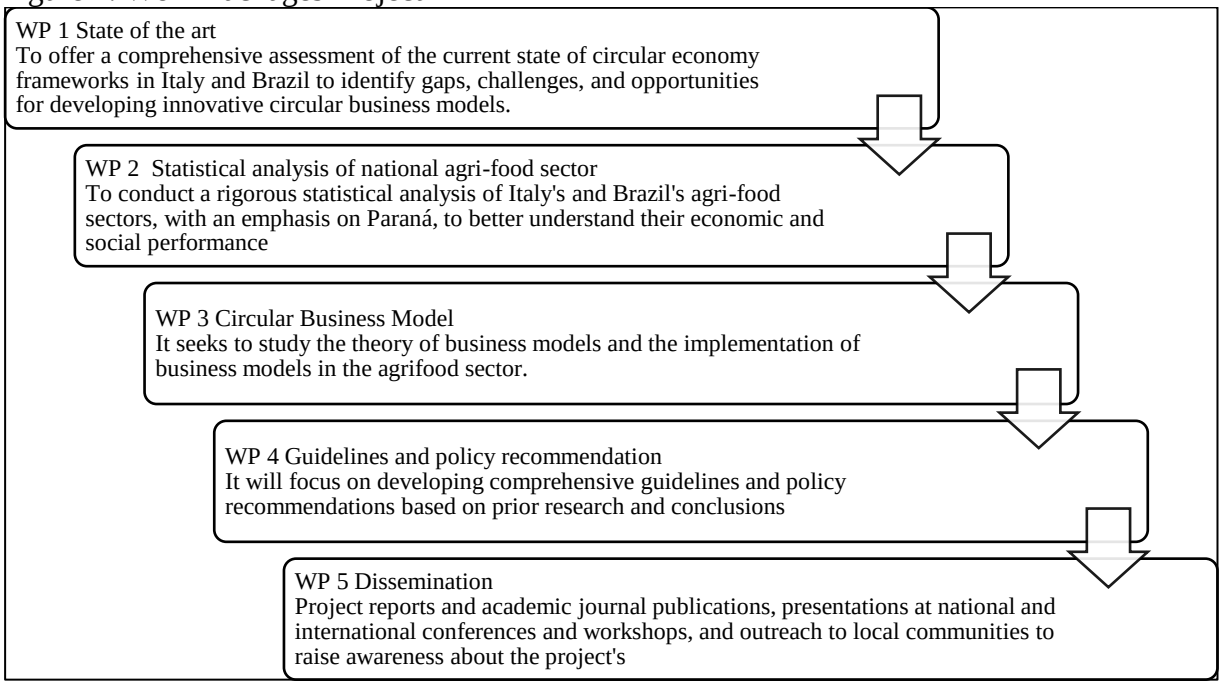
[1] This project is a results of the Call for Proposals launched on September 23th, 2024 by the Brazilian National Council for State Funding Agencies (CONFAP) in partnership with the Italian Ministry of Foreign Affairs and International Cooperation (MAECI) (CONFAP, 2026).

Gohier; De Vries, 2020). These models promote value creation through the reuse of resources, valorization of by-products, and improved resource efficiency across production and distribution processes. In the agri-food sector, such approaches can contribute not only to environmental sustainability but also to economic resilience and competitiveness. International collaboration can play a crucial role in accelerating the transition toward circular agri-food systems by fostering knowledge exchange and the diffusion of best practices. In this regard, cooperation between Brazil and Italy offers a particularly relevant perspective. While Brazil presents significant agricultural potential and emerging experiences in circular supply chains, Italy and the European Union have developed advanced policy frameworks and strategic initiatives aimed at promoting a resource-efficient and competitive circular economy. Combining these complementary experiences may support the development of innovative solutions for food production, by-product valorization, waste management, and supply chain optimization, while also generating new opportunities for sustainable regional development.

**Methodology**

The project will be organized in 5 Work Packages (WP) implemented in 3 years (1/2025–12/2027), see Figure 1.

Figure 1. Work Packages Project




Source: the author (2026).

WP1– State-of the-art (1/2025–6/2025) (UNIVPM-UNIOESTE)

It seeks to offer a comprehensive assessment of the current state of circular economy frameworks in Italy and Brazil to identify gaps, challenges, and opportunities for developing innovative circular business models.

• subtask 1.1 - State-of-the-art in Italy (UNIVPM): in-depth analysis of the circular economy in Italy, focusing on key sectors and initiatives relevant to the agri-food industry.

• subtask 1.2 State-of-the-art in Brazil (UNIOESTE): this will mirror the efforts in Italy, focusing on Brazil's current state in circular economy particularly the adoption region of Paraná.

WP2 – Statistical analysis of national agri-food sector (6/2025–12/2025) (UNIVPM-UNIOESTE).

It seeks to conduct a rigorous statistical analysis of Italy's and Brazil's agri-food sectors, with an emphasis on Paraná, to better understand their economic and social performance. The statistical data will help shape future circular business models by identifying key areas for improvement and intervention to enhance sustainability and resource efficiency.

• Subtask 2.1 Statistical analysis in Italy (UNIVPM): it will gather and analyze key data on Italy's agri-food sector, covering aspects such as number of enterprises, number of persons employed, turnover, quantity of waste/by-products produced, etc.

• Subtask 2.2 Statistical analysis in Brazil (Paraná) (UNIOESTE): a similar statistical analysis will be performed for the agri-food sector in Paraná, focusing on production systems and waste management.

WP3 – Circular Business Model (CBM) (5/2025–5/2027) (UNIVPM-UNIOESTE)

It seeks to study the theory of business models and the implementation of business models in the agrifood sector.

• Subtask 3.1 CBM study (UNIVPM-UNIOESTE): This WP will research and analyze current literature on circular business models relevant to the agri-food sector, to find best practices, difficulties, and potential for their implementation in Italy and Brazil.

• Subtask 3.2 CBM definition (UNIVPM-UNIOESTE): this WP will design and create bespoke circular business models for the Italian and Brazilian agri-food industries (particularly Paraná). The models will address crucial challenges such as resource efficiency, waste minimization, value creation from by-products, and sustainable manufacturing. This work package will include stakeholder consultations (cooperatives) and pilot testing to ensure that the models are realistic, scalable, and adaptive to local circumstances.

WP4 – Guidelines and policy recommendation (3/2027–10/2027) (UNIVPM-UNIOESTE)

It will focus on developing comprehensive guidelines and policy recommendations based on prior research and conclusions. The guidelines will provide practical methods for developing circular business models in the agri-food sector, while the policy suggestions will be directed at governments and policymakers in Italy and Brazil to assist a circular economy transformation. The recommendations will address legislative frameworks, incentives, and prospects for international collaboration. Special attention will be given to developing regulations that foster innovation, lower barriers to circular processes, and promote long-term sustainability in the agri-food sector.

WP5 – Dissemination (1/2026–12/2027) (UNIVPM-UNIOESTE)

The final WP will guarantee that the project's results, findings, and innovations reach key stakeholders such as industry experts, legislators, researchers, and the public. Dissemination activities will include project reports and academic journal publications, presentations at national and international conferences and workshops, and outreach to local communities to raise awareness about the project's.

**Expected Results and Conclusions**

This project would like to propose and advancement of the current knowledge about circular economy applied to the agri-food sector, by proposing viable circular business models that could be applied both in Italy and Brazil. In this perspective, the main expected outcomes of this work will be:

- Comparative report about circular economy state-of-the-art in Italy and Brazil-Paraná summarizing the differences and similarities.

- Comparative report of statistics about the agri-food sector in Italy and Brazil-Paraná identifying opportunities for circular economy interventions .

- Comprehensive report summarizing the existing literature on circular business models, capturing the functioning essence and covering best practices, case studies, and theoretical frameworks and circular business models for strategic sectors in Italy and Brazil-Paraná.

- Practical guidelines for stakeholders and policy recommendations to support the transition towards a circular agri-food economy in both countries.

- Project reports, scientific publications, conferences, workshops.

By focusing on the development of circular business models and innovative practices, the project will drive technological advancements that can be applied in both Italy and Brazil. In addition, the project will contribute to building scientific and technological capacity in both countries by favoring knowledge exchange and providing opportunities for researchers and entrepreneurs, equipping them with skills necessary for future challenges in sustainable development. The collaboration will not only strengthen both countries' capacities to transition toward a circular economy but also contribute to global sustainability goals, showcasing the potential for international partnerships in addressing complex economic challenges.

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## 2. Circular economy adoption in the agri-food sector: Measuring by-products, barriers and opportunities through Italian multiple case studies

**Riccardo Biagioli (Polytechnic University of Marche, Department of Agricultural, Food and Environmental Sciences D3A)**

It is undeniable that the agri food system is one of the greatest waste-producing sectors, with the inevitable generation of a certain quantity of scraps due to processing at an industrial level. Circular economy may offer a valid solution to overcome this problem, but the application of the model requires the availability of reliable data about the quality and quantity of waste, which are currently missing. For this purpose, the objective of this study is to address the issue of waste generation in the Italian agri-food industry using a survey questionnaire. In depth interviews were conducted with the owners or the technicians of selected case studies from the Marche region agri food sector. Then, mass balance was applied based on primary data collected during the interviews. Moreover, to explore the potentiality of the circular model for the development of a regional agri food sector, barriers, opportunities and services were also investigated. Results identified the vegetable and olive oil transformation as the most impacting in terms of quantities of waste produced. Food business operators currently find it difficult to give a proper definition of circular economy and envision the implementation of the model soon. However, they are also very enthusiastic and positive in finding alternative solutions to recover the waste. A great support could be provided by establishing a regional database for waste qualification and quantification. This work could be useful for policy makers, helping to understand the hurdles that agribusiness entrepreneurs shall face in this economic transition.

### Theoretical Framework

The shift from a traditional take-make-use-dispose model to the application of circular principles offers relevant opportunities to agrifood businesses for reducing their impacts, considering waste as a secondary resource (Teigiserova et al, 2020).
However, a lot still needs to be done concerning the regulatory framework and the technical aspects. One controversial aspect posed by the regulations is the definition of what is a food waste. This creates problems to entrepreneurs that, according to the status of their waste, should manage them differently, with different risks and costs. In addition, one of the main problems is that quantification of food by-products and waste is characterised by conflicting results, mainly due to different methods and practices. In most cases the used data is retrieved from databases (FAO, Eurostat), reports and food balance sheets (Ioannou et al, 2022; Amicarelli et al, 2020). Despite that, it is difficult to find high quality data by-products and waste driving from direct measurement and analysis.
On these premises, this study aims to answer the following research questions: Which type and how much by-product and waste are produced during the processing of raw materials into food products? Which are the barriers and opportunities in implementing the CE in the Italian agri-food sector? Which services are needed to facilitate the adoption of a circular model?

### Methodology

The study adopted a multiple case study approach to investigate by-product and waste generation and the potential transition toward a circular economy model within the agri-food sector of the Marche region (Yin, 2018). Although case studies may be criticised for limited generalisability, the use of multiple cases allowed the comparison of several companies

operating in different supply chains, providing a comprehensive understanding of the regional context and enabling potential replication of the results in similar environments (Noor, 2008). Selected companies had to belong to different agri-food supply chains, operate in sectors identified as particularly relevant in the regional statistical analysis, possess a solid brand reputation, and run mature and profitable businesses capable of investing in circular transition processes. Furthermore, companies needed to generate by-products with potential circular uses. Based on these criteria, five representative supply chains were selected: fruit and vegetable processing, olive oil production, baked and starchy products (fresh and dry pasta), coffee production, and wine production. Data collection was conducted through questionnaires and semi-structured interviews with entrepreneurs and technical staff. For each company, at least two participants were interviewed, usually the owner and the production technician, through face-to-face meetings or online calls when necessary. The questionnaire was structured in three sections: company profile, analysis of by-product and waste generation, and perceptions of circular economy. Waste generation was estimated using the mass balance method, which tracks material flows by comparing inputs and outputs along the production process. Interviewees were asked to describe production flow charts, quantities of inputs and outputs, types of by-products and waste, and their current destination and management costs. The final section explored knowledge, barriers, and opportunities related to circular economy adoption using Likert-scale questions. Collected data were analysed independently by three researchers with expertise in qualitative research and agri-food supply chains. Due to the limited number of valid responses, statistical analysis was not feasible; therefore, the study relied on a qualitative interpretation of the case study results.

**Results and Conclusions**

The results highlight the characteristics of the selected case studies and the main patterns of by-product and waste generation in different agri-food supply chains of the Marche region. The analysed companies are mainly small and medium-sized enterprises, often family-run, confirming the typical structure of the regional agri-food sector. The mass balance analysis revealed that waste and by-products are unavoidable during food processing, although their quantities differ significantly across supply chains. Vegetable processing and extra-virgin olive oil production generated the highest volumes of waste, mainly consisting of non-edible plant parts, olive pomace, and pits, whereas coffee roasting generated comparatively lower losses. Several by-products already have alternative uses. For example, wine pomace and lees are delivered to distilleries, pruning residues are reused in fields as soil conditioners, and some biomass can be used for energy production or animal feed. However, certain materials, such as packaging waste or coffee jute sacks, are still disposed of without further valorisation. Interviews revealed that entrepreneurs generally recognise the importance of the circular economy but often find it difficult to clearly define the concept. Nevertheless, most respondents expressed a positive attitude towards exploring new solutions for waste recovery, particularly in areas such as water reuse and energy production. The main barriers to the adoption of circular economy practices include bureaucratic procedures, an unclear regulatory framework, high investment costs, the absence of economic incentives, and the lack of trained professionals able to guide the transition. At the same time, several opportunities were identified, such as waste valorisation, job creation, income diversification, and improved environmental sustainability. Respondents also emphasised the need for supporting services, including networking systems among companies, logistics platforms for waste management, training initiatives, and the creation of a regional database to quantify and classify agri-food waste. Overall, the findings

suggest that while the circular economy model is still at an early stage in the regional agri-food sector, it presents significant potential for improving resource efficiency and promoting sustainable regional development.

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## 3. Comparative analysis of circular economy practices in the agri-food sector: a study of Brazil and Italy[2]

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### Introduction and Objectives

The transition toward more sustainable production systems has intensified the debate on the role of the Circular Economy (CE) in addressing environmental challenges, resource constraints, and the need for more resilient regional economies. In the agri-food sector, CE principles – such as waste valorization, resource efficiency, and industrial symbiosis – have been increasingly associated with sustainable regional development strategies. Despite this growing interest, empirical evidence on how CE practices reshape business models in different territorial contexts remains limited, particularly in comparative cross-national analyses. The agri-food sector is especially relevant for this discussion because it is deeply embedded in regional production systems and strongly connected to natural resources, value chains, and territorial development dynamics. Understanding how CE practices are implemented in different institutional and socio-economic contexts can provide insights into how firms and regions transition toward more sustainable models of production and consumption. In this context, this study aims to analyze the implementation of Circular Economy practices in the agri-food sector through a comparative perspective between Brazil and Italy. Specifically, the research seeks to: (i) assess how national regulatory frameworks address CE principles; (ii) identify CE practices adopted by agri-food firms (Christ *et al.*, 2025); and (iii) examine how these practices contribute to business model transformation and regional development. The empirical analysis focuses on two territories: the Intermediate Geographic Region (RGInt) of Cascavel, in Paraná State (Brazil), and the Marche Region (Italy). These regions were selected due to their strong agri-food specialization and the relevance of cooperative and agro-industrial systems in their economic structures.

### Theoretical Framework

The study is grounded in the literature on Circular Economy, sustainable regional development, and business model innovation. The Circular Economy has emerged as a systemic approach that seeks to decouple economic growth from resource consumption by promoting closed-loop systems, waste reduction, and resource recirculation (Geissdoerfer *et al.*, 2020; Kirchherr; Reike; Hekkert, 2017). In the agri-food sector, CE practices may include nutrient recovery, reuse of organic residues, bioenergy generation, water reuse, and industrial symbiosis across supply chains. These practices not only reduce environmental impacts but may also create new economic opportunities and foster innovation in production systems. From a regional development perspective, CE is increasingly interpreted as a territorial strategy that depends on institutional frameworks, governance arrangements, and interactions among local actors. Regional production systems, clusters, and cooperative networks can play a crucial role in facilitating resource circulation and knowledge exchange. Another important dimension relates to the transformation of business models. The adoption of CE practices often requires firms to rethink value creation, delivery, and capture mechanisms. This transformation may involve new partnerships, changes in supply chain organization, and the integration of

[2] PhD thesis of Gabriela Daiana Christ (2025).

sustainability objectives into strategic decision-making. However, the trajectories of CE adoption are strongly influenced by national policies, institutional contexts, and cultural factors. While European countries have incorporated CE into broader sustainability strategies, emerging economies often experience more fragmented or emergent initiatives driven by competitiveness pressures and market opportunities.

**Methodology**

This research adopts a qualitative and comparative research design based on multiple case studies. The analysis focuses on the agri-food sector in two distinct regional contexts: the Intermediate Geographic Region of Cascavel, in Paraná State (Brazil), and the Marche Region (Italy). Data collection involved two main sources. First, documentary analysis was conducted to examine national regulatory frameworks related to Circular Economy and sustainability in both countries. Second, semi-structured interviews were conducted with representatives of agri-food firms and sectoral stakeholders, allowing the identification of CE practices and their implications for business strategies and regional development. The interview protocol explored themes such as sustainability practices, resource management strategies, innovation processes, partnerships within the value chain, and perceptions regarding regulatory frameworks and market pressures. The collected data were analyzed using qualitative content analysis, enabling the identification of recurring themes and patterns across cases. This approach allowed for a comparative interpretation of how CE principles are translated into business practices within different institutional and regional contexts.

**Results and Conclusions**

The results reveal three main findings regarding the implementation of Circular Economy practices in the agri-food sector. First, effective CE implementation requires balancing pragmatism, inclusiveness, governance arrangements, and socio-political contexts. In Brazil, CE initiatives tend to emerge from firm-level strategies focused on competitiveness, resource efficiency, and cost reduction. In contrast, in Italy CE practices are more closely linked to broader sustainability agendas and institutional frameworks, although the regulatory environment remains fragmented across sectors. Second, the transition toward circularity depends not only on technological adoption but also on cultural and organizational change. Aligning people's mindsets with circular economy principles requires clear strategic goals, long-term commitment, and continuous monitoring of sustainability performance across environmental, social, and economic dimensions. Third, the two regions exhibit distinct development trajectories. The Intermediate Geographic Region of Cascavel shows strong growth dynamics driven by livestock production and agroindustrial diversification. Circular practices are often associated with waste valorization and integration between agricultural and industrial activities. In contrast, the Marche Region reflects a more mature production system that is increasingly oriented toward high-value niches, product differentiation, and sustainability-driven innovation. Overall, the study contributes to the literature by providing comparative empirical evidence on the relationship between Circular Economy practices and regional development in the agri-food sector. The findings highlight that the transition toward circularity is not uniform and depends on the interaction between institutional frameworks, business strategies, and regional production structures. From a policy perspective, the results suggest the importance of fostering governance mechanisms, encouraging collaboration among value chain actors, and aligning regulatory frameworks with innovation policies that support the development of circular production systems.

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## 4. Circular Transitions in Agri-Food Systems: Institutional Limits of Reverse Logistics for Agrochemical Packaging in Brazil

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### Introduction and Objectives

The transition toward more sustainable agri-food systems has stimulated the adoption of institutional instruments associated with the circular economy. Among these instruments, Extended Producer Responsibility (EPR) has gained prominence by assigning manufacturers responsibility for the environmental management of their products throughout the entire life cycle, including the disposal phase (Lifset; Atasu; Tojo, 2013; OECD, 2001).

In the agricultural sector, one of the most common mechanisms for implementing EPR policies is reverse logistics or take-back systems, designed to ensure the proper collection and treatment of agricultural waste. In Brazil, one of the most prominent examples is the Campo Limpo System, coordinated by the National Institute for Processing Empty Containers (inpEV), responsible for collecting and processing empty agrochemical packaging nationwide.

Although the system reports high recovery rates and is frequently cited as an international reference in agricultural waste management, important questions remain regarding its actual contribution to broader sustainability transitions in agri-food systems.

This study aims to analyze the institutional and territorial limits of reverse logistics for agrochemical packaging in Brazil, examining to what extent this instrument contributes to circular transitions in agri-food systems.

Specifically, the research seeks to:

1. Examine the relationship between regional agricultural structures and the efficiency of agrochemical packaging collection systems.
2. Identify asymmetries in the participation of different groups of farmers in reverse logistics systems.
3. Discuss the limits of circular economy approaches when applied to agricultural production systems highly dependent on chemical inputs.
4. Contribute to the debate on governance and public policies aimed at sustainable agri-food systems.

### Theoretical Framework

The circular economy has been widely discussed as an alternative to the traditional linear economic model characterized by the “take–make–dispose” pattern (Kirchherr; Reike; Hekkert, 2017). By promoting material loop closure, waste reduction, and the valorization of by-products, circular economy strategies aim to increase resource efficiency and reduce environmental impacts.

Within this framework, **Extended Producer Responsibility (EPR)** policies seek to internalize environmental costs by assigning producers responsibility for the post-consumption phase of their products (Lifset; Lindhqvist, 2008; Lifset; Atasu; Tojo, 2013).

In the agri-food sector, circular strategies have often been implemented through reverse logistics schemes designed to manage agricultural residues such as pesticide containers (Lagarda-Leyva et al., 2019; Picuno et al., 2020).

However, several studies highlight that circular economy practices do not automatically guarantee broader sustainability outcomes. In some contexts, recycling or waste recovery

systems may coexist with expanding production systems that remain environmentally intensive (Hobson, 2021).

In this perspective, the concept of **rebound effect** becomes particularly relevant. Efficiency improvements in waste management may unintentionally reinforce the very production systems that generate environmental pressures (Zink; Geyer, 2017; Figge; Thorpe, 2019).

Therefore, analyzing circular transitions requires considering not only technical recycling systems but also the **institutional structures, agricultural production patterns, and territorial inequalities** shaping agri-food systems.

## Methodology

The study adopts an exploratory and descriptive approach based on secondary data and documentary analysis.

Three main sources of data were used:

- **Brazilian Institute of Geography and Statistics (IBGE)** – Agricultural Census 2017.
- **Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)** – national data on agrochemical commercialization.
- **National Institute for Processing Empty Containers (inpEV)** – sustainability reports and data on packaging recovery.

The empirical strategy consisted of examining the relationship between the **volume of agrochemicals sold across Brazilian states and the amount of packaging collected by the Campo Limpo System**.

Additionally, variables describing the **regional agricultural structure** were considered, including:

- crop distribution,
- participation of large-scale and family farming,
- land concentration indicators,
- regional agricultural production patterns.

These variables allowed the identification of territorial patterns of efficiency and coverage in reverse logistics operations.

## Results and Discussion

The results suggest that the efficiency of the Campo Limpo System is strongly associated with the presence of large-scale agricultural producers, particularly in regions dominated by soybean production.

States characterized by large agricultural properties and strong integration with export-oriented agribusiness show higher volumes of packaging recovery. In contrast, regions with a stronger presence of family farming tend to display lower levels of participation in the reverse logistics system.

This pattern suggests that the operational logic of the collection system favors regions where agricultural production is spatially concentrated and logistically accessible, allowing higher recovery rates at lower operational costs.

However, this efficiency-oriented structure raises important sustainability concerns:

- small-scale farmers remain partially marginalized within the collection network;
- infrastructure and monitoring challenges persist in peripheral agricultural regions;

- recycling agrochemical packaging does not alter the structural dependence of agricultural systems on chemical inputs.

In this context, efficient waste management may coexist with the intensification of agrochemical use, illustrating a potential rebound effect in circular economy initiatives.

**Conclusions**

The study demonstrates that reverse logistics systems based on Extended Producer Responsibility can improve waste management in the agri-food sector. However, such mechanisms present significant limitations when evaluated from the perspective of broader sustainability transitions.

In Brazil, the Campo Limpo System achieves high operational efficiency but tends to favor regions and producers integrated into large-scale agribusiness.

Therefore, transitions toward more sustainable agri-food systems require policies that go beyond waste management and incorporate broader dimensions such as territorial governance, inclusive agricultural development, and structural transformations in agricultural production systems.

The analysis suggests that circular economy strategies need to be articulated with regional development policies and institutional innovation in order to effectively contribute to sustainable agri-food systems.

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**5. The sugarcane agroindustry and the circular economy: a case study at the Bandeirantes Mill (Paraná/Brazil)**

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## Introduction and Objectives

The rapid growth of the global population has intensified concerns regarding food security and the sustainable use of natural resources. In November 2022, the world population reached approximately eight billion people, increasing the demand for food and energy while also intensifying debates on sustainable production systems (United Nations - ONU, 2022). Historically, industrial production has been based on a linear model characterized by the sequence of extraction, production, and disposal, which has contributed to environmental degradation and the depletion of natural resources (Campello, 2021).

In response to these challenges, the circular economy has emerged as an alternative framework capable of reconciling economic development with environmental sustainability. Its principles focus on reducing waste generation, maintaining materials and products in use for longer periods, and restoring natural systems (Ellen Macarthur Foundation - EMF, 2017). Within this context, the Brazilian sugarcane agroindustry has strategic relevance because it contributes both to food security through sugar production and to energy security through ethanol production and biomass-based electricity generation (Shikida et al., 2022).

Brazil is the largest sugarcane producer in the world, with production exceeding 650 million tons in recent harvests (Brazilian Sugarcane Industry Association - UNICA, 2022a). Given this importance, understanding how circular economy principles are applied within this sector becomes essential. Therefore, the objective of this study is to analyze the circular economy practices adopted by the Bandeirantes Sugar and Alcohol Plant (Usiban), located in Paraná. Specifically, the research aims to identify which by-products are reused, how circular practices are implemented within the production process, and what benefits result from adopting this approach in the sugarcane agroindustrial system.

## Theoretical Framework

The concept of circular economy is based on production systems organized in closed loops, in which materials and products maintain their value and utility throughout the production cycle (Finco et al., 2022; Weetman, 2019). Unlike the traditional linear model, the circular economy promotes the reuse of resources, waste reduction, and the regeneration of natural systems.

In Brazil, one of the main institutional frameworks related to circular economy principles is the National Solid Waste Policy, established in 2010, which encourages reverse logistics and the reintegration of residues into production processes (Brasil, 2010). According to Finco et al. (2022), the transition from a linear to a circular economy requires the development of new technologies, innovative processes, and changes in production and consumption patterns.

The sugarcane agroindustry presents significant potential for the implementation of circular economy practices because of the large number of by-products generated during the production of sugar and ethanol. These by-products include sugarcane bagasse, straw, vinasse, filter cake, and yeast (Pacheco, 2011). According to Raízen (2023), bagasse and straw can be

used to generate bioelectricity, enabling energy self-sufficiency for many sugar mills and allowing the sale of surplus energy to electricity distributors.

Other by-products also contribute to circular production processes. Filter cake can be used as an organic fertilizer due to its high nutrient content (Almeida Júnior et al., 2011), while vinasse can be applied in fertigation systems, improving soil fertility and increasing sugarcane productivity (Piracicaba Engenharia Sucroalcooleira, 2015). In addition, technological innovations have enabled the development of second-generation ethanol produced from lignocellulosic residues such as bagasse and straw (Calil Neto, 2017). These practices reinforce the importance of circular economy strategies for improving environmental sustainability and economic efficiency within the agroindustrial sector.

## Methodology

This research adopts a qualitative and descriptive approach using a case study methodology. According to Gil (2008), case studies allow an in-depth analysis of specific phenomena within their real-life contexts, particularly when the boundaries between the phenomenon and its environment are not clearly defined.

The selected case is the Bandeirantes Sugar and Alcohol Plant (Usiban), located in the municipality of Bandeirantes in the northern region of Paraná. The plant was founded in 1942 and represents one of the most traditional sugarcane agroindustrial units in the state (Ribeiro; Endlich, 2010).

Data collection involved both literature review and field research. The fieldwork was conducted during the final stage of the sugarcane harvest in October 2022 and included a technical visit to the plant's administrative and industrial facilities. The research team observed the different stages of the sugar and ethanol production process, focusing on the reuse of by-products and the presence of circular economy practices.

In addition, semi-structured interviews were conducted with managers from several sectors involved in the production chain, including agriculture, industry, quality control, human resources, legal, and environmental departments. These interviews aimed to identify how circular practices are implemented in the production process and how by-products are managed and reused (Casarin; Casarin, 2012).

## Expected Results and Conclusions

The results indicate that Usiban has implemented several circular economy practices aimed at improving both economic performance and environmental sustainability. One of the most important strategies adopted by the company is the reuse of by-products generated during the production of sugar and ethanol.

Sugarcane bagasse, for instance, is fully reused by the plant as a source of bioenergy for internal electricity generation. This practice ensures energy self-sufficiency and reduces dependence on external energy sources. Similar practices are common in the Brazilian sugar-energy sector, where biomass-based electricity generation has become an important component of the energy matrix (Teixeira et al., 2020).

Other important by-products include vinasse and filter cake, which are used in fertigation processes to fertilize sugarcane fields. According to Almeida Júnior et al. (2011), these residues are rich in nutrients such as phosphorus, potassium, and nitrogen, making them effective natural fertilizers. Their use reduces the need for industrial fertilizers and can generate significant cost savings for producers.

Despite the adoption of several circular economy practices, some potential innovations are not yet implemented at Usiban. For example, the production of second-generation ethanol and pelletized biomass is not currently economically viable due to high technological investment costs (Pacheco, 2011; Calil Neto, 2017).

Overall, the study demonstrates that circular economy practices can significantly contribute to improving efficiency, reducing costs, and enhancing environmental sustainability in the sugarcane agroindustry. The case of Usiban illustrates how the reuse of by-products and the adoption of circular strategies can strengthen the competitiveness of agroindustrial systems. However, the expansion of these practices will depend on technological advancements and continued investment in innovation within the sector.

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