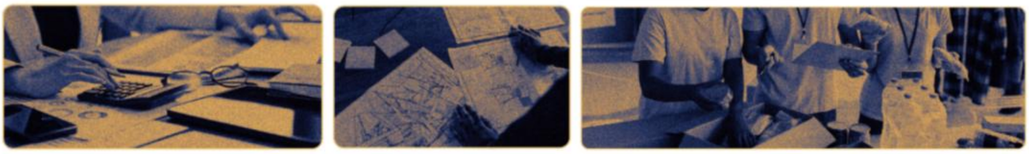

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EDITORA

SUSTAINABLE MANAGEMENT AND REUSE OF AGRO-INDUSTRIAL WASTE: AN APPROACH FROM THE PERSPECTIVE OF THE CIRCULAR ECONOMY AND AGRIBUSINESS MANAGEMENT

GESTÃO SUSTENTÁVEL E REUTILIZAÇÃO DE RESÍDUOS AGROINDUSTRIAIS: UMA ABORDAGEM SOB A PERSPECTIVA DA ECONOMIA CIRCULAR E DA ADMINISTRAÇÃO DO AGRONEGÓCIO

GESTIÓN SOSTENIBLE Y REUTILIZACIÓN DE RESIDUOS AGROINDUSTRIALES: UN ENFOQUE DESDE LA PERSPECTIVA DE LA ECONOMÍA CIRCULAR Y LA GESTIÓN AGROEMPRESARIAL

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ABSTRACT
This theoretical-analytical paper investigates sustainable management and the reuse of agro-industrial residues from the perspective of Management, Circular Economy, and ESG practices. It aims to understand how residues such as filter cake, vinasse, and bagasse can be reintegrated into production chains, enhancing efficiency, innovation, and sustainability. The study is based on an interdisciplinary literature review covering environmental management, circular economy, and public policy. It concludes that the strategic reuse of agro-industrial residues, by aligning sustainability and competitiveness, strengthens regional development and the bioeconomy.

Keywords: Circular Economy. Sustainability. Agro-industrial Waste. Bioeconomy.

RESUMO
Este artigo teórico-analítico investiga a gestão sustentável e a reutilização de resíduos agroindustriais sob a ótica da Administração, da Economia Circular e das práticas ESG. Busca-se compreender como os resíduos provenientes de processos agroindustriais, como torta de filtro, vinhaça e bagaço, podem ser reintegrados às cadeias produtivas, promovendo eficiência, inovação e sustentabilidade. A abordagem teórica foi desenvolvida a partir de revisão bibliográfica interdisciplinar, envolvendo autores de economia circular, gestão ambiental e políticas públicas. Conclui-se que a reutilização estratégica de resíduos

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agroindustriais, ao alinhar sustentabilidade e competitividade, consolida um modelo de gestão que favorece o desenvolvimento regional e a bioeconomia.

Palavras-chave: Economia Circular. Sustentabilidade. Resíduos Agroindustriais. Bioeconomia.

RESUMEN

Este artículo teórico-analítico investiga la gestión sostenible y la reutilización de residuos agroindustriales desde la perspectiva de la administración, la economía circular y las prácticas ESG. Busca comprender cómo los residuos de procesos agroindustriales, como la torta de filtración, la vinaza y el bagazo, pueden reintegrarse en las cadenas productivas, promoviendo la eficiencia, la innovación y la sostenibilidad. El enfoque teórico se desarrolló a partir de una revisión bibliográfica interdisciplinaria, con la participación de autores en economía circular, gestión ambiental y políticas públicas. Concluye que la reutilización estratégica de residuos agroindustriales, al alinear la sostenibilidad y la competitividad, consolida un modelo de gestión que favorece el desarrollo regional y la bioeconomía.

Palabras clave: Economía Circular. Sostenibilidad. Residuos Agroindustriales. Bioeconomía.

1 INTRODUCTION

Sustainability and efficient waste management are configured as structuring axes for the reconfiguration of contemporary production paradigms, especially in the context of Brazilian agribusiness (Sachs, 2008). The growing global demand for food, energy and raw materials imposes unprecedented challenges to agro-industrial production, requiring management strategies that reconcile economic competitiveness and socio-environmental responsibility (Barbieri, 2011). In this scenario, the proper disposal of agro-industrial waste emerges as a strategic dimension for the consolidation of sustainable production models aligned with the circular economy (Ellen MacArthur Foundation, 2019).

Brazilian agribusiness occupies a prominent position in the international scenario due to the breadth of its production base and the significant contribution to the Gross Domestic Product (GDP). According to the National Supply Company (CONAB, 2024), the sector accounts for approximately a quarter of the national economy and a significant portion of Brazilian exports. This relevance, however, is accompanied by challenges related to environmental sustainability, especially regarding the generation and disposal of solid waste. By-products such as filter cake, vinasse, bagasse and straws require innovative solutions for reuse and recovery (OECD, 2011).

The inadequate disposal of this waste can lead to impacts such as soil degradation, water contamination and greenhouse gas emissions (Hart & Milstein, 2003). However, when subjected to technical and economic reuse processes, these materials can be reinserted into the production chain, assuming new functions in the context of the bioeconomy and resource efficiency (Freeman, 1984). This duality — residue as a problem or opportunity — highlights the importance of administrative practices guided by sustainability and technological innovation (Elkington, 1997).

The Circular Economy proposes a break with the traditional linear model, structured in the logic of extraction, production, consumption and disposal. According to the Ellen MacArthur Foundation (2019), the circular model seeks to establish closed flows of materials and energy, promoting the regeneration of natural systems and extending the life cycle of products. This perspective has direct implications for agribusiness, whose production chain is resource-intensive and has a high potential for reintegrating waste as productive inputs (Geissdoerfer et al., 2017).

In the field of management, the contributions of Elkington (1997) and Freeman (1984) consolidate the view that business performance should incorporate economic, social and environmental dimensions, inaugurating the notion of the *Triple Bottom Line* and the *Stakeholder Theory*. The integration of these principles into governance gave rise to the ESG

(*Environmental, Social and Governance) movement*, which has established itself as a global benchmark for corporate sustainability (Porter & Kramer, 2011).

In the Brazilian context, public policies such as RenovaBio, the ABC+ Plan, and the National Solid Waste Policy (PNRS) institute instruments to encourage a low-carbon economy and productive circularity (Brasil, 2010; Brazil, 2017; Brazil, 2021). Such policies, articulated with the Sustainable Development Goals (SDGs) of the UN 2030 Agenda, reinforce the convergence between economic development and environmental preservation (BNDES, 2024). Thus, the sustainable management of agro-industrial waste transcends the technical character, configuring itself as a strategic pillar of competitiveness and innovation in Brazilian agribusiness (Barbieri, 2011).

The present study aims to analyze the sustainable management and reuse of agro-industrial waste from the perspective of Administration and the Circular Economy, discussing the interrelationships between productive efficiency, innovation and sustainability (Ellen MacArthur Foundation, 2019). The theoretical-analytical approach seeks to understand how the incorporation of the principles of circularity and ESG practices strengthens competitiveness and regional development, inserting Brazilian agribusiness in the global ecological transition (Sachs, 2008).

2 THEORETICAL BASIS

2.1 CIRCULAR ECONOMY AND THE TRANSITION FROM THE LINEAR MODEL

The circular economy is a production model based on the regeneration of resources, the reduction of waste and the maximization of the value of materials (Ellen MacArthur Foundation, 2019). As opposed to the linear model — extract, produce, consume, and dispose of — circularity proposes the reuse, recycling, and redesign of production processes, closing material and energy cycles (Geissdoerfer et al., 2017).

Figure 1

Comparison between the Linear and Circular Economy Models

Aspects	Linear Model	Circular Model
Production Flow	Extraction → Production → Consumption → Disposal	Reuse → Reuse → Regeneration → New Cycle
Relationship with Natural Resources	Based on the continuous and finite exploitation of raw materials	Based on renewable use and extending the life cycle of materials

Waste Destination	Final disposal in landfills or incineration	Return of waste to the production process as inputs or energy
Value Focus	Volume and short-term profit	Long-term efficiency, innovation and sustainability
Environmental impact	High, with irreversible losses of resources	Reduced, with regeneration and less pressure on the ecosystem

Source: Adapted from Ellen MacArthur Foundation (2019).

Geissdoerfer et al. (2017) state that the circular economy represents a new paradigm of sustainability, by shifting the focus from waste management to regenerative design. In agribusiness, this approach is essential, as the sector's value chains generate large volumes of by-products that can be reinserted into the processes as productive inputs (OECD, 2011). The reuse of vinasse, filter cake and sugarcane bagasse is a concrete example of circularity, reducing costs and mitigating environmental impacts (Hart & Milstein, 2003).

The bioeconomy complements this paradigm by valuing the sustainable use of biomass and agricultural waste (OECD, 2011). According to the Organization for Economic Cooperation and Development, the bioeconomy is based on the integration of science, technology and innovation to generate value from renewable biological resources, reinforcing the transition to a low-carbon model (Sachs, 2008).

2.2 SUSTAINABLE MANAGEMENT AND CORPORATE GOVERNANCE

Sustainable management involves the systematic incorporation of ethical, environmental, and social principles into business strategy (Barbieri, 2011). Elkington (1997) developed the concept of the *Triple Bottom Line*, according to which organizational performance should be measured by interdependent economic, social and environmental results. This approach broadens the notion of corporate success and drives the adoption of responsible and innovative practices (Hart & Milstein, 2003).

Freeman (1984), with the *Stakeholder Theory*, argues that the company must generate value not only for shareholders, but also for employees, suppliers, the community and the environment. Sustainable management, in this perspective, transforms corporate governance into a mechanism for balancing profitability and social legitimacy (Carroll, 1999).

For Barbieri (2011), companies that internalize environmental practices obtain sustainable competitive advantages, such as risk reduction, increased institutional reputation and access to new markets. Hart and Milstein (2003) add that sustainability is a source of innovation and value, converting environmental constraints into strategic opportunities.

2.3 ESG AND THE INTEGRATION BETWEEN SUSTAINABILITY, INNOVATION AND COMPETITIVENESS

The term **ESG** emerged in the early 2000s, consolidating itself as a conceptual framework for evaluating business performance in three dimensions: environmental, social, and governance. According to **Carroll (1999) and Porter and Kramer (2011),** contemporary companies are increasingly evaluated by their ability to generate shared value — that is, to create economic prosperity while promoting social benefits and reducing negative environmental impacts.

In the **environmental** dimension, indicators such as waste management, carbon emissions, rational use of water and energy efficiency stand out. The **social** dimension involves topics such as working conditions, diversity, inclusion and contribution to local development. The **governance dimension** encompasses corporate ethics, transparency, decision-making structure, and regulatory compliance.

The advancement of ESG in Brazil has been driven by pressure from institutional investors, the growing adoption of international standards, and consumer demand for responsible business practices. According to **B3 (2024),** the number of companies with sustainability reports aligned with the standards of the Global Reporting Initiative (GRI) has grown significantly in the last decade. In agribusiness, the application of ESG gains particular contours, as it combines strict environmental requirements with the need for global competitiveness and traceability of production chains.

The integration between ESG and technological innovation has allowed the emergence of business models based on eco-innovation, defined by **Bocken et al. (2014)** as strategies that reconcile economic performance and environmental benefit. Such practices range from the redesign of production processes and supply chains to the use of clean technologies and digital solutions for environmental monitoring. Thus, sustainability becomes a vector of competitiveness, and not just an instrument of regulatory compliance.

2.4 GREEN INNOVATION AND SUSTAINABILITY IN AGRIBUSINESS

Green innovation, or eco-innovation, consists of the creation and adoption of processes and technologies that reduce environmental impacts and increase resource efficiency (OECD, 2011). Hart and Milstein (2003) state that sustainable innovation is essential to the generation of long-term value, as it allows the development of new markets and business models. In agribusiness, this practice translates into the transformation of waste into productive inputs — such as vinasse into biogas and bagasse into energy biomass (Barbieri, 2011).

The OECD (2011) emphasizes that green innovation contributes to the modernization of production systems and to the strengthening of the bioeconomy. In Brazil, the use of waste such as natural fertilizers and energy sources exemplifies the convergence between competitiveness and sustainability (BNDES, 2024). In this way, agribusiness assumes a leading role in the transition to a low-carbon economy (Sachs, 2008).

In the Brazilian case, practical examples include the use of **vinasse** as a biofertilizer and source of biogas, **filter cake** as a soil conditioner and **sugarcane bagasse** as energy biomass. Such practices not only reduce the use of chemical fertilizers and fossil fuels, but also contribute to the diversification of the sources of revenue for mills and cooperatives. In this way, green innovation reinforces the role of agribusiness as a protagonist of the ecological transition and the low-carbon bioeconomy.

2.5 PUBLIC POLICIES AND REGULATORY FRAMEWORKS FOR SUSTAINABILITY IN BRAZIL

The strengthening of the circular economy and sustainable management depends on coherent public policies and robust regulatory instruments (Brasil, 2010; Brazil, 2017). The **National Solid Waste Policy (PNRS)** — Law No. 12,305/2010 — introduced shared responsibility and reverse logistics, consolidating a legal framework for the environmentally appropriate disposal of waste (Barbieri, 2011). **RenovaBio,** established by Law No. 13,576/2017, promotes the production of biofuels and the commercialization of Decarbonization Credits (CBIOs), integrating energy efficiency and emission mitigation (Brasil, 2017).

Table 2

Public Policies and Green Incentives in Brazil

Policy/Program	Objective / Contribution
RenovaBio	Establishes the National Biofuels Policy (Law No. 13,576/2017), promoting the production and sustainable use of biofuels and the commercialization of Decarbonization Credits (CBIOs), with a focus on reducing greenhouse gas emissions.
ABC+ Plan (Low Carbon Agriculture)	Updated in 2021, it encourages sustainable agricultural practices, such as crop-livestock-forest integration, no-till farming, and organic waste management, aiming at mitigating emissions and adapting to climate change.

National Solid Waste Policy (PNRS)	Established by Law No. 12,305/2010, it defines principles, objectives and instruments for the management and environmentally appropriate disposal of solid waste, based on shared responsibility and reverse logistics.
BNDES Green	Line of financing aimed at environmental innovation, energy efficiency and adoption of clean technologies projects, supporting companies that invest in ecological transition and circular economy.
Climate Fund	Financial instrument to support actions to mitigate and adapt to climate change, coordinated by the Ministry of the Environment, with a focus on renewable energy, sanitation and waste management projects.

Source: Prepared by the authors based on BRASIL (2010; 2017; 2021) and BNDES (2024).

Another relevant instrument is RenovaBio, instituted by Law No. 13,576/2017, which created the Decarbonization Credits (CBIOs) system, a market mechanism aimed at valuing reductions in greenhouse gas emissions in the energy sector (Brasil, 2017). According to the Organization for Economic Cooperation and Development – OECD (2011), policies of this type are part of the new generation of economic instruments to encourage decarbonization and have been essential to promote the sustainable use of biofuels and energy efficiency in agro-industrial chains. Thus, RenovaBio boosts the adoption of sustainable production practices and represents an international reference in programs to encourage the low-carbon economy (Sachs, 2008; Barbieri, 2011).

The ABC+ Plan (Low Carbon Emission Agriculture), launched by the Ministry of Agriculture, Livestock and Supply (MAPA, 2021), also plays an essential role in this process. The program encourages the adoption of sustainable agricultural practices, such as integrated crop-livestock-forestry (ICLFS), no-till farming, biological nitrogen fixation, and organic waste treatment, technologies recognized for reducing emissions and increasing the climate resilience of rural properties (Brasil, 2021; OECD, 2011). These actions reinforce the convergence between technological innovation and sustainability in the field, favoring the rational use of resources and the recovery of degraded areas (Hart & Milstein, 2003).

In addition, financial initiatives such as BNDES Verde and the Climate Fund expand access to credit for environmental innovation, waste management, and energy efficiency projects (BNDES, 2024). According to the Ellen MacArthur Foundation (2019), green financing mechanisms are key to accelerating the transition towards the circular economy, by allowing companies to internalize environmental costs and invest in clean technologies. Such instruments, aligned with the Sustainable Development Goals (SDGs) of the UN 2030 Agenda, highlight the integration between public policy, innovation and competitiveness (Porter & Kramer, 2011; Sachs, 2008).

Together, these institutional frameworks consolidate the regulatory environment necessary for the transition of Brazilian agribusiness to a circular, low-carbon, and socially inclusive economy (Geissdoerfer et al., 2017). Based on them, there has been a progressive advance in the integration between sustainability and business strategy, which stimulates a new organizational culture based on environmental responsibility, operational efficiency and the generation of shared value (Elkington, 1997; Freeman, 1984).

Thus, the reuse of agro-industrial waste is part of a broader context of productive transformation, in which companies and institutions seek to align economic growth, environmental conservation, and social equity (Barbieri, 2011). The theoretical foundation, therefore, supports the analysis developed in this study, by demonstrating that sustainable waste management is an essential element for the consolidation of the circular economy and for the strengthening of the bioeconomy in Brazilian agribusiness (Ellen MacArthur Foundation, 2019; OECD, 2011).

3 METHODOLOGY

The present research adopts a **qualitative** approach, of a **theoretical-conceptual and applied nature**, based on bibliographic review and interpretative analysis. The methodological objective was to identify, systematize and analyze the main strategies for **sustainable management and reuse of agro-industrial waste** from the perspective of **Administration** and **Circular Economy**, considering their impacts on competitiveness, productive efficiency and sustainability of agribusiness organizations.

The choice of the qualitative approach is justified by the exploratory and interpretative nature of the object of study, which involves complex and interdisciplinary phenomena, such as corporate sustainability, green innovation and environmental governance. According to **Gil (2019),** qualitative research makes it possible to understand meanings and relationships between social and institutional variables, allowing the researcher to interpret contexts and practices from multiple theoretical perspectives.

The theoretical-conceptual design was based on a systematic review of the literature, using primary and secondary sources. Recognized scientific databases — **SciELO, Scopus, and Google Scholar** — with a time frame between **2010 and 2025** were consulted, in order to cover both classic contributions and contemporary studies on circular economy, ESG, environmental public policies, and innovation in agribusiness. The descriptors used in the searches were: *circular economy, agro-industrial waste, sustainable management, ESG in agribusiness, bioeconomy, environmental policies,* and *green innovation.*

In addition to the academic literature, **institutional documents and technical reports** issued by national and international reference bodies, including **the Organization for Economic Cooperation and Development (OECD),** the **Food and Agriculture Organization of the United Nations (FAO),** the **National Supply Company (CONAB) and the National Supply Company (CONAB), the National Supply Company (CONAB) and the National Supply Company (CONAB) were analyzed.Ministry of Agriculture and Livestock (MAPA).** These materials provided contextual data and empirical evidence on the generation and reuse of agro-industrial waste in Brazil, as well as on the role of public policies and economic incentives in promoting sustainable practices.

The selection of sources followed the following criteria: (i) thematic relevance in relation to the research problem; (ii) scientific and methodological relevance; (iii) timeliness of publications; and (iv) diversity of analytical perspectives, including economic, managerial and environmental studies. To ensure the rigor of the analysis, the texts were organized into conceptual matrices that related categories such as *productive circularity, sustainable innovation, waste management, operational efficiency,* and *environmental incentive policies.*

The **applied** nature of the research is justified by the potential for practical use of the results, especially for managers and public policy makers who work in the agro-industrial sector. The analysis sought to identify **replicable models and strategies** for waste reuse, capable of contributing to the reduction of environmental impacts and the strengthening of business competitiveness.

Finally, the research is characterized as **descriptive and analytical**, since, in addition to gathering information on the state of the art on the subject, it seeks to interpret and correlate theoretical concepts to the reality of the Brazilian agribusiness production chains. The triangulation between theory, empirical evidence and public policies allowed the construction of an integrated vision, able to subsidize future investigations of a quantitative nature and comparative studies between productive sectors.

4 RESULTS AND DISCUSSION

The management of agro-industrial waste is a strategic field of intersection between **productive efficiency, environmental sustainability and business innovation** (Barbieri, 2011). The literature and sectoral evidence demonstrate that the reuse of agricultural and industrial by-products reduces environmental impacts, diversifies revenues and strengthens the corporate image (Hart & Milstein, 2003). In the context of Brazilian agribusiness, there is a transition from corrective approaches — focused only on waste disposal — to proactive and integrated models, based on **the Circular Economy** and **ESG** (*Environmental, Social and Governance*) governance (Geissdoerfer et al., 2017; Ellen MacArthur Foundation, 2019).

The technical dimension of agro-industrial waste management involves the adoption of technologies and processes that reinsert materials into the production cycle, reducing costs and environmental impacts (OECD, 2011). The sugar-energy sector is exemplary in this regard. Residues such as filter cake and vinasse have been used as biofertilizers and soil conditioners, partially replacing chemical fertilizers (Brasil, 2021). According to Barbieri (2011), the use of organic waste improves the physical structure of the soil, increases fertility and increases moisture retention, in addition to reducing dependence on imported mineral inputs.

Vinasse, in turn, is a liquid effluent rich in potassium and organic carbon. Traditionally considered an environmental liability, it has become a strategic input in the production of biogas and biofertilizers, integrating with the principles of energy reuse and circular economy (Hart & Milstein, 2003). The combined use of vinasse with sugarcane bagasse, used as biomass for energy cogeneration, illustrates the concept of a closed cycle of materials, the central core of circular thinking (Ellen MacArthur Foundation, 2019).

These practices highlight the concept of industrial symbiosis, in which waste from one process becomes inputs for another (Geissdoerfer et al., 2017). According to the OECD (2011), industrial symbiosis is fundamental for sustainable production systems, as it reduces negative externalities and optimizes the use of natural resources. In Brazil, agro-industrial companies have implemented integrated digital fertigation monitoring systems, applying sensors and algorithms to calibrate the use of vinasse, which reinforces the internalization of sustainability as an operational component (B3, 2024).

From an economic point of view, the reuse of agro-industrial waste is a **strategy for creating shared value** (Porter & Kramer, 2011). Well-structured sustainable practices contribute to reducing operating costs, increasing productivity and strengthening the competitiveness of companies (Elkington, 1997). In agribusiness, the replacement of external inputs with reused by-products increases **productive resilience** and **green return on investment (ROI)** (Bocken et al., 2014).

Table 3

ESG indicators applicable to Agro-industrial Waste Management

Dimension	Indicator	Description

Environmental	**Reuse of waste (%)**	It measures the percentage of agro-industrial waste reinserted into production cycles, whether as input, energy or reused by-product. It indicates the degree of circularity and environmental efficiency of the company.
Social	**Green jobs created**	It quantifies the direct and indirect jobs linked to the implementation of circular economy, recycling and sustainable innovation practices in the rural and industrial environment.
Governance	**ESG certifications obtained**	It records the number of sustainability certifications and seals adopted by the organization (e.g., ISO 14001, Bonsucro, ISCC, GRI), reflecting the institutional commitment to good governance practices.
Economic	**Green Return on Investment (ROI%)**	It evaluates the percentage of financial return resulting from sustainability projects, comparing the investments made with the savings generated and the associated reputational gains.

Source: Prepared by the authors based on ESG criteria and Geissdoerfer et al. (2017).

Companies in the sugar-energy sector, such as Raízen, BP Bunge Bioenergia and São Martinho S.A., have stood out in the adoption of circular production models, aligned with the principles of the Circular Economy and ESG (Environmental, Social and Governance) practices (Ellen MacArthur Foundation, 2019; Geissdoerfer et al., 2017). Raízen, for example, implemented the E+ Circular program, aimed at maximizing the reuse of waste and by-products, using 100% of sugarcane bagasse and straw as biomass for energy cogeneration and generating biogas from vinasse — an emblematic case of industrial symbiosis and energy reuse (Raízen, 2023; OECD, 2011).

BP Bunge Bioenergia, in turn, has developed circular economy projects aimed at recycling industrial waste and the energy recovery of organic by-products, integrating technological innovation and corporate sustainability (B3, 2024). São Martinho S.A. it invested in bioenergy units and fertigation systems controlled by artificial intelligence, increasing the efficiency in the use of water resources and nutrients, which reflects the advance of digitalized environmental management practices in agribusiness (Hart & Milstein, 2003; Barbieri, 2011).

These business experiences demonstrate that circularity not only reduces operating costs, but also strengthens environmental, social, and corporate governance (ESG), making it more attractive to sustainable investors and funds (Porter & Kramer, 2011). According to B3 (2024), companies that report ESG indicators in accordance with the standards of the Global Reporting Initiative (GRI) have superior financial performance, especially in sectors of high environmental intensity. This relationship confirms the thesis of Elkington (1997) and Freeman (1984), according to which corporate sustainability and social responsibility are sources of lasting competitive advantage.

In agribusiness, this integration between ESG, technological innovation, and circularity translates into greater access to green credit, BNDES Verde financing lines, and partnerships with international decarbonization programs (BNDES, 2024). The application of circular economy principles also enhances the concept of shared value, in which economic benefit is inseparable from environmental and social benefit (Porter & Kramer, 2011; Sachs, 2008).

By transforming waste into productive inputs, organizations not only save money, but also generate green jobs, strengthen local production chains, and contribute to the Sustainable Development Goals (SDGs), especially SDG 9 (*Industry, Innovation, and Infrastructure*), SDG 12 (*Responsible Consumption and Production*), and SDG 13 (*Action against Global Climate Change*) (UN, 2023; OECD, 2011).

From an environmental point of view, the reuse of agro-industrial waste contributes directly to the mitigation of the negative impacts of intensive agricultural production (Sachs, 2008). The use of filter cake and vinasse as natural fertilizers replaces synthetic fertilizers based on nitrogen and phosphorus, whose production is intensive in energy and CO_2 emissions (Hart & Milstein, 2003). This replacement reduces the carbon footprint of the plants and increases the energy self-sufficiency of the properties (OECD, 2011).

In the social field, the circular economy stimulates the generation of green jobs, a concept defined by the International Labor Organization (*ILO, 2019*) as activities that contribute to the preservation of the environment and economic sustainability. According to Barbieri (2011), waste reuse programs expand opportunities for productive inclusion and technical training in rural communities. In addition, partnerships between companies, universities, and cooperatives strengthen regional development and the dissemination of clean technologies (Brasil, 2021; MAPA, 2021).

The integration between environmental governance, social responsibility, and technological innovation reinforces the notion of systemic sustainability, in which organizational performance is measured by the ability to create shared value among different stakeholders (Freeman, 1984; Elkington, 1997).

Although the advances observed are significant, the consolidation of the circular economy in Brazilian agribusiness still faces institutional, technological, and cultural barriers

(Geissdoerfer et al., 2017). According to Seuring and Müller (2008), the adoption of sustainability practices in supply chains requires cooperation between multiple actors — suppliers, producers, distributors, and the government — and depends on integrated governance structures with standardized performance metrics. This vision reinforces the need to align public policies, technological innovation, and corporate management to ensure the effectiveness of circular practices (Barbieri, 2011).

Among the main challenges, the following stand out: (i) the lack of standardization of circularity indicators; (ii) the scarcity of tax and financial incentives aimed at small and medium-sized producers; (iii) the lack of technological infrastructure for the reuse of waste on a large scale; and(iv) the need for technical training of managers and rural workers for the adoption of sustainable practices (OECD, 2011; Sachs, 2008).

At the institutional level, public policies such as RenovaBio, the ABC+ Plan, and the National Solid Waste Policy (PNRS) have contributed to creating a regulatory environment that is more favorable to the ecological transition (Brasil, 2010; Brazil, 2017; MAPA, 2021). However, there is still a gap between normative formulation and practical implementation, especially in small and medium-sized rural properties (BNDES, 2024). Bureaucratic complexity, limited credit in certain regions, and the difficulty of measuring environmental results are factors that restrict the reach and effectiveness of these programs (Barbieri, 2011; Hart & Milstein, 2003).

Despite these limitations, there is a growing movement of integration between the public and private sectors, with emphasis on the strengthening of Decarbonization Credits (CBIOs) and environmental certifications (Ellen MacArthur Foundation, 2019). According to Geissdoerfer et al. (2017), such market instruments are essential to stimulate sustainable competitiveness, by converting environmental benefits into economic advantages. In addition, the participation of research institutions, such as Embrapa and public universities, has been decisive in the development of technologies aimed at the reuse of waste, such as accelerated composting, compact biodigesters, and biochar, reinforcing the articulation between science and management (OECD, 2011; Sachs, 2008).

The strengthening of public-private partnerships and the encouragement of open innovation are promising ways to overcome structural barriers (Hart & Milstein, 2003; Porter & Kramer, 2011). The promotion of sustainable local productive arrangements (LPAs) makes it possible to optimize the use of agricultural and agro-industrial waste on a regional scale, creating productive ecosystems based on cooperation and circularity (Barbieri, 2011; Sachs, 2008). According to the Ellen MacArthur Foundation (2019), the consolidation of these cooperative systems represents the most advanced stage of the circular economy, in which technological innovation, social capital, and environmental governance are intertwined to promote a low-carbon, high-value-added productive transition.

Table 4

Maturity Levels of Agroindustrial Circularity

Level	Description	Key features
Level 1 – Minimum Environmental Compliance	Basic compliance with environmental legislation and timely adoption of corrective practices.	Reactive actions, focus on damage control and regulatory compliance.
Level 2 – Operational Efficiency and Waste Reduction	Implementation of processes aimed at energy efficiency and reduction of production losses.	Improvement of internal processes, rational use of resources and emission control.
Level 3 – Integration of Circular Processes	Insertion of waste reuse and reuse practices in production routines.	Reintegration of materials and by-products, energy generation from biomass and use of clean technologies.
Level 4 – Sustainable Innovation and ESG Certifications	Consolidation of sustainability as a business strategy and adoption of recognized certifications.	Investments in R&D, corporate transparency and integration between environmental, social and governance dimensions.
Level 5 – Leadership and Sectoral Dissemination	Acting as a reference in circular economy, with a positive impact on suppliers and public policies.	Institutional leadership, dissemination of good practices and influence on production chains and markets.

Source: Prepared by the authors based on Geissdoerfer et al. (2017).

The **integrated analysis of technical, economic, social and institutional factors** demonstrates that the **sustainable management of agro-industrial waste** is more than an environmentally correct practice – it represents an **instrument of productive and strategic transformation** (Barbieri, 2011; Hart & Milstein, 2003). The **circular economy,** by **reconfiguring the relationships between production and consumption**, challenges linear business models and drives a logic of **systemic and regenerative innovation**, in which waste is understood as a resource and not as a waste (Ellen MacArthur Foundation, 2019; Geissdoerfer et al., 2017).

Companies that **internalize sustainability** as an operational and strategic principle start to operate at a **new competitive level**, characterized by **cost reduction**, **strengthening institutional reputation** and **expanding access to sustainable** markets(Elkington, 1997; Porter & Kramer, 2011). This transition is associated with the creation of shared value, in which economic performance is directly linked to the generation of social and environmental benefits (Freeman, 1984; Carroll, 1999).

In the context of **Brazilian agribusiness**, such a movement is not limited to a response to regulatory and environmental pressures, but is configured as a **strategic opportunity for international repositioning**, especially in the face of a global scenario that values **low-carbon practices, productive traceability, and efficiency in the use of natural** resources (Sachs, 2008; OECD, 2011). By adopting circularity and sustainable governance policies, the agro-industrial sector aligns itself with the **decarbonization and ecological transition** trends promoted by instruments such as **RenovaBio** and the **ABC+ Plan** (Brasil, 2017; MAPA, 2021).

Thus, the discussion shows that the **management of agro-industrial waste**, when structured under the principles of **circular economy** and **ESG governance**, constitutes a **vector of innovation, competitiveness and sustainability**, capable of aligning **economic development and environmental conservation** (Geissdoerfer et al., 2017; Ellen MacArthur Foundation, 2019). The challenge, however, lies in **consolidating institutional, economic, and cultural mechanisms** that sustain this paradigmatic shift and ensure the **continuity of circular practices** in Brazilian production chains (Barbieri, 2011; Sachs, 2008).

Figure 1

Integration between ESG, Innovation and Competitiveness in Agribusiness

Conceptual flow:

ESG (Environmental, Social and Governance)

⬇

Green and Technological

⬇

Innovation Operational Efficiency and Sustainable Resource

⬇

Management Sustainable Competitiveness and Shared Value

Source: Prepared by the authors (2025).

The model illustrates the synergistic relationship between **ESG governance, green innovation, and business competitiveness** in agribusiness. The adoption of environmental, social, and governance practices acts as a catalyst for technological innovation, which, in turn, increases production efficiency, reduces costs, and increases the socio-environmental value generated. This cycle strengthens the sustainable competitiveness of organizations and their insertion in low-carbon markets.

The effective incorporation of circular economy principles in agro-industrial production chains requires coordinated action between business managers, public policy makers, and research institutions (Geissdoerfer et al., 2017; Ellen MacArthur Foundation, 2019). This transition goes beyond the adoption of reuse technologies, implying a profound reconfiguration of management practices, governance mechanisms, and regulatory instruments that guide the sector (Barbieri, 2011). In this context, sustainability should be understood as a strategic axis of organizational management and not only as an environmental requirement, being integrated with business planning, risk management and green innovation (Elkington, 1997).

From a managerial point of view, companies that internalize sustainability as an operational principle incorporate performance indicators related to emissions, energy efficiency and waste reuse in their evaluation systems (OECD, 2011). According to Hart and Milstein (2003), the commitment of senior management is decisive to transform sustainability into a vector of competitive and reputational advantage. Such engagement creates a corporate culture guided by ethical and socio-environmental values, increasing operational efficiency and favoring the innovation of processes and products. In this way, sustainability ceases to represent an additional cost and becomes a long-term strategic asset (Porter & Kramer, 2011).

At the institutional level, the consolidation of the circular economy depends on coherent public policies and economic incentive mechanisms (Brasil, 2010; Brazil, 2017). Instruments such as the Decarbonization Credits (CBIOs), provided for in RenovaBio, and BNDES' green financing lines have proven to be fundamental to stimulate investments in clean technologies and energy efficiency (BNDES, 2024). The National Solid Waste Policy (PNRS) and the ABC+ Plan (Low Carbon Emission Agriculture) also play a structuring role, by introducing the principles of shared responsibility, reverse logistics, and emission mitigation through sustainable agricultural practices, such as the use of biodigesters and organic composting (MAPA, 2021; OECD, 2011).

Public management can further strengthen the circular economy by adopting smart environmental regulation policies and encouraging sustainable certifications, such as ISO 14001, Bonsucro and ISCC (Sachs, 2008). These certifications function as instruments of governance and transparency, establishing verifiable standards of environmental and social performance (Porter & Kramer, 2011). Its adoption increases the credibility of organizations, facilitates access to international markets, and contributes to the consolidation of a low-carbon economy (Ellen MacArthur Foundation, 2019). In addition, the articulation between public policies, financial incentives and certification standards promotes multilevel environmental governance, articulating government, the productive sector and civil society (Elkington, 1997; Barbieri, 2011).

Finally, the integration between the public sector, private companies and educational and research institutions is an indispensable condition for strengthening a competitive and sustainable bioeconomy (Sachs, 2008). Inter-institutional collaboration allows the development of technologies adapted to regional realities, the training of qualified professionals and the dissemination of technical knowledge (Geissdoerfer et al., 2017). Universities and research centers, such as Embrapa, play a strategic role in the generation and transfer of innovations, acting as a link between science, market, and society (Brasil, 2021). Thus, the managerial and political implications of the circular economy transcend the technical sphere and configure a new model of environmental governance, in which sustainable performance becomes an essential element of competitiveness and organizational legitimacy (Freeman, 1984; Hart & Milstein, 2003).

5 FINAL THOUGHTS AND FUTURE PERSPECTIVES

The present research showed that the **reuse of agro-industrial waste** is one of the **structuring axes of sustainability in contemporary agribusiness.** The theoretical-empirical analysis demonstrated that the incorporation of the **principles of circular economy and sustainable management** promotes the transition from a linear model — based on extraction, transformation, and disposal — to a **regenerative and innovative model,** capable of adding economic, social, and environmental value (Ellen MacArthur Foundation, 2019; Geissdoerfer et al., 2017). In this context, the reuse of agricultural by-products, such as **filter cake, vinasse and sugarcane bagasse**, goes beyond waste management, configuring itself as **a systemic innovation strategy** that transforms environmental liabilities into productive assets and strengthens the competitiveness of the sector (Barbieri, 2011).

Sustainability, when internalized as **a management principle**, ceases to be an additional cost and becomes a **factor of perpetuity and social legitimacy** (Elkington, 1997; Hart & Milstein, 2003). The integration between technology, governance and socio-environmental values stimulates process, product and business model innovations (Porter & Kramer, 2011). In Brazilian agribusiness, this convergence translates into **productive**

efficiency, cost reduction, and access to sustainable markets, reinforcing the country's role as a protagonist of the **global ecological transition** (Sachs, 2008; OECD, 2011). Experiences of companies such as **Raízen, BP Bunge Bioenergia and São Martinho S.A.** prove that **circular models** increase profitability, optimize the use of natural resources, and increase attractiveness to investors and consumers (B3, 2024).

The results of this study confirm that the adoption of **circular practices** depends on a robust institutional base and articulated public policies. Instruments such as **RenovaBio,** the **National Solid Waste Policy (PNRS)** and the **ABC+ Plan (Low Carbon Emission Agriculture)** create conditions to integrate **technological innovation, environmental regulation and economic incentives** (Brasil, 2010; Brazil, 2017; MAPA, 2021). The consolidation of these policies, associated with **the Green BNDES** and climate credit programs, strengthens environmental governance and expands investment in clean technologies (BNDES, 2024). However, **structural challenges persist**, such as the absence of standardized circularity metrics, the limitation of credit in peripheral regions, and the difficulty of technological diffusion among small and medium-sized producers (Seuring & Müller, 2008).

Overcoming such barriers requires **strengthening cooperation between the State, the productive sector and research institutions** (Sachs, 2008). The creation **of clear and verifiable performance indicators,** based on tools such as **life cycle analysis (LCA)** and **material flow mapping (MFA),** is essential to measure the degree of circularity of production chains and guide strategic decisions (OECD, 2011). The use of **digital technologies**, such as remote sensing, artificial intelligence, and *big data*, increases **traceability and transparency**, consolidating evidence-based management practices (Geissdoerfer et al., 2017).

In addition, the consolidation of **environmental certifications and ESG standards — such as ISO 14001, Bonsucro** and **ISCC —** is an essential element of **governance and international credibility** (Porter & Kramer, 2011). By establishing measurable performance parameters, these certifications bring Brazilian agribusiness closer to the requirements **of global low-carbon markets** and reinforce companies' commitment to the **Sustainable Development Goals (SDGs)** of the 2030 Agenda (UN, 2023). The adoption of certified management systems increases the confidence of investors and consumers, converting sustainability into a competitive advantage (Elkington, 1997).

From an academic and scientific point of view, the research contributes to the **deepening of the debate on sustainability and competitiveness in agribusiness,** reaffirming that contemporary business performance must consider **economic, social and**

environmental dimensions in an integrated way (Freeman, 1984; Barbieri, 2011). Future studies can advance in the **quantification of the economic and environmental impacts of circularity**, in **the evaluation of the effects of ESG certifications on financial performance,** and in the analysis of **the dynamics of multilevel governance,** involving the interaction between municipalities, states, and the Union. Interdisciplinary approaches that unite **economics, administration, engineering, and public policy** tend to strengthen the field and **applied bioeconomy,** providing evidence for more effective and inclusive regional policies.

The results confirm that **the reuse of agro-industrial waste** is a strategic vector of **innovation, competitiveness and sustainability.** By integrating the principles of **circular economy, sustainable management**, and **bioeconomy, Brazilian agribusiness** positions itself as a protagonist in the transition to a low-carbon, **high-efficiency production system.** This trajectory, however, depends on **the continuous engagement between science, management and governance,** supported by integrated public policies and permanent environmental education (Sachs, 2008; Barbieri, 2011). Transforming waste into resources and challenges into opportunities is the way to build a circular and inclusive agro-industrial model, capable of balancing **economic growth, environmental conservation, and social equity,** contributing to the achievement of the **Sustainable Development Goals** and the consolidation of an **innovative and competitive bioeconomy.**

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