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Producing with sustainability: A study on circular practices in a rural property in Brazil

Produzir com sustentabilidade: Um estudo sobre práticas circulares em uma propriedade rural no Brasil

Producir con sustentabilidad: Un estudio sobre las prácticas circulares en una propiedad rural en Brasil

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ABSTRACT

The study aimed at identifying sustainable production practices on a rural property in Mato Grosso, Brazil from the perspective of the Circular Economy. The approach in the form of a single case study involved a location whose main activity is the production of grains and adopted qualitative data obtained through structured interviews with managers of the production units, observation and documentary research. The results show that, although sustainable production practices are adopted, there is room for advances. The study contributes by reporting sustainable production practices that can be related to circular agriculture, which has as the main goal the efficient and effective use of productive resources. At the end, 11 Circular Economy elements directed to agriculture are listed.

Keywords: sustainable agriculture; circular practices; rural properties; grains production; sustainability.

RESUMO

O estudo teve como objetivo identificar práticas sustentáveis de produção de uma propriedade rural em Mato Grosso, Brasil sob a ótica da Economia Circular. A abordagem na forma de estudo de caso único envolveu um local cuja atividade principal é a produção de grãos e adotou dados qualitativos obtidos via entrevistas estruturadas com gestores das unidades de produção, observação e pesquisa documental. Os resultados evidenciam que embora sejam adotadas práticas sustentáveis de produção, há espaço para avanços. O estudo contribui ao relatar práticas de produção sustentáveis que podem ser relacionadas à agricultura circular, a qual visa o uso eficiente e eficaz dos recursos produtivos. Ao final são elencados 11 elementos de Economia Circular direcionados à agricultura.

Palavras-chave: agricultura sustentável; práticas circulares; propriedades rurais; produção de grãos; sustentabilidade.

RESUMEN

El estudio tuvo como objetivo identificar prácticas sostenibles de producción en una propiedad rural en Mato Grosso, Brasil, desde la perspectiva de la Economía Circular. El enfoque, en forma de un estudio de caso único, involucró un lugar cuya actividad principal es la producción de granos y se basó en datos cualitativos obtenidos a través de entrevistas estructuradas con los gestores de las unidades de producción, observación e investigación documental. Los resultados muestran que, aunque se adoptan prácticas sostenibles de producción, todavía hay espacio para mejoras. El estudio contribuye al informar sobre prácticas de producción sostenibles relacionadas con la agricultura circular, la cual busca el uso eficiente y efectivo de los recursos productivos. Al final se enumeran 11 elementos de Economía Circular dirigidos a la agricultura.

Palabras clave: agricultura; sostenible; prácticas circulares; propiedades rurales; producción de granos; sostenibilidad.

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1 INTRODUCTION

The concept of Circular Economy (CE) presents several definitions of different authors and it is evolving along the years. Its recent rise is due to the urgency of reducing the environmental pollution, which is resultant from the greenhouse gasses emission (Ghisellini et al., 2016). An economy based on circular practices constitutes a solid base to consolidate the environmental development of cities and countries and the world society (community) for its contribution to reach both the Sustainable Development Goals (SDGs) on the United Nations 2030 Agenda for Sustainable Development and the Paris Agreement (Aponte, 2022).

The Circular Economy is a model of economic development to maximize the use of resources and protect the environment (Wei et al., 2014). The idea is not new, and it is associated to a series of concepts with emphasis on the optimization of the productive resources in a system along the time (House of Commons, 2014).

Regarding the scope of Circular Economy, Aponte (2022) found that, before the variety of definitions, these ones are characterized by three principles in common: to eliminate the waste and the pollution from the conception, to maintain products and materials in use and to regenerate natural systems. It is a type of economy with a closed loop of material flow, which is the opposite of the traditional one, open circuit of materials (Su et al., 2013). It has the potential to overcome the current environmental problems and resources management, while encouraging the development of a conservation-oriented society, seeking to reduce consumption and the waste production (Geng et al., 2009; Lleder & Rashid, 2016).

Among the sectors with the greatest opportunities in the circular economy, Aponte (2022) highlights the food sector in terms of solutions which enable the farmers to make the transition to regenerative agricultural production. Velasco-Muñoz et al. (2021) mention the importance for the food security sector and the current predominance of the linear models of production.

Some efforts have already been observed in approaching the Circular Economy (CE) in agriculture, as well as the existence of a concept of Circular Agriculture (CA) that, according to the United Nations Department of Economic and Social Affairs Economic Analysis (UN/DESA, 2021), discusses the unsustainability of the world production of food and due to this, the need of adopting circular practices in agriculture. An example of circularity in the agriculture practice is the use of manure as an organic fertilizer and the use of wastewater in irrigation, which contributes to reducing the amounts of external inputs, closing nutrients cycle, regenerating the soil and minimizing the impact on the environment (UN/DESA, 2021).

UN/DESA (2021) still highlights that there is the need for a broad set of policies, technologies and institutions engaged in the adoption of circular practices in agriculture. In this aspect, Basso et al. (2021) points out that Brazil, a

great grain producer, needs to advance, considering that, unlike some other countries, do not have policies aimed at circular practices for grain production.

In view of the above mentioned, it is possible to notice that, if on one hand this approach is relevant and urgent, on the other hand, there are few studies that discuss it, both in the theoretical and empirical fields. In a systematic review carried out in October 2021, in the Scopus and Web of Science bases, 702 articles were located for the terms “circular economy”, “agriculture”, “crop-livestock” and “sustainability”. After reading the title and abstract, considering the protocol adopted for the systematic review of the literature regarding the contribution of the studies: very high, high, low and very low, 7 articles were selected because they have a high contribution, that is, relation with the themes Sustainability and Circular Economy (CE) in agriculture, and two of these ones were theoretical studies that support the data collection of this research. Due to the fact that empirical studies analyze. It was noticed in the review carried out, a significant number of empirical studies, however the focus on sustainable agriculture and CE was based on urban agriculture-growing/cultivation of vegetables and/or fruits. Due to the fact that the empirical studies did not address the CE in the large-scale production of grains, it was deemed pertinent to discuss empirically the theme, having as a basis two theoretical studies, that of Basso et al. (2021) involving the dynamics of the CE in a rural property of Mato Grosso, and therefore, contribute to the discussion of the theme/topic based on the empirical data.

The pertinence of this study is due to the perspective brought by the CE in the face of the demand for food production, in a sustainable way, which will be increasingly demanded in the Brazilian context, given its representativeness as the world's largest food supplier. In addition to the need of such an approach, in the aforementioned context, empirical studies contribute for a better understanding of this phenomenon, considering the scarcity of this type of study on the subject. In view of the above mentioned, the main objective of this study was to identify sustainable practices of production, in a Brazilian rural property which produces grains, located in Campo Novo do Parecis-MT, municipality/town which ranks as the sixth soy producer in Brazil, according to data from the Brazilian Institute of Geography and Statistics (IBGE) 2020.

2 THEORETICAL REFERENCE

2.1 Agriculture and Sustainability

The transition to a development paradigm focused on sustainable and resilient production, impacts the global economy. Perspectives called circular economy (CE), collaborative economy, creative economy, green economy and bioeconomy redesign the old economy and suggest alternatives aimed at low-carbon to respond to the erosion of the relationship between humanity and nature (Lopes, 2015).

CE has recently gained worldwide attention as an alternative to overcome the current production and consumption model based on continuous growth and resources use. The adoption of a production format that closes the cycle within a system makes the use of resource production more efficient, consequently generating a balance among economic, environmental and social factors (Lopes, 2015; Ghisellin et al., 2016). The CE overcomes the “take, make and discard” model for optimizing the use of materials for over one cycle (Nguyen, Stuchtey & Zils, 2014).

CE aims at increasing the efficiency of the resources use, whether extending the useful life of products or reusing resources and leftover materials (Sehnm et al., 2019), thus reducing the use of natural resources and environmental impacts derived from economic activities (United Nations Environment Programme [UNEP], 2018; Bibas, Chateau & Lanzi, 2021). The rational use of the production resources allows the economic growth to be uniquely dependent on the growing consumption of new resources as Ellen Macarthur Foundation points out (EMF, 2015). According to EMF (2015), the transition to a model of CE requires the adoption of actions related to regeneration of the Earth's biocapacity; sharing of goods, resources and products; optimization in the performance of products and processes; circulation of goods, resources and virtualization of products and change of materials, (EMF, 2015; Rosa et al., 2019; Jabbour et al., 2019).

The idea of CE is not new and it is associated with several concepts which emphasize the importance of optimizing the resources used in a system along the time and includes a variety of processes, or cycles, in which the resources are used repeatedly. (House of Commons, 2014). It constitutes a sustainable development strategy based on the best use of materials and energy (Su et al., 2013). It is a model of economic development that maximizes the use of resources and protects the environment (Wei et al., 2014), based on the philosophy “win-win” (everyone wins) in which a prosperous economy and a healthy environment can coexist (Tukker, 2015). Different from the traditional linear economy (make, use, discard), resources are extracted at their maximum value during use (Byars, Morales & Zhu, 2004).

The global scenario of attention to food production, leads to the economic and political importance (regulation, protection) of the sector and the growing challenge of agriculture/cattle raising, with implications for the direction of innovation from this sector (Sehnm et al., 2022). Agricultural and food systems seem to distance themselves from the circular ones, once that less than 2% of the reused nutrients is recycled, the rest is released in the environment as pollutants (EMF, 2015). Taking the CE approach, the role of innovation has been highlighted concerning its importance in this transition, as a factor capable of generating disruption and reformulation, creating infrastructure and alternatives to promote new ways in producing goods, waste management, retention of values in

productive processes or in commercialization and interaction with consumers, and in obtaining information that support the necessary changes (Sehnm et al., 2022).

Research directions on how innovation leverages CE range from the need to understand more about the dynamics of implementing and operating circularity to how to monitor and control to maintain circularity. The studies also involve several areas of knowledge. Studies in technical areas discuss solutions for eliminating waste products from agricultural production and their integration in CE, such as exploring the concept of a biological and biodegradable base for the production of sustainable materials and allowing the use of biopolymers for EC (Platnieks et al., 2020).

2.2 Circular agriculture

Given this scenario, the public sector needs to develop strategies aimed at CE and promote cooperation between technology and innovation developers and users, as well as design financing plans and incentives to facilitate the implementation of these actions (Aznar-Sánchez et al., 2020). Actions in this direction, however, are recent. An example is the case of the Netherlands, where the Ministry of Agriculture adopted Circular Agriculture (CA), presenting perspectives for achieving sustainability in agriculture. CA in practice develops consistent policies for farmers, who receive clear guidance and monitoring (Dagevos & Lauwere, 2020).

Although grain production should be a target for circular economy strategies, there are limitations. Aznar-Sánchez et al. (2020) point out barriers to the implementation of circular actions, among which economic limitations stand out. Both the development and the use of sustainable materials demand high investments and increased costs that must be assumed by the sector. However, both producers and technology developers tend to prioritize investments that improve the efficiency of the production process, leaving in the background those that do not generate immediate benefits. For Zucchella and Previtali (2019), there are factors related to the orchestration and relationships among actors in an ecosystem that influence the development models of circular business in agriculture.

Unlike the Netherlands, in grain production systems in the United States, China, Brazil, Argentina, Canada, Russia, Australia and Europe, there is a lack of policies aimed at circular practices with long-term benefits for society and the environment (Basso et al., 2021).

Velasco-Muñoz et al. (2021) highlight that given the scarcity of resources, world climate change, environmental degradation and growth demand for food, the circular economy presents itself as a strategy to support sustainable, restorative and regenerative agriculture. The authors reinforce that it is necessary to adapt the CE reference for the agricultural field and propose a definition for the CE focused on agriculture as follows: The set of activities aimed not only at ensuring economic, environmental and social sustainability in agriculture

through practices aimed at the efficient and effective use of resources at all stages of the value chain, but also at guaranteeing the regeneration and biodiversity of agroecosystems and surrounding ecosystems.

Another definition of circular agriculture comes from Wageningen University Research (WUR), 2018: It is a collective quest by farmers, concerned citizens, businesses, scientists and researchers for the ideal combination of ecological principles and modern technology, with new partnerships, new economic models and reliable social services. It not only focuses on good yields and the economical use of resources and energy, but also emphasizes the importance of putting as little pressure as possible on the environment, nature and climate.

Considering that areas for agriculture are finite resources, crops will be used for successive harvests throughout the year, and whenever possible with mixed crops that vary in species. The plants will serve dual purposes as food, while the remains (leaves and stems) will serve as raw material for livestock or biofertilizers to improve the soil. Farmers will also make the most of the agrobiodiversity of the soil with mixed cultivation systems and will also be able to use new forms of mechanization and precision technologies, with the aid of sensors and robotics (WUR, 2018)

In this sense, Poponi et al. (2022) realize that actions should be directed to the agri-food sector that enable the transition to a sustainable development model, guided by the CE principles. This is in line with what the UN points out about the focus on alternatives that reduce the impact of land use by agriculture (such as the practices of integrating crops and livestock), impacts that are responsible for 30% of global emissions of greenhouse gasses. (UN/DESA, 2021).

2.2.1 Circular practices in agriculture

CE adoption in the grain production goes through the optimization of the agrochemical and energy inputs necessary for the cultivation and that represent a significant part of the production cost, as well as they reduce the environmental impact. The precision farming technologies have been present in the last three decades and allow the use of inputs rates accurately, which favors the circularity of the productive resources. When it comes to agriculture, this is favored by the adoption of digital agricultural technologies, regenerative practices, new genetics, robotics, among others (Basso et al., 2021).

Innovations provide farmers with options for managing the land and crops and are instrumental in facilitating the transition to more circular grain production. In this sense, Basso et al. (2021) highlight the main technologies (current, medium and long term) grouped into five main areas with the capacity to impact on improving circularity: a) Digital agriculture technologies to optimize decisions about the use of land and resources; b) Recycling of energy, water and nutrients on the farm; c) Autonomous

systems for the use of precision resources; d) Biological and genetic improvements to narrow nutrient and energy cycles and e) Incentives for the adoption of technologies that enable the circular economy. Below, there are some examples in each of the areas:

- a) Digital agriculture (AD) technologies to optimize land and resource use decisions: production maps; weather forecast; internal ecological processes to replace inputs (eg natural predators); ideal harvest time (harvesting with high humidity results in more energy to dry the grain); efficiency in the use of fertilizers, pesticides, plant populations; choosing the right land area to produce grains and the low yielding and unprofitable areas for alternative plantations (pollinator habitat or tree plantations for bioenergy or cellulose);
- b) Recycling of energy, water and nutrients on the farm: recycling of water and generation of renewable energy on the farms (solar energy and use of animal manure);
- c) Autonomous systems for the use of precision resources: autonomous systems allow decision-making regarding the use of inputs in real time; smaller, lighter or airborne equipment saves fuel or electricity, will minimize soil compaction (which allows for better water retention, crop root penetration), reduced runoff of water and nutrients; improved pesticide and nutrient efficiency with site-specific on-demand spraying; electrification (electric tractors) zero emission agricultural equipment; automatic action due to the replacement of human labor, will make it an attractive option for land managers;
- d) Biological and genetic improvements to narrow/decrease nutrient and energy cycles: plant varieties with deeper roots (optimizes water and nutrient absorption); plants more resistant to diseases (less use of agrochemicals for crops and cattle); biological or microbial products can fix more nitrogen in the roots, manufacturing inorganic N (reduces the need for chemical fertilizers); microbial biostimulants that reduce the use of synthetic fertilizers;
- e) Incentives for technologies that enable the circular economy: the adoption is fast and widespread when it becomes evident that a new technology is more productive and profitable compared to the previous one. Thus, the transition from linear to circular agricultural systems requires incentives for investments and the formulation of strategies for their adoption in the agricultural area.

Although digital and mechanical technologies can improve the economic efficiency of circular systems, farmers must be convinced of their superior economic performance before investing. In this sense, government

policies can favor profitability in benefits of circular systems. For example, agricultural policies to deal with environmental impacts such as: conservation programs with subsidies for the adoption of practices that reduce soil erosion, air and water pollution (which can be used to encourage circular practices); “carbon bank” climate policy that would pay farms to reduce Greenhouse Gas (GHG) emissions; allocation (compensated) of unproductive areas for ecosystem services; establish standards for circular and sustainable practices (organic labeling and certification) and establish reliable links between consumers and producers (Basso et al., 2021).

The approach provided by Basso et al. (2021) regarding innovations favorable to the transition to more circular grain production: a) Digital agriculture technologies to optimize decisions about land and resource use; b) Autonomous systems for the use of precision resources; c) Biological and genetic improvements to narrow/reduce nutrient and energy cycles; d) Recycling of energy, water and nutrients on the farm and e) Incentives for the adoption of technologies that enable the circular economy, is complemented here by Poponi et al. (2022). The perspective of the latter derives from a review of the literature on circular economy in agriculture and includes elements such as water consumption, energy, specific indexes of productive activity, among others, considered as indicators of the “environmental” area. In terms of “economy”, they include indicators, including profit and productivity, profitability and investment performance. In the “social” area, they point out that although they are scarce in the literature, they deal with qualitative analysis related to human well-being.

As for the scope of sustainability areas, Poponi et al (2022) list, based on Kristensen and Mosgaard (2020), three levels: a) macro, involving indicators to assess aspects related to the agro-food production of a country, region or city; b) meso, dealing with indicators that measure aspects of production in an eco-industrial park and c) micro, referring to aspects related to the production of a company or an individual product.

In terms of scope, which refers to the context in which the indicator is applied, the authors point out 8: a) air, b) water, c) soil, d) energy, e) waste, f) scope of cost, value and productivity, g) equality and h) knowledge and innovation, and in them the definition and some elements that can be verified qualitatively. Next, each of the scopes is defined, based on Poponi et al. (2022):

- a) Air: involves more general indicators such as the effect on climate change and risks associated with human health, as well as more specific ones, including the potential damage of chemical products released into the environment.
- b) Water: contamination, toxicity and preservation of water. It includes, among others, indicators regarding the use of water for irrigation and its exploitation.

- c) Soil: involves management, organic production and biodiversity, use of fertilizers, pesticides or organic materials, proportion of land that is degraded over the total land area, biodiversity: birds, insects, animals and soil quality.
- d) Energy: Refers to the use of energy, sustainable production and energy in the total production/use of energy from non-renewable sources. Example: wood fuel production, renewable energy: source and capacity.
- e) Waste: relates to how the various types of waste are managed, whether waste is sent to landfill and food waste.
- f) Cost, value and productivity: it has to do with quantifying the cost of production, the economic value generated and the result indicators demonstrating the efficiency of the system over time.
- f) Equality: addresses social inclusion, healthy and enough food, safety and respect for human rights;
- g) Knowledge and innovation: deals with training people, knowledge and innovation and investment in new technologies.

3 METHODOLOGY

Considering the approach proposed in this study based on Basso et al. (2021) who highlight the main technologies capable of contributing to circularity in production and the scopes pointed out by Poponi et al. (2022), the case study strategy was chosen and the use of primary and secondary qualitative data, analyzed in an interpretative way. The choice made it possible to establish relationships between the findings and the theoretical assumptions related to CE and sustainability in the agricultural context (Vieira, 2004; Collis & Hussey, 2005). The exploratory purpose of this research, to qualitatively analyze a phenomenon, becomes relevant in the face of a topic that is still little explored (Yin, 2010).

In this research, a single case was chosen, which provided the basis for the theoretical discussion in the face of empirical evidence (Eisenhardt & Graebner, 2007; Yin, 2010) to understand the phenomenon that involves the circular economy in a rural property, which has as a main activity the integrated cultivation of agriculture (soy and corn) and livestock. The place under study began its activities in 1989 in the town of Campo Novo do Parecis - MT and in 2022, in addition to agriculture and livestock, it operates in the areas of forestry and storage. The fact that the rural property is recognized in its area of operation due to the awards and certificates received, both at state and national level, was considered relevant for the choice of case in approaching the topic in question.

The summary of the organization of data collection and its adopted sources can be consulted in Table 1. Data collected in documents available for physical access and on the company website were analyzed, in addition to semi-

structured interviews and on-site observations. The data collection script was based on Basso et al. (2021), regarding the technologies used to promote circular agriculture, and in Poponi et al. (2022) concerning the scope of sustainability in agriculture related to the circular economy.

Semi-structured interviews were conducted with company managers between March 24th and 28th, 2022 via Google Meet. They lasted on average between 50 min and 60 min, after which the relevant data were transcribed in full and extracted. The following were interviewed: a livestock manager (interviewee 1-E1) and another from the agricultural sector (E2), who were chosen because they are in charge of the two main productive activities of the rural property. However, it was necessary to complement the information with other informants, interviewing other

individuals from the support sectors, in this case the warehouse manager (E3) about energy produced by firewood and photovoltaics, and the supply manager (E4) about waste generated and their final destination.

For the documentary research, data was collected from the Program for Rewards for Results (PPR) - Harvest 2021-2022, and from the reports of projects/actions developed by the company, sent by email by the farm managers, on the three scopes proposed by Poponi et al (2022): “cost, value and productivity scope”, “knowledge and innovation” and “equality”. Complementary data on “equality” were also collected through an interview with the human resources manager (E5), as well as on-site observations and readings in other company reports, available for on-site access.

Table 1
Theoretical support and sources for data collection.

Analysis categories	Considered Elements	Source of Data
Technologies for circular agriculture (Basso et al., 2021).	Main grouped technologies capable of impacting the improvement of circularity (current, medium and long term): a) Digital agriculture (DA) technologies to optimize land and resource use decisions. b) Autonomous systems for use of precision resources. c) Biological and genetic improvements to reduce nutrient and energy cycles. d) Recycling of energy, water and nutrients on the farm. e) Incentives for the adoption of technologies that enable the circular economy.	*Semi structured interview. *Observation.
Scopes for Sustainability in agriculture (Poponi et al., 2022).	a) Air: effect on climate change and associated risks to human health. b) Water: contamination, toxicity and preservation of water. c) Soil: management. Organic production and biodiversity, to the use of fertilizers and pesticides or organic materials. d) Energy: Energy Use. Sustainable Energy Production in Total Production/Use of Energy from Non-Renewable Sources. e) Waste: how waste is managed. f) Scope of cost, value and productivity. Quantify the cost of production, the economic value generated and the result indicators – show the efficiency of the system over time. g) Equality: social inclusion, healthy and enough food, safety and respect for human rights. h) Knowledge and innovation: training people, knowledge and innovation. Investment in new technologies.	*Semi structured interview. *Observation. *Semi structured interview. *Documentary research. *Observation.
Characterization of the rural property	a) History of the rural property. b) Productive activities.	*Documentary research.

Source: Elaborated by the authors, based on Basso et al (2021) and Poponi et al (2022).

The data derived from the mentioned sources were analyzed using the content analysis technique (BARDIN, 2004), highlighting the empirical elements that were later discussed in the light of the approach on CE and sustainability in agriculture.

4 ANALYSIS AND DISCUSSION OF RESULTS

4.1 Characterization of the analyzed case

The data obtained from the company's website indicate that it is a family business that started its activities in 1989, and completed 33 years of existence in 2022. It has a fixed staff of 80 people distributed by the sectors they call: agriculture, warehouse, financial, livestock, supplies and people management. The total area cultivated with soy and corn occupies an area of 9,500 ha. In livestock, which started in 2014, they rear and fatten Nelore cattle in semi-

confinement and confinement and develop animal welfare programs. The annual cattle capacity is 6 thousand heads in a total area of 1000 ha. In addition, to optimize resources and increase productivity, they adopt practices such as rotational grazing, crop-livestock integration (ILP) and livestock-forest integration (IPF). In periods of drought, integration with agriculture allows the use of 600ha of pasture as a second crop. They adopt a traceability system for controlling the herd, which allows the final consumer to know the origin of the product.

They also operate in the forestry area, cultivating eucalyptus, which in addition to diversifying income, contributes to better use and conservation of sandy areas with lower productivity, as well as animal welfare due to the shade produced. They use part of the extracted firewood for their own consumption in the warehouse and another part is sold. They also have their own grain storage structure with

a capacity of 500,000 bags, which guarantees a competitive advantage due to logistical factors, commercialization advantages, contributing to cost reduction and revenue increase.

The awards and certificates received from 2005 to 2022 are also mentioned, which, among others, relate to: best company to work in agribusiness, Round Table on Responsible Soy, Sustainable Supply Solutions and Environmental, Social and Governance (ESG). The company's website contains the statement: "Contributing to the development of agribusiness in a sustainable way" and "we use technology in favor of productivity and sustainability". In this sense, they define sustainability as "meeting the needs of the present without compromising the future and the next generations is the clearest definition of sustainability", which is the path they say they follow in their agricultural production activities and, thus, adopt practices to support a virtuous cycle based on producing and preserving.

Still, on the company's website, they present the SDGs, among which they point out three targets aimed at improving their productive activities, with the goal of contributing to: SDG 2: 2.2 - Zero Hunger and sustainable agriculture; company goal: improve soil fertility to increase soybean productivity by 0.44% by 2023; SDG 4 – Quality education; company goal: raise the education level of 18.75% of employees by 2025 and SDG 8 – Decent work and economic growth; company's goal: to increase the company's immobilized technological capital by 47.8%.

4.2 Main Technologies capable of impacting the improvement of circularity in agriculture

According to UN/DESA (2021) circular agriculture discusses the unsustainability of worldwide food production and before this, the need of adopting circular practices in agriculture. In this sense, the study considered the assumptions pointed out by Basso et al. (2021) regarding the main technologies (for the current, medium and long term) with the capacity to impact the improvement of circularity in agriculture, and next presents the data of the analyzed case;

a) Digital agriculture (DA) technologies to optimize land and resource use decisions

Based on the interviewees' reports (I1 and I2), it was found that productivity and planting maps are used based on technologies installed in agricultural machines, which contributes to a more efficient use of inputs. During planting, they monitor the population of plants per meter, which allows for greater productivity by making better use of the areas. They have a planter with technology that, when crossing in places where it has already been planted (e.g. crop edges) automatically turns off, avoiding the waste of seeds and fertilizers. It also allows leaving space (trails) for the passage of the sprayer for the cultural treatments, which

avoids wasting seeds in places that would be "trampled" by the equipment.

As for inputs, they use plant species to produce organic matter and improve soil quality and the incidence of diseases (nematodes). They replace chemical inputs from production, for their own use of biological products for soy and corn crops in the entire area, which reduces the use of chemical fertilizers.

They have a meteorological station that provides data on wind, temperature, humidity, which helps in planting, by monitoring the necessary humidity so that it does not affect germination, as guaranteeing the appropriate climatic conditions to eliminate waste of inputs. Regarding the harvest, they choose the best moment when the humidity is low, which avoids drying costs (expenses with firewood) and losses in the quality of the grains.

With regard to fertilizers, livestock use 10% of organic compost from the manure generated by livestock in confinement. Annually, 200 to 300 tons are generated and used to fertilize the entire pasture and a small part in grain production. They still make use of fertirrigation, which results from the collection of the liquid that flows when the rain comes into contact with animal manure, which is stored in containment boxes and then spread across the pastures.

As for the less productive areas, they use them to plant trees such as eucalyptus to produce firewood. There are areas that consist only of trees, others composed together with pasture for cattle.

The data presented regarding the item "digital agriculture technologies (DA) to optimize decisions about the use of land and resources", considered a priori Basso et al. (2021) are presented in the empirical field. The adoption and contribution of precision agriculture technologies to optimizing the use of inputs was evident, which favors the circularity of productive resources.

b) Autonomous systems for use of precision resources

Even though the presence of autonomous systems was not verified, I2 mentioned palliative actions regarding less soil compaction. He reported that in order to reduce soil compaction, they matched the sprayer's range to that of equipment that performs "broadcast" fertilization, since this generates less traffic in the crop, consequently less compaction. This is possible by using the same track for both devices.

With regard to better efficiency of fertilizers and pesticides with spraying on specific demand at the site, I2 reported that 2 farm technicians, accompanied by an agronomist, carry out constant monitoring for pesticides, which allowed, at several times, to reduce pesticide applications, previously carried out weekly. In addition to reducing the environmental impact, there was a reduction in application costs. They adopt Integrated Pest Management (IPM), which makes it possible to apply inputs only when it is necessary based on pest control parameters.

The technology embedded in a sprayer was also mentioned to monitor in real time the efficiency of pesticide application in relation to the climatic conditions in which it was applied. The efficiency sought is 95%, given that efficiency, for example, than 60% will require a new application. With the use of the other equipment, except the one mentioned, it has an estimated efficiency between 85% and 90%.

The use of “autonomous systems for the use of precision resources” considered by Basso et al. (2021) as practices favorable to sustainability in agricultural production, in the analyzed context, were not observed in terms of autonomous systems. On the other hand, there were actions related to the efficient use of productive resources (fertilizers and pesticides), which is made possible by precision agriculture technologies embedded in machines and equipment, which allow rational use of resources.

c) Biological and genetic improvements to narrow nutrient and energy cycles

In this regard, the interviewees mentioned the use of plants for covering the soil to facilitate its decompression and better rooting of corn and soybeans and, consequently, better absorption of water and nutrients (they use crotalaria and brachiaria). According to I2, brachiaria also serves as food for cattle and sunn hemp in treating soil diseases that attack plants (nematodes), which reduces the use of chemical inputs. The use of biological products to fix nitrogen in plants was also mentioned. They also said (I1 and I2) that when choosing corn and soybean varieties for cultivation, in addition to productivity, they considered those with greater resistance to diseases and pests.

The mentioned data converge with what was predicted by Basso et al. (2021) regarding the use of “biological and genetic improvements to narrow nutrient and energy cycles”, since they use plants with the purpose of improving soil quality and, at the same time, as food for livestock. In addition, they use biological products and choose high-yield soy and corn cultivars, all of which enhance the use of inputs.

d) Recycling of energy, water and nutrients on the farm

In this regard, the interviewees reported that they capture rainwater for use in the application of products in the field, for washing machines, irrigation of vegetable gardens, orchards and gardens.

As for energy recycling, I1 reported that they produce photovoltaic energy, compost manure for fertilization and use manure as fertilizers and have a project to build a biodigester (generation of energy from manure) in 2024.

Note the presence of the item “recycling of energy, water and nutrients on the farm” pointed out by Basso et al. (2021) in the form of rainwater harvesting, photovoltaic energy generation and the use of manure as fertilizer.

e) Incentives for the adoption of technologies that enable the circular economy

In this respect, I1 illustrated by mentioning the investment to be made in the biodigester. I2, on the other hand, declared that the farm follows the news on the market, citing an antenna to be installed to capture a satellite signal, being one of the few to have in Brazil. According to this informant, this will improve the communication of satellite equipment. I2 added that he realizes the contribution of technology to sustainability through the more efficient use of productive resources. As for “incentives for the adoption of technologies that enable the circular economy” mentioned by Basso et al. (2021) as promoting circularity in the use of resources, investments and plans for this were observed, as well as the perception of its importance.

4.3 Scopes of sustainability in agriculture

The agri-food sector demands the adoption of practices that ensure the transition to a more sustainable development pattern, in line with the principles of the circular economy (Poponi et al, 2022). In this sense, the authors present 8 sustainability scopes in agriculture with a focus on circularity. The description of each scope from the data follows.

a) Air Scope

With regard to the potential for human toxicity, be it the release into the environment of the compound or potential dose, it was reported that they receive all the Personal Protective Equipment (PPE) necessary for the application and handling of toxic products and rotate among employees as a way to minimize the exposure of the same people to the products (I2). They also informed that in a meeting held they dealt with care with the use and handling of chemical products, as well as highlighting that the most recent products have low toxicity and that many older and more toxic ones have already left the market (I1 and I2). Such reports are consistent with Poponi et al. (2022) for evidence of concern with air quality and human health.

b) Water Scope

It can be seen for the question of water exploitation that rainwater has been captured since 2008, as reported by I3. The water that falls from the roofs of the sheds is taken to the reservoirs. There are 5 reservoirs with a total static capacity of 6.5 million liters of water. The action they carry out in the “water scope” contributes to minimizing the negative impact on the environment, as highlighted by Poponi et al. (2022).

c) Soil scope: management, organic production and biodiversity, use of fertilizers and pesticides or organic material

As stated by I2, they have adopted soil conservation practices such as direct planting (minimum disturbance and

presence of organic matter) since 1999, they also perform crop rotation (crop exchange at each new planting) and intercropping (simultaneous crops) since 2007, which favors soil renewal and nutrient replenishment.

Some elements related to the use of pesticides were mentioned, based on the information given by I2, which prioritize products with low toxicity, store, use and handle within the required standards. Regarding the proportion of land that is degraded over the total land area, interviewees I1 and I2 mentioned the existence of a gravel pit that is in the process of being recovered with grass and native trees with a size of 1.5 ha. As for Biodiversity: birds, insects, animals, I1 mentioned a reserve area for this purpose, but without mentioning species of animals and I2 mentioned the presence of animals such as tapir, wolf, wild pig, also highlighting the presence of bees, which make it possible to create a project for the production of honey in an apiary in the middle of the Cerrado (biome). Finally, the quality of the soil measured by the presence of carbon, I1 did not mention anything, however I2 said he has a project with the company Bayer to monitor carbon in the soil, which also generates the possibility of selling carbon credits.

It was observed in view of what Poponi et al. (2022) for the “soil scope: management, organic production and biodiversity, to the use of fertilizers and pesticides or organic materials” soil conservation practices through varied cultivations, concern with the use of pesticides, soil degradation, the presence reserve area to maintain biodiversity, among others.

d) Energy Scope

I1 was unable to inform, whereas I2 said that it meets the demand and producer surplus for sale. The information was supplemented by the warehouse manager (E3) regarding the production of wood fuel. He informed that they are self-sufficient in the firewood used in silo dryers for a consumption of 2,500 cubic meters; and that use 90% and sell the leftovers, that is, 10% of the eucalyptus production. Furthermore, they also produce photovoltaic energy through 528 panels with a production capacity of 17,000 Kwh/month and an average of 204,000 Kwh/year. This energy is sufficient except for four months of the year when consumption increases due to the soybean harvest (Jan and Feb) and the corn harvest (Jun and Jul) due to the demand generated by the warehouses. In this sense, the observed actions are in line with the “energy scope” predicted by Poponi et al. (2022)

e) Waste Scope

According to interviewees I1 and I2, a small amount of waste is sent to landfills, since selective collection is carried out and the materials are sent to a collectors' cooperative in the municipality of Tangará da Serra-MT. Other materials, such as pesticide packaging, are delivered to a center for this purpose. As for other materials, the manager of the supply sector, I3, informed us that waste

from the machine shop (oils, greases) has a company that collects it on the farm. As for the disposal of scrap metal, it is separated into two parts: one with the possibility of reuse on the farm and the other that is considered useless for the farm, is sold for scrap metal. The correct disposal of hydraulic oils used in agricultural machines, which are sold, was also mentioned. Waste generated in the pre-cleaning of soy and corn grains is also sold. Waste that, if disposed of on the farm, would cause environmental damage.

As for food waste, they make a weekly plan to avoid losses and unused food or food left over from meals, it is used to feed domestic animals (cats) and/or thrown into compost. As for the waste of animal feed, I2 mentioned that they seek to reach almost zero, for that, throughout the day, they have been monitoring the feed in the troughs. They only refuel when there's nothing left in the trough and avoid feeding the animals when it's raining. It only remains without this monitoring during the night.

Based on the data presented, for the “waste scope”, actions are also developed that converge with what is mentioned by Poponi et al. (2022).

f) Cost Scope, value and productivity

It involves quantifying the cost of production, the economic value generated and the result indicators, that is, it shows the efficiency of the system over time. In this sense, regarding total remuneration for work based on the total economic output, based on documentary research in the Program for Rewards for Results (PPR) Harvest 2021-2022, it was found from documentary data that there are awards for productivity and by sector performance for soybean, corn and cattle production. Once the targets of 71 bags per hectare (sc/ha) for soybeans and 135 bags per hectare for corn are reached, the expected amount is paid. If the target is exceeded, starting at 72 sc/ha for soybeans and 136 sc/ha for corn, the premium will have a bonus of 25% more. Production lower than the targets of 71 sc/ha for soy and 135 sc/ha for corn are also subsidized between 40% and 90%. For meat production, the biological efficiency will be 160 kg of dry matter (DM) per arroba produced.

As for the profitability indicator, according to data obtained from the 2021-2022 Crop PPR, performance indicators are established for each of the company's 6 sectors, as follows:

- a) Agricultural: 1 - Control of the production cycle (plant population, spacing coefficient between plants, sowing depth, phytosanitary management, grain losses at harvest - below 0.7 bags/ha); 2 - Miscellaneous controls (stock of pesticides and control of revisions of machines and equipment);
- b) Warehouse: 1 - Controls (electricity, firewood, thermometry and aeration, entry into confined environments); 2 - Revisions and infrastructure (compliance with the schedule and conservation of solar energy panels);

- c) Financial: 1 - Earnings Before Interest, Taxes, Depreciation and Amortization (EBITIDA) - (monthly operating profit; depreciation and amortization). 2 - Percentage of indebtedness (costing; financing). 3 - Financial ratios (quarterly presentation; monthly meeting with managers; cash flows);
- d) Livestock (cattle raising): 1 - Food quality (drinker cleaning; trough spacing; trough reading; treatment efficiency). 2 - Animal health (sanitary round; medication control; mortality). 3 - Controls (stock of inputs; traceability);
- e) Supplies: 1 - Stock (follow-up of purchase contracts for inputs; compliance of parts inventory; compliance of fuel inventory). 2 - Purchase and sale (delivery time for purchase requests; compliance with the purchase schedule; control of by-product sales);
- f) People management: 1 - Corporate education (planning of courses and training; increase in the level of education of workers by 5%; control of training (hours, certificates) and sending workload to employees). 2 - Turnover (retention – target 81%; dismissals general turnover 25%; cost). 3 - Satisfaction rates (compliance with processes; organizational climate survey; satisfaction with organizational climate of 92%).

As for the production cost indicator, it is contemplated in item “Financial C”.

With regard to the “scope of cost, value and productivity”, a set of actions are carried out that converge and therefore are convergent to what was predicted by Poponi et al. (2022), which ensure the maintenance and support of the system over time.

g) Equality Scope

I5 informed that the diet is varied because it has different types of meat, always with fruits in the meals in order to balance the diet. In terms of human rights, in addition to the labor obligations met, there is the Position, Career and Salary Plan (PCCS) with remuneration above the market average. They also offer a package of social benefits such as a health plan, meal vouchers and productivity bonuses, among others. Regarding involvement in circular practices, in addition to the actions mentioned in the previous items, we mention the 5s Program started in 2012, which contemplates in one of its “S” the use and organization of materials in an optimized way. In terms of social inclusion, nothing was found.

The practices mentioned by Poponi et al. (2022) for the “equality scope” and observed in loco, are related to food, labor standards, professional career and continuous improvement.

h) Knowledge and Innovation Scope

It covers training people, knowledge and innovation. As for the presence of new technologies: which ones and updating, E1 mentioned investments in warehouse construction. For this, they rented an inflatable warehouse with a capacity for 10,000 tons. It will be used to store inputs for animal feed, which is only installed when there are storage demands, that is new on the farm. I2, on the other hand, reported the case of the planter that works at a speed 2.5 times faster than the old ones. It is considered the best technology due to its performance and higher quality than the others on the market.

With regard to the ability to innovate, I1 realizes that there is adherence to innovations related to environmental conservation and economy in the use of productive resources. However, he understands that they still have a lot to improve compared to what many countries already do. In this sense, I2 said that they receive training from resellers when they purchase equipment regarding its use and also from the farm for different areas, from the technical area to mental health

Finally, for the “knowledge and innovation scope”, several convergent initiatives with Poponi et al. (2022) involving the acquisition of technologies and also the training of people in different areas.

Although many practices predicted by de Poponi et al. (2022) and Basso et al. (2021) were observed in the analyzed context, there is still room for advances. In this regard, considering the scope proposed by Poponi et al. (2022), the data point to the lack of an area with organic agriculture, an area equipped for irrigation and social inclusion. In relation to what is proposed by Basso et al. (2021) regarding the main technologies that favor the circular economy, related to the use of productive resources in agriculture, even though most of the technologies mentioned are present, there is still room for advances. Among those stands out the absence of: a) biological control for pests and diseases in crops and/or livestock; b) use of natural predators for insects or diseases; c) autonomous systems (machines/equipment) autonomous without human intervention; smaller, lighter or airborne equipment (so as not to compact the soil) and electric tractors (zero emission agricultural equipment).

It is relevant to point out that, when conducting the interviews based on the theoretical assumptions adopted, it was noticed that some responses were repeated, which pointed to a convergence with regard to the perspectives of Basso et al. (2021) and Poponi et al. (2022). In order to consolidate and also add the two theoretical frameworks adopted, a column “convergences and empirical evidence” was inserted, in which the element “management” is also included in Table 2, considered a posteriori, since its contribution to a context of sustainable production was evident, that is, it permeates/tangides the other elements mentioned by Basso et al. (2021) and Poponi et al. (2022).

Table 2

Sustainable production practices in agriculture: approaches and convergences for circular agriculture.

Analysis categories		Convergences and empirical evidences	Pillars of Sustainability: Social, Environmental and Economic.
Technologies for circular agriculture (Basso et al., 2021)	Scopes for Sustainability in agriculture (Poconi et al., 2022)		
Elements considered a priori		Elements considered a posteriori (suggested from the study))	
-Technologies of digital agriculture (DA) to optimize decisions about the use of land and resources.	-Knowledge and innovation: People's formation/education, knowledge and innovation. Investments in new technologies.	-Knowledge and innovation: involving people and technology.	- Social
- Incentives for the adoption of Technologies that enable the circular economy.		-Incentives for the adoption of Technologies that enable the circular economy.	- Environmental
- Autonomous systems for the use of precision resources.		- Investment in modern technologies that reduce the environmental impacts.	- Environmental
- Biological improvements and genetics to reduce the cycles of nutrients and energy.	- Soil: management, organic production and biodiversity, for the use of de fertilizers and pesticides or organic materials. - Waste: the way waste is managed.	- Biological and genetic improvement used in the production. - Organic production and or the use of alternative products to the chemical ones. - The way the waste is managed.	- Environmental
- Recycle energy, water and nutrients on the farm.	- Water: water contamination, toxicity and preservation. - Energy: use of energy. Sustainable production of energy in the production/total of use of energy of the non-renewable sources.	-Preservation of Water (use and catchment) - Energy: use and sources of renewable production.	- Environmental
	- Scope of cost, value and productivity: quantify the cost of production, the economic value generated and the result indicators – show the efficiency of the system over time.	- Economic Indicators of result – efficiency result over time	- Economic
	- Equality: Social inclusion, enough security and respect for human rights.	- Equality: Social inclusion, enough security and respect for human rights.	- Social
Results from the empirical field		Management: creation e implementation of sustainable practices; adaptation to optimize the resources used.	- Economic - Environmental - Social

Source: Elaborated by the authors.

The perspective presented in Table 2 contemplates the categories of analysis: a) technologies for circular agriculture (Basso et al., 2021) and b) scopes for sustainability in agriculture (Poconi et al., 2022), considered as a priori elements: From the collection and analysis of data, it was noticed some convergences between both, which added to the empirical evidence, resulted in a third column under the denomination “elements considered a posteriori”.

In this sense, the elements “digital agriculture technologies (DA) to optimize decisions on the use of land and resources (Basso et al., 2021) and “knowledge and innovation: training, knowledge and innovation, investment involving people and technologies”.

The elements “incentives for the adoption of technologies that enable the circular economy” (Basso et al., 2021) were not overlapped, only a small change was made in the wording, assuming the following: “incentives for the adoption of technologies favorable to the circular economy”.

In the item “autonomous systems for the use of precision resources” (Basso et al., 2021), it followed the pattern of the previous one, that is, only the wording was changed, having this content: “investment in modern technologies that reduce the environmental impacts”.

For the elements “biological and genetic improvements to reduce nutrient and energy cycles” (Basso et al., 2021) and “soil: management. Organic production and biodiversity, to the use of fertilizers and pesticides or organic materials; Waste: how waste is managed” (Poconi et al., 2022), the combination of both resulted in: “Genetic and biological improvement used in production; Organic production and or use of alternative products to chemicals; How waste is managed.

Regarding the elements “recycling energy, water and nutrients on the farm” (Basso et al., 2021) and “water: contamination, toxicity and preservation of water; Energy: Energy usage. Sustainable Energy Production in Total Production/Use of Energy from Non-Renewable Sources” (Poconi et al., 2022), we have the following: “water

preservation (use and collection); Energy: use and renewable production sources”.

For the “scope of cost, value and productivity. Quantifying the cost of production, the economic value generated and the result indicators – they show the efficiency of the system over time” (Poponi et al., 2022), this was also only given a new writing, as follows: “economic indicators of results – efficiency of the system over time”.

The same condition was applied to the scope “equality: social inclusion, healthy, sufficient food, safety and respect for human rights” (Poponi et al., 2022), with a small change in the writing, thus: “equality: social inclusion, healthy food, safety, security and respect for human rights”.

Considering what is presented in Table 2, the element “management” was inserted, which is justified in view of the dynamics observed in the empirical field and not explicit in Basso et al. (2021) and Poponi et al. (2022), however, it is understood as a factor that, in addition to permeating circular practices in agriculture, seems to be decisive.

This behavior which was realized denotes the interface between CE and the ability to manage productive resources, which, due to the way it occurred over time, resembles the concept of emerging strategies (Mintzberg & Waters, 1985) - as a model of action that occurs from unforeseen circumstances and that can lead to patterns that are repeated by presenting answers to the problems experienced.

What is here called “ability to manage”, based on the evidence of this case, is a capacity developed as a flow of actions and can form strategic patterns, favoring the use and optimization of productive resources and sustainable practices, whether or not they are innovative however capable of impacting CE in agriculture.

Such evidence is empirically supported in the face of actions they have adopted for decades, even when sustainable agricultural production was not discussed/disseminated or demanded in the current way. Examples include the adoption of no-till planting since 1999, rainwater harvesting since 2008, which they use for cultural practices, washing machinery and irrigating gardens. Another is the selective garbage collection started in 2009, which is delivered to a collectors' cooperative.

Still in this line of reasoning, the ability to optimize the use of resources with regard to adapting equipment stands out, as observed in the report on the adjustments to match the range of the sprayer x fertilizer spreader and avoid soil compaction. In addition to these actions, others can be mentioned, such as the IPM for pests (which prevents the misuse of inputs), among others.

Thus, the study suggests 11 elements that favor sustainability in agricultural production from the perspective of the circular economy/agriculture, namely: a) Knowledge and innovation involving people and technologies; b) Incentives for the adoption of technologies favorable to the circular economy; c) Investment in modern technologies that reduce environmental impacts; d) Genetic and

biological improvement used in production; e) Organic production and/or use of alternative products to chemicals; f) How waste is managed; g) Water preservation (use and capture); h) Energy: use and renewable production sources; i) Economic indicators of results - System efficiency over time; j) Equality: social inclusion, healthy and sufficient food, safety and respect for human rights and l) Management: i) Creation and implementation of sustainable practices and ii) Adaptation to optimize the use of resources. Furthermore, each of these 11 elements was related to one of the three Pillars of Sustainability: social, environmental and economic.

5 FINAL CONSIDERATIONS

Given the objective of the study, which was to identify circular practices of agricultural production in a rural property in the state of Mato Grosso-Brazil, it was found that most of the identified circular practices are present in the categories of analysis adopted from Basso et al. (2021) regarding the main technologies that favor the circular economy and the 8 scopes for sustainability in agriculture presented by Poponi et al. (2022). Although this aspect is relevant, there is still room for progress, that is, there are circular practices that are not yet in use in the analyzed location. As an example, for the categories of Basso et al. (2021) elements such as absence of: a) biological control for pests and diseases in crops and/or livestock; b) use of natural predators for insects or diseases; c) autonomous systems (machines/equipment) autonomous without human intervention; smaller, lighter or airborne equipment (so as not to compact the soil) and electric tractors (zero emission agricultural equipment). Regarding Poponi et al. (2022), the data revealed the lack of an area with organic agriculture, an area equipped for irrigation and social inclusion.

It was also observed in conducting the interviews, based on the theoretical assumptions adopted, that there was a certain convergence between the theoretical perspectives involved, as well as a non-explicit element in the theoretical framework used. With that, and in order to consolidate and also add to the conceptual framework considered, the “management” element is included, since its contribution to a context of sustainable production was evident, that is, it permeates the others.

In view of this finding, 11 elements are proposed as favoring CE in agriculture: a) Knowledge and innovation involving people and technologies; b) Incentives for the adoption of technologies favorable to the circular economy; c) Investment in modern technologies that reduce environmental impacts; d) Genetic and biological improvement used in production; e) Organic production and/or use of alternative products to chemicals; f) Waste management; g) Water preservation (use and capture); h) Energy: use and renewable production sources; i) Economic results indicators – system efficiency over time; j) Equality: social inclusion, healthy and sufficient food,

safety and respect for human rights and k) Management involving i) Creation and implementation of sustainable practices and ii) Adaptation to optimize the use of resources.

As limits/restraints, we can mention the data coming from only one rural property, located in a single Brazilian state and, due to this characteristic, cannot be generalized to the others because it is a single case study. It also refers to a case that has already received certifications and awards for producing sustainably, which may denote/evidence an exceptional case. This also applies to the theoretical lens adopted, since other approaches may bring evidence beyond those presented here, as well as in the case of Poponi et al. (2022) only a few indicators were extracted, which could be analyzed qualitatively.

Theoretical contributions are made effective through the analysis of a practice compared to theory, as there is a scarcity of studies that bring empirical data on CE in rural grain producing properties. This allowed observing that the adoption of circular practices is possible, since they are already adopted, however it can still advance, and this goes beyond the capacity of the producers, considering that it involves, in addition to the micro, the meso and macro levels.

Likewise, in view of the statement by Aznar-Sánchez et al. (2020) that intensive food production systems will guarantee supply in the coming decades; they have already proven their efficiency, but they are not exempt from limitations, the empirical data presented here contribute by reporting production practices that demonstrate the transition from the linear to the circular system. What converges with Basso et al. (2021) regarding the need to migrate from "unsustainable" linear systems in grain production in countries such as the USA, China, Brazil, Argentina, Canada, Russia, Australia and Europe to circular and sustainable systems in order to face the double challenge: depletion of resources, environmental degradation in the face of global demand for food.

As a proposition for future studies, considering the spatial dimension adopted by Poponi et al. (2022), the fact that this study addresses the micro level (rural property), it is suggested to analyze the other levels: meso (industries) where actions for sustainability can be developed and also at the macro level, which involves the formulation of policies for micro-level support. Another suggestion is to study the integrated production systems that integrate crops and livestock, considered by the UN as an alternative practice favorable to CE due to the circularity of resources within the system. This practice, still little studied/researched, is present in this case study.

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