LUMEN ET VIRTUS
ISSN: 2177-2789

THE ROLE OF INNOVATION IN THE SUSTAINABILITY OF AGRIBUSINESS COMPANIES

https://doi.org/10.56238/levv12n30-001

Submitted on: 20/03/2021 **Publication date:** 20/04/2021

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SUMMARY

This article aims to analyze the contribution of innovation to the sustainability of Brazilian agribusiness companies. The research is based on the premise that the incorporation of sustainable technologies and new management models has the potential to transform the agricultural sector into an agent of balanced development, capable of reconciling economic growth, environmental conservation and social justice. The methodology used is qualitative, based on a literature review and critical analysis of secondary data extracted from official reports and scientific articles. Throughout the text, the concepts of sustainability and innovation, the main technological practices adopted in the field, the challenges faced by producers and managers, as well as the emerging opportunities in the face of the growing demand for responsibly produced food are explored. The results indicate that innovation, when implemented in a strategic and accessible way, has the potential to promote significant advances in productivity, reduce environmental impacts and strengthen the competitiveness of rural companies. However, the dissemination of these practices still encounters structural and cultural obstacles that need to be overcome through effective public policies, continuous investments in technical training and strengthening of collaboration networks. It is concluded that Brazilian agribusiness has favorable conditions to become a global reference in sustainability, as long as innovation is incorporated as a permanent and inclusive process.

Keywords: Innovation. Sustainability. Agribusiness. Technology. Rural development.

INTRODUCTION

Brazilian agribusiness represents one of the country's economic pillars, contributing significantly to the Gross Domestic Product (GDP), job creation and trade balance. Over the past few decades, the sector has established itself as an international reference in the production and export of food, fibers, and bioenergy, being recognized for its capacity for productive and technological expansion, even in the face of climatic and logistical adversities (Camargo and Soares, 2021).

However, the accelerated growth of agricultural production has imposed new challenges related to sustainability, especially in a global scenario in which consumers and commercial partners have started to demand greater socio-environmental responsibility in production chains. In view of this, it is imperative to rethink traditional production models and incorporate more efficient, ethical, and ecological practices, capable of ensuring the balance between economic development and preservation of natural resources (Soares, 2021).

Innovation emerges in this context as a fundamental vector of transformation, by allowing the rational use of inputs, increasing productivity, and mitigating environmental impacts. Solutions such as precision agriculture, crop-livestock-forest integration, bioinputs, the use of smart sensors, and the digitalization of the field have been adopted to promote sustainable production, in line with the objectives of responsible rural development (Camargo, 2021).

On the other hand, the effective application of these innovations depends on factors such as access to information, financing, technical training, and infrastructure, which are not always available in all regions of the country, especially in the most remote areas or those with a lower development index. Thus, the benefits of innovation are not always democratized, which requires public policies and integrated private initiatives to ensure the dissemination of technologies in an equitable manner (Pereira et al., 2022).

Thus, understanding the role of innovation in the sustainability of agribusiness companies is essential to diagnose the advances, bottlenecks, and opportunities for improvement in the sector. This is a necessary investigation not only for the strengthening of national agribusiness, but also for Brazil's contribution to global commitments to combat climate change and promote food security (Arruda et al., 2022).

The general objective of this article is to analyze how innovation has contributed to the sustainability of Brazilian agribusiness companies. To this end, it is proposed to identify the main innovative practices adopted in the sector, evaluate their impacts in the

environmental, social and economic dimensions and discuss the obstacles faced in the implementation of these practices.

The justification for this research lies in the relevance of the theme to the current context, in which sustainability is not only a legal or ethical requirement, but a strategic condition for the competitiveness of agricultural companies. The growing pressure for environmentally responsible practices, combined with the need to increase productivity, places innovation as an indispensable instrument to reconcile these interests (Borges, 2022).

In addition, Brazilian agribusiness is at an opportune time to advance its sustainability agenda based on existing public policies, such as the ABC+ Plan, the National Bioinputs Program, and Pronasolos, which strengthen the technical and institutional basis for sustainable innovation (Camargo and Soares, 2021).

Based on this, the article is structured in chapters that address the theoretical foundation on sustainability and innovation, the main advances and technologies implemented in the sector, the obstacles to their dissemination, and a critical discussion on the possible ways to consolidate sustainability as a structuring axis of agribusiness companies.

THEORETICAL FOUNDATION

Sustainability in agribusiness encompasses more than environmental conservation, as it also involves economic and social factors that ensure the continuity of productive activities over time, in this scenario, companies in the sector need to align their operations with responsible practices, capable of minimizing negative impacts and maximizing benefits for society, the environment and the market, as a result, sustainability becomes a management guideline and not just a normative requirement (Pereira et al., 2022).

Innovation emerges as a means to reconfigure the way resources are used, contributing to productive efficiency and the rational use of soil, water and energy, in addition to opening space for new forms of production, such as crop-livestock-forest integration and the use of bioinputs, these technologies aim to reduce environmental impacts and increase the resilience of properties in the face of climate change (Camargo and Soares, 2021).

The relationship between innovation and sustainability is not only desirable, but necessary for the competitiveness of rural companies, since consumers and investors are increasingly aware of the origin of products and the methods used in their production, in this

way, sustainable practices not only avoid environmental damage, but also add value and expand access to more demanding markets (Soares, 2021).

According to recent studies, Brazilian agriculture has demonstrated a great capacity to adapt technologically, although there are still challenges regarding the democratization of these innovations, especially among small and medium-sized producers, which highlights the need for more effective public policies to ensure access to resources, infrastructure, and technical training (Camargo, 2021).

The ABC+ Plan, for example, is a public policy that has encouraged the adoption of low-carbon agricultural practices, with emphasis on no-tillage, pasture recovery and biological nitrogen fixation, these mechanisms have proven effective in mitigating the effects of agricultural activities on the climate, while increasing productivity (Camargo and Soares, 2021).

Technological innovation is also directly associated with the so-called agriculture 4.0, which incorporates tools such as sensors, drones, big data, and artificial intelligence to optimize production and reduce losses, this approach contributes to more accurate decisions, based on real data from the field, and to the efficient use of available natural resources (Soares, 2023).

Even so, it is necessary to consider that the transition to innovative and sustainable systems requires not only technology, but also cultural change and continuous training of producers, many of whom still have difficulty accessing technical information or resist the replacement of traditional practices by new methodologies (Rodrigues and Marietto, 2010).

Another important factor is traceability, which has become a competitive advantage for agricultural products, allowing greater control over the origin and production processes, with the use of digital platforms and monitoring systems, companies are able to prove the adoption of good practices and meet the requirements of international markets (Soares, 2021).

Scientific research provides the basis for the development and validation of new solutions aimed at sustainability, universities, research centers, and institutions such as Embrapa have promoted studies that aim to adapt technologies to the specific conditions of Brazil, respecting the regional and cultural characteristics of the field (Camargo and Soares, 2021).

Sustainability in agribusiness cannot be detached from the socioeconomic reality of the producing regions, and it is necessary to create mechanisms for the inclusion and appreciation of rural communities, income generation, food security, and the improvement

of the quality of life in the countryside are objectives that must go hand in hand with environmental preservation (Pereira et al., 2022).

In addition to the technical aspects, it is important to reflect on the structural factors that hinder the expansion of sustainable practices in the countryside, such as land concentration, informality in rural work and inequalities in access to credit and technical assistance, such elements directly impact the ability of companies to innovate and sustain their businesses in a lasting way (Soares, 2023).

Corporate social responsibility in agribusiness is also part of the equation, with companies that seek to promote actions aimed at environmental education, inclusion of young people and women in the countryside, and partnerships with cooperatives and local organizations, these initiatives strengthen the bond between company and community, creating support networks and incentives for sustainability (Rodrigues and Marietto, 2010).

It is equally relevant to consider the role of environmental certifications and quality seals, which work as mechanisms for recognizing good practices and increase the visibility of companies committed to sustainability, by obtaining these certifications, producers gain competitiveness and privileged access to market niches (Camargo, 2021).

The international scenario also directly influences the strategies adopted by Brazilian agribusiness companies, environmental treaties, trade agreements, and export protocols impose increasingly strict rules, and countries that do not adapt to the new requirements may lose space in global value chains (Camargo and Soares, 2021).

Thus, the role of innovation in the sustainability of agribusiness companies must be understood as part of a continuous, dynamic and collaborative process, which requires the engagement of all actors involved, from the producer to the consumer, including public institutions, the financial sector, research centers and civil society organizations, only with this articulation will it be possible to build a truly sustainable agricultural model (Pereira et al., 2022).

INNOVATION IN AGRIBUSINESS: SUSTAINABLE TECHNOLOGIES AND PRACTICES

Innovation applied to agribusiness has profoundly transformed the way production is done in the field, promoting the integration between productivity and environmental conservation, through the use of cutting-edge technologies, it has been possible to optimize the use of natural resources, reduce waste and make production systems more efficient and resilient to climate change, among the main technological advances are precision agriculture, the use of drones, sensors, big data, machine automation, and artificial intelligence (Camargo and Soares, 2021).

Precision agriculture, for example, allows detailed monitoring of soil, plant and climate conditions, offering real-time information that guides the producer's decisions, this practice reduces the excessive application of inputs, such as fertilizers and pesticides, generating savings, lower environmental impact and increased productivity, being a clear example of how technology can enhance results in the field (Soares, 2023).

Drones have proven to be important allies in the identification of pests, in the mapping of cultivated areas and in the analysis of plant health, with high-resolution images and georeferenced data, producers are able to act more quickly and accurately, correcting failures and making more assertive decisions, this type of digital tool is increasingly accessible and present in Brazilian properties (Soares, 2021).

The collection and analysis of large volumes of data, known as big data, has also gained ground in agribusiness, allowing the identification of patterns, harvest forecasts and monitoring of the performance of each area of the property, by associating this information with the use of artificial intelligence, it is possible to anticipate scenarios, optimize planting and harvesting, in addition to mitigating operational and climate risks (Pereira et al., 2022).

Another important practice is the use of bioinputs, such as microorganisms and organic compounds that replace traditional chemicals, these inputs are more sustainable, as they reduce soil and water contamination, promote biological balance and increase plant health, in addition to being safer for workers and end consumers (Rodrigues and Marietto, 2010).

Integrated crop-livestock-forestry (ICLFS) is an innovative production system that seeks to diversify and optimize land use through crop rotation and intercropping, animal husbandry and reforestation, this practice promotes benefits such as improved soil fertility, increased productivity, diversified income generation and environmental recovery of degraded areas (Camargo and Soares, 2021).

The use of sensors in the field is another relevant innovation, these devices are installed in the soil, plants or machines and send continuous data to control systems, allowing the monitoring of moisture, temperature, nutrients and other fundamental parameters for crop growth, this technology facilitates rational management and avoids significant losses due to crop failures (Soares, 2023).

The automation of agricultural machinery has also contributed to sustainability in the field, with automated tractors, harvesters and sprayers, it is possible to ensure greater precision in operations, save inputs and fuel and reduce soil compaction, in addition, the use of autonomous vehicles is already a reality in some properties, further increasing production efficiency (Camargo, 2021).

In the aquaculture sector, innovation has enabled sustainable practices through water recirculation, aquaponics systems, and automated water quality control, these resources avoid water waste, improve the well-being of farmed organisms, and reduce the environmental impact of production, integrating the activity into the concept of bioeconomy (Oliveira et al., 2024).

It is noteworthy that digital traceability allows you to follow the entire trajectory of products from the field to the final consumer, through QR codes, blockchain and integrated databases, it is possible to guarantee the sustainable origin of food, increase transparency in production chains and meet the requirements of more rigorous and conscious markets (Camargo and Soares, 2021).

The development of intelligent irrigation systems, which automatically control the volume and frequency of irrigation based on the real needs of the plants and climatic conditions, represents a great advance in water savings and productivity, these systems avoid both scarcity and excess of irrigation, optimizing resources and avoiding erosion and salinization of the soil (Soares, 2023).

It is also worth mentioning the creation of digital platforms that connect producers, technicians, researchers and buyers, through these tools, it is possible to access information, share good practices, schedule services and sell products directly and efficiently, the use of mobile applications and digital networks facilitates digital inclusion in the field and strengthens cooperation between the various links in the chain (Pereira et al., 2022).

Innovations in storage and transportation are also part of sustainable practices, with low-consumption refrigerated systems, biodegradable packaging and intelligent logistics management, it is possible to reduce post-harvest losses, reduce carbon emissions and deliver fresh and healthy products to the consumer, promoting efficiency throughout the agri-food chain (Rodrigues and Marietto, 2010).

However, despite all these possibilities, the adoption of sustainable technologies still faces obstacles such as the high cost of implementation, the cultural resistance of some producers, and the difficulty in accessing specialized technical assistance, so it is essential to strengthen rural extension programs, facilitated credit lines, and partnerships with universities and research institutions (Camargo, 2021).

Therefore, it is evident that innovation in agribusiness has been an instrument for transforming production practices, promoting environmental sustainability, social inclusion and economic competitiveness, by incorporating new technologies in a strategic way, companies in the rural sector position themselves as protagonists of a more conscious,

efficient and responsible production model in the face of the demands of the twenty-first century (Camargo and Soares, 2021).

DIFFICULTIES AND OPPORTUNITIES FOR SUSTAINABILITY IN AGRIBUSINESS

Despite the advances promoted by innovation in the field, Brazilian agribusiness still faces numerous challenges that limit the full expansion of sustainable practices, among the main obstacles are the lack of technological infrastructure in remote regions, the shortage of qualified labor, the high initial investment costs and the lack of financial incentives compatible with the reality of small and medium-sized producers, these barriers hinder the democratization of access to technologies and compromise the achievement of sustainable results on a large scale (Soares, 2023).

Regional inequality in Brazil also directly influences the adoption of innovative practices, while large properties in states with high agricultural development have structure and technical support, many regions in the North and Northeast still face logistical and connectivity difficulties, which prevents the efficient use of digital tools and limits the modernization of rural activities, accentuating technological exclusion and compromising equity in the sector (Rodrigues and Marietto, 2010).

In addition to technical and financial limitations, cultural resistance also appears as an important obstacle, many rural producers are still afraid to change their traditional forms of production, either due to mistrust in relation to new technologies, or due to the lack of clear and objective information about the benefits of sustainable practices, this resistance can be overcome with continuous actions of rural extension, training and practical demonstration of the positive results generated by innovation (Camargo and Soares, 2021).

Sustainability in agribusiness also requires a change in business mentality, in which profit is not seen as an antagonist to environmental conservation, but rather as a natural consequence of efficient, ethical management committed to the future, this implies the adoption of integrated environmental, social and economic indicators, capable of measuring the performance of properties holistically, considering not only the financial return, but also the impact on the territory and the community (Pereira et al., 2022).

An important obstacle concerns environmental regulation and the legal uncertainty faced by many producers, the frequent changes in standards, excessive bureaucracy and the absence of clear guidance on compliance with legal requirements make it difficult to voluntarily adhere to environmental programs, in addition, producers who adopt good practices are often not properly recognized or valued in the market, which discourages the continuity of efforts (Camargo and Soares, 2021).

The absence of more robust and integrated public policies also limits the advancement of sustainability in the field, although there are programs such as ABC+, Pronaf and the Crop Plan, many of which still do not reach the full diversity of producers or lack effective execution, it is necessary to expand the dialogue between governments, research institutions, companies and civil society organizations to ensure that policies reflect the real needs of the field and are easy to use. access and application (Soares, 2021).

The challenges faced also open up important opportunities for the reinvention of the sector, the growing demand for healthy food, produced with social and environmental responsibility, has driven the appreciation of sustainable production chains, companies that invest in innovation and transparency are more likely to conquer new markets, especially international ones, where sustainability standards are stricter (Rodrigues and Marietto, 2010).

The advancement of digital agriculture also represents a great opportunity for transformation, as technologies such as rural connectivity, remote sensors, and farm management software become more accessible, there is a potential to include thousands of producers who were previously on the margins of the innovation process, this movement can generate significant gains in productivity and sustainability, while reducing regional inequalities (Soares, 2021).

Another opportunity lies in the valorization of agroecological production, which is based on practices that respect natural cycles, promote biodiversity and prioritize the well-being of local communities, this model has gained space both for its environmental appeal and for its social contribution, strengthening family economies, promoting food security and stimulating conscious consumption (Pereira et al., 2022).

Digital traceability and sustainable certification seals are mechanisms that strengthen the link between producer and consumer, offering guarantee of origin and quality of products, in addition to increasing market confidence, these systems value producers committed to good practices and enable competitive differentiation, which can generate better profit margins and customer loyalty (Camargo and Soares, 2021).

The expansion of partnerships between the public and private sectors can also accelerate the transition to a more sustainable agribusiness, companies, universities, cooperatives and governments have a strategic role in the creation of innovation ecosystems, in which knowledge circulates and is transformed into practical solutions to the challenges of the field, the strengthening of these partnerships promotes greater synergy, reduces duplication of efforts and expands positive impacts (Soares, 2023).

Carbon markets represent another opportunity for agribusiness companies, properties that adopt practices that capture or reduce greenhouse gas emissions can be remunerated for the generation of carbon credits, this model encourages forest conservation, the recovery of degraded areas and the use of regenerative production systems, creating a virtuous cycle between profitability and preservation (Rodrigues and Marietto, 2010).

The performance of new generations in the field, especially young entrepreneurs and professionals with technical and technological training, has driven innovation in the sector, with a more integrated vision and connected to global trends, these actors have promoted creative solutions, sustainable business models and collaborative forms of management that expand the reach of good practices, renewing the image of the field and attracting new talents (Soares, 2021).

The inclusion of women in agricultural activities and decision-making processes also stands out as a strategic opportunity, studies show that properties with female management tend to be more resilient, innovative and committed to sustainability, fostering gender equity policies in the field is a fundamental step towards strengthening agribusiness and building a fairer and more productive environment (Pereira et al., 2022).

Therefore, at the same time that agribusiness faces significant challenges, it is also facing a historic window of opportunities, with innovation as an ally, it is possible to overcome obstacles, generate shared value and consolidate Brazil as a global leader in sustainable production of food, energy and fibers, as long as there is commitment, articulation between sectors and a clear vision of the future based on social justice and environmental responsibility (Camargo and Soares, 2021).

FINAL CONSIDERATIONS

The trajectory of Brazilian agribusiness reveals a sector in constant evolution, which has sought to balance economic growth with environmental responsibility, progressively inserting practices that respect the limits of natural resources and value the social role of rural companies, this transformation process, although challenging, opens paths for agricultural production to be aligned with the principles of sustainable development.

Innovation has proven to be a key element for this transformation, as it is through it that companies are able to adapt their production systems, introduce clean technologies, optimize the use of inputs and improve their operational efficiency, in addition, innovation strengthens competitiveness, generates new business opportunities and contributes to the inclusion of small producers in value chains.

Although the sector has advanced significantly on several fronts, challenges persist, especially with regard to regional inequality, limited access to technology, and the difficulty of adopting sustainable practices by smaller farmers, overcoming these obstacles requires a coordinated effort between public policies, affordable financing, rural education, and continuous technical support.

Sustainability in agribusiness cannot be restricted to an institutional discourse, it needs to materialize in concrete practices within the properties, in the management models, in the daily choices of producers and in the commitment to transparency, it is necessary to build a culture that values responsible production, that rewards good practices and that strengthens the awareness that the future of the field depends on the decisions made in the present.

The technologies currently available offer viable and affordable solutions to many of the problems faced in the field, but the use of these tools requires technical preparation, strategic vision and constant support, it is not enough to make the technology available, it is necessary to ensure that it is understood, appropriated and applied efficiently by those who are in the day-to-day production.

Brazil has enormous potential to be a world reference in sustainable agriculture, with its biological diversity, territorial extension, water wealth and accumulated technical competence, the country can lead the development of a new agricultural model that produces responsibly, generates income without compromising the environment and brings food security to billions of people in the world.

The consolidation of this model, however, involves a change in mentality and the adaptability of the various actors involved in the agribusiness chain, producers, managers, researchers, financial agents and public policy makers need to be aligned by a common purpose: to transform productivity into shared prosperity, respecting ecological limits and promoting social justice.

Strengthening partnerships between universities, cooperatives, companies, and governments can accelerate this process, creating collaborative innovation networks that connect knowledge, experience, and resources in favor of real solutions for the field, innovation environments, such as agricultural hubs and technological hubs, can work as points of articulation and generation of sustainable impact.

The inclusion of historically underrepresented groups, such as women, young people and traditional communities, should also be part of the sustainability agenda, the protagonism of these groups expands the diversity of perspectives, enriches the production

process and contributes to the construction of a fairer, more resilient field adapted to the changes that are already underway.

It is up to agribusiness companies to adopt a more proactive stance in the search for sustainable solutions, not only to meet legal requirements or obtain commercial advantages, but to understand that the viability of their business is directly related to the health of ecosystems, climate stability, and the well-being of the communities with which they interact.

The current moment represents a crossroads for Brazilian agribusiness, on the one hand, there are the intensive production models that ignore the limits of the planet, on the other, there is the possibility of building a new productive logic, based on science, innovation and responsibility, the path to be followed will depend on the courage to change, the willingness to learn and the sensitivity to listen to what the earth, The climate and society are telling it.

International markets are increasingly attentive to the production practices and socio-environmental policies of exporting countries, it is not only a matter of complying with external requirements, but of recognizing that sustainable positioning strengthens the image of the national product, increases consumer confidence and guarantees access to more demanding and profitable markets.

In this sense, innovation should be seen as a continuous process and not as a one-off solution, it requires constant investment, permanent updating and management open to learning, it is necessary to foster an institutional environment that values research, encourages experimentation and disseminates results in a way that is accessible to all profiles of producers.

The sustainability of agribusiness companies also depends on strategic management that sees value in socio-environmental practices, companies that adopt sustainability indicators, monitor their impacts, establish clear goals and communicate their results tend to gain greater recognition, attract partners and obtain better performance in the long term.

Therefore, the construction of an innovative and sustainable agribusiness is a collective project, which requires articulation between sectors, engagement of leaders and commitment to future generations, it is time to act consciously, to invest in knowledge and to transform rural production into an example of balanced prosperity, based on the appreciation of life, the land and the relationships that sustain our existence.

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