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# Sustainable Entrepreneurship and Digital Technologies: Challenges and Potential Aspects for Brazilian Agtechs

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## ABSTRACT

**Objective:** this study analyzes sustainable entrepreneurship practices in Brazilian agribusiness startups, specifically agtechs, identifying challenges and opportunities for the application of digital technologies. **Methods:** the qualitative research approach is based on multiple case studies. Data collection was conducted through interviews with 10 agtechs CEOs and secondary data sources. The ATLAS.ti 23 software was utilized as a resource for data organization and analysis support, employing content analysis as the method. **Results:** the findings reveal that agtechs adopt practices of entrepreneurship by opportunity and are sustainability-oriented in resource allocation, organizational configuration, and establishment of management systems, principles that contribute to creating an organizational environment conducive to sustainable innovation. Predominantly weak initiatives related to sustainability were identified, which means that there is evidence of adoption of practices that align with sustainability assumptions, but which are not the core of operations and business. These practices are interconnected the potential application of digital technologies. **Conclusions:** this study provides valuable insights for researchers, professionals, and policymakers interested in promoting sustainable entrepreneurship in the agtech sector.

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## INTRODUCTION

Sustainable entrepreneurship has become a growing and timely topic in the field of agricultural startups, known as agtechs (Dhayal et al., 2023), especially in emerging countries (Sehnem, Provenci et al., 2022), where agricultural technology appears to be a viable solution for addressing economic and environmental challenges (Smith et al., 2022). The implementation of sustainable and innovative business practices, coupled with digital technologies, has been crucial in driving the agribusiness sector and sustainable food production (Sehnem, Bispo et al., 2022).

The adoption of sustainable entrepreneurial practices in agtechs is associated with improved financial performance (Wöhler & Haase, 2022) and greater resilience in economic crises (Silveira et al., 2022). Furthermore, companies that invest in environmentally friendly and socially responsible solutions have shown higher stakeholder satisfaction (Secundo et al., 2022) and demonstrate more efficient and optimized natural resource management (Sehnem, Provenci et al., 2022), aligning the rational use of resources, for the development of sustainable innovations (Jacomossi et al., 2021).

Entrepreneurs involved in agtechs in emerging countries face specific challenges such as lack of funding and poor infrastructure (Olteanu & Fitcher, 2022). However, these entrepreneurs have been successful in implementing sustainable digital solutions and creating social, environmental, and economic value for their communities, highlighting the importance of sustainable entrepreneurship (SE) in the sector (Evans et al., 2017).

Aspects like public-private partnerships are considered essential for promoting sustainable entrepreneurship in agtechs. According to Bertucci Ramos and Pedroso (2021), collaboration among different stakeholders, including governments, universities, and businesses, contributes to overcoming challenges related to innovation and the implementation of sustainable agricultural technologies.

Research examining sustainable entrepreneurship in different contexts has fueled interest in emerging topics. This relevance is recognized in academic research as well as in policy and business practices (Johnson & Schaltegger, 2020). The importance of the relationship between sustainable entrepreneurship and agtechs, especially in emerging countries, is also emphasized (Castro & Ramos, 2021; Sehnem, Provenci et al., 2022). Other themes such as public policies and international cooperation should be considered to analyze the development of innovative and sustainable solutions in the sector, contributing to addressing the economic and environmental challenges faced by these nations.

For example, Wöhler and Haase (2022) identify the relationship between sustainable practices and financial performance. Zhao et al. (2021) analyze the development of sustainable entrepreneurship and its relationship with appropriate government policies. The importance of public-private partnerships is highlighted by Dutia (2014). Such initiatives support the need for regional entrepreneurial support systems as a foundational infrastructure for accelerating innovation. Silveira et al. (2022) analyze the importance of international cooperation in sustainable entrepreneurship in agtechs. Aspects like the training and capacity building of entrepreneurs are considered in the research by Mendes et al. (2022). Patel and Kumari (2021) emphasize that a diverse and inclusive workforce stimulates innovation and creativity, which are essential factors for the success of agtechs in emerging countries.

However, it is observed that the factors influencing the efforts of entrepreneurial companies to develop sustainable innovation are not well explored (Horne & Fichter, 2022). Di Vaio et al. (2022) highlight that it is unclear how startups develop and present market innovations aimed at sustainability. Cavazza et al. (2023) note that the use of digital technologies can leverage production automation, especially in the context of agribusiness. These studies have contributed to advancing knowledge and promoting sustainable solutions in the agtech sector, which is recognized as an emerging research field (Holzmann & Gregori, 2023), justifying the relevance and opportunity for research in this segment.

Although there are studies on sustainable entrepreneurship and technologies in agtechs (Bertucci Ramos & Pedroso, 2021); Sehnem, Bispo et al., 2022), the Brazilian context presents unique characteristics that can influence the implementation and impact of these practices in the country's agricultural sector. Identifying and exploring this theoretical gap can contribute to a better understanding of the challenges, opportunities, and successful practices in sustainable entrepreneurship in Brazil. Some specific aspects of the Brazilian context that may justify the need for a study include regulatory and political environment, socio-economic and cultural challenges, diversity and complexity of the agricultural sector, and potential for innovation and growth, as supported by Agripino et al. (2023).

Therefore, understanding how sustainable entrepreneurship can be driven and supported for the development of the agricultural startup sector in a more sustainable and prosperous manner for the country can provide valuable insights for researchers, professionals, and policymakers, as well as contribute to advancing knowledge on the topics and their practices in the sector. Research on sustainable entrepreneurship

increasingly recognizes the transformative potential of digital technologies in mitigating and neutralizing major environmental and social challenges through entrepreneurial action (Holzmann & Gregori, 2023).

A study on sustainable entrepreneurship and agtechs in Brazil can contribute to promoting a more sustainable and equitable future for Brazilian society and potentially inspire positive changes in other national and international contexts. Given the presented context, this research aimed to analyze sustainable entrepreneurship practices in Brazilian agtech agricultural startups, identifying typologies, technologies, challenges, and emerging opportunities.

The study is structured by this introduction, after which it presents the theoretical framework that addresses the themes of sustainable entrepreneurship, agtechs and digital technologies. Followed by the methodological procedures defined to conduct the research. It presents the results and discusses the research findings. After that, it presents the final considerations and, finally, the references are provided.

## THEORETICAL BACKGROUND

### Sustainable entrepreneurship: Taxonomy and typologies

The concept of sustainable entrepreneurship provides an expanded definition for the field of entrepreneurship by linking entrepreneurs' motivation to opportunities for creating goods and services that go beyond economic results (Parrish, 2010) seeking to align social and environmental perspectives for business (Cohen, 2006; Cohen & Winn, 2007). Schaltegger and Wagner (2011) characterize SE as a contribution to social and environmental issues through the realization of a business that promotes sustainable development through entrepreneurial activities. Innovations are logical and central to these activities as they convert market imperfections into business opportunities and aim to replace unsustainable forms of production and consumption, creating sustainable value for stakeholders with a social impact (Di Vaio et al., 2022).

In this context, entrepreneurship is increasingly cited as a significant channel for the transformation of sustainable products and processes (Hall et al., 2010). Sustainable entrepreneurship is an accelerator of innovation opportunities throughout (Védula et al., 2022), while economic entrepreneurship primarily focuses on market mechanisms (Venkataraman et al., 2016).

Thus, the concept of sustainable entrepreneurship combines the creation of businesses with activities related to practices and concerns for the environment, society, and the economy (Dean & McMullen, 2007). To this end, proposals for classifications of dimensions, categories, types, and taxonomies have been identified in the literature by seminal authors such as Cohen and Winn (2007), Dean and McMullen (2007), Shepherd and Patzelt (2011), Hockerts and Wüstenhagen (2010), and Parrish (2008), as presented below.

Cohen and Winn's (2007) research proposes that sustainable ventures need to be multifaceted by considering not only the financial performance of the company but also social wealth measures that take into account the economic, social, and environmental impacts of new ventures. This typology proposes three dimensions, namely: (1) environmental entrepreneurship: focusing on reducing negative impacts on the environment; (2) social entrepreneurship: focusing on social well-being and improving the living conditions of communities; and (3) sustainable entrepreneurship: an integrated approach that combines environmental, social, and economic aspects.

Hockerts and Wüstenhagen (2010) identified three approaches to sustainable entrepreneurship and classified the dimensions as follows: (1) environmental entrepreneurship: focusing on creating environmental value; (2) social entrepreneurship: focusing on creating social value; and (3) sustainable entrepreneurship: integrating environmental, social, and economic aspects in value creation.

In the same perspective, unlike the previous authors, the typology proposed by Parrish (2008) considers sustainable entrepreneurship based on three dimensions, namely: (1) conservation entrepreneurship: seeks to conserve natural resources and minimize negative impacts on the environment; (2) socially just entrepreneurship: promotes social equity and seeks to reduce inequalities and injustices; and (3) ethically responsible entrepreneurship: operates with ethical responsibility and integrity in all its activities.

The research by Schaltegger and Wagner (2011) proposed three different categories of analysis for sustainable entrepreneurship: (1) eco-innovators: focusing on ecological innovations; (2) social entrepreneurs: focusing on social and environmental solutions; and (3) sustainable entrepreneurs: focusing on balancing the three pillars of sustainability (environmental, social, and economic).

The literature also presents proposals for taxonomies of sustainable entrepreneurship that explore different categories of analysis. Cohen and Winn (2007) proposed two main categories of sustainable entrepreneurship: (1) opportunity entrepreneurship: exploring economic opportunities resulting from environmental degradation; and (2) necessity entrepreneurship: motivated by the need to solve socio-environmental problems, lined up with Shane and Venkataraman (2000).

Shepherd and Patzelt (2011) developed a taxonomy based on three dimensions of sustainable entrepreneurship: (1) environmental entrepreneurship: focusing on the preservation and improvement of the environment; (2) social entrepreneurship: focusing on the enhancement of human and social well-being; and (3) sustainable entrepreneurship: seeking to integrate environmental, social, and economic goals.

It is also worth considering that the perspective of sustainable entrepreneurship (Schaltegger & Wagner, 2011) is closely aligned with the concepts of strong and weak sustainability (Daly, 2004), which are terms used to describe different approaches or orientations. These terms do not necessarily reflect the effectiveness or success of entrepreneurship but rather the extent to which sustainable and socially responsible practices are incorporated into the objectives and operations of a company (Gupta & Matharu, 2022).

In weak sustainability, sustainable and socially responsible practices are incorporated to a limited or superficial extent in the objectives and operations of the business (Amini & Bienstock, 2014). Generally, companies that adopt a weak sustainability approach are more focused on economic and financial aspects, with sustainability and social responsibility considered secondary. On the other hand, strong sustainability is characterized by a deeper and more comprehensive commitment to sustainability and social responsibility (Meadows et al., 2004). Companies that adopt a strong sustainability approach integrate sustainable and socially responsible practices in all aspects of their objectives and operations, from strategic planning to daily decision-making.

The research by Johnson and Schaltegger (2020) synthesizes the literature on social, environmental, and sustainable entrepreneurship and observes that as a combination of insights, the three categories characterize sustainable entrepreneurship. Although these dimensions have unique distinctions, common denominators include a focus on business processes and preparing the business model for sustainable development.

## Digital technologies and agtechs

For this research, the concept of sustainable entrepreneurship is analyzed from the perspective of the agribusiness sector, in startup companies called agtechs, which, according to Dutia (2014), develop innovations in inputs for agricultural production, digital technologies for transportation, processing, distribution, storage, and waste disposal, and have evolved through an increasing number of entrepreneurs connected to public and private investors to create an even more vibrant sector in the global economy.

The research by Bolfe et al. (2020), conducted with 504 Brazilian farmers on the use of digital technologies, indicates that emerging technological innovations such as big data, internet of things (IoT), artificial intelligence, machine learning, robotics, remote sensing, automation and robotics, digital platforms, GPS (Global Positioning System), and blockchain are used as a means to accelerate the transformation of agribusiness.

Technologies used to accelerate knowledge processes and improve performance have agricultural and economic benefits such as better production and agricultural management, dissemination of important information, improvement in planning, monitoring, and production pace, access to research results in the field, and automation of activities (Zanuzzi et al., 2020), and they have the potential to drive progress in sustainability (Pivoto et al., 2018). According to Castro and Ramos (2021), agtechs make it possible to transform Brazilian agricultural productivity and production through the development of more technological products and services.

In this context, it is important to analyze the perspectives addressed in the literature regarding the proposed relationship between sustainable entrepreneurship and agtech startups in the challenges of emerging countries. For example, applying and gaining competitive advantage in innovative and sustainable solutions (Smith et al., 2022), the adoption of sustainable technologies (Bertucci Ramos & Pedroso, 2021); and challenges related to infrastructure and resource mobilization, such as financing (Olteanu & Fitcher, 2022), benefiting more from international cooperation by accessing cutting-edge resources, knowledge, and technologies (Pivoto et al., 2018). The need for appropriate government policies and financial support in emerging countries also stands out (Zhao et al., 2021).

In this context, it is observed that the rapid and broad diffusion of digital technology has redefined both the fundamental nature of the economy and our core assumptions about entrepreneurship (Si et al., 2023), modifying the structures of business models in the agribusiness sector. Technologies, innovation, digitization, and AI can therefore represent some of the ways and strategies to achieve sustainability goals and manage the sector's challenges (Cavazza et al., 2023).

The research by Von Briel et al. (2018) questions whether there are effective ways of analyzing the influence of digital technologies in the process of creating ventures, and whether they play roles as facilitators and agents of change, especially when the start of the venture takes place through opportunity. Agreeing with the

authors, there is an opportunity for this research to expand this understanding and discuss entrepreneurship in startups in the agribusiness sector, mainly highlighting emerging countries such as Brazil.

## METHODOLOGICAL PROCEDURES

To address the proposed objective, a qualitative research approach was adopted. The method of multiple case studies was used, exploring 10 Brazilian agtech cases to identify patterns and common practices of sustainable entrepreneurship. The sample is intentional and derived from the 100 Open Startups database, where the top 10 highlighted agtechs in Brazil are ranked. Additionally, the Agri Hub Tools database was consulted, including participants in the research.

In the data collection phase, invitations were sent to 25 agtech managers. Contact was made via email, LinkedIn, WhatsApp, telephone, and Instagram. Out of all the invitations sent, 10 managers agreed to participate in the study. The pre-structured interview script included questions regarding: (a) profile, (b) company characterization, (c) historical evolution of the agtechs, (d) management dynamics, (e) adopted sustainability practices, (f) products and services offered to society, and (g) elements associated with entrepreneurship and innovation.

Furthermore, secondary and documentary data were consulted, including technical reports, institutional videos, social media platforms such as LinkedIn, Instagram, Facebook, and websites. To ensure data reliability, data triangulation was performed from different sources, as well as researcher triangulation and data analysis, as recommended by Yin (2015). The criterion of multiple researchers was also adopted in the data collection, transcription, and analysis stages, with the findings being analyzed by other members who agreed to be the research control unit, as recommended by Denzin et al. (2008).

Regarding ethical aspects, this research followed the guidelines of the research protocol in the areas of humanities and social sciences. To maintain the anonymity of the researched agtechs, their names were suppressed and coded with the letter E (interviewee) followed by the interview order number, for example (E1, E2, E3, etc.), followed by the uppercase letter A (Agtech) (E1A, E2A, E3A, etc.).

**Table 1.** Sample characterization.

| Agtechs | Position | Education level | Time in company | City | Size | Number of employees | Time |
|---|---|---|---|---|---|---|---|
| E1A | CEO | Bachelor's degree | 3 years | São Paulo, SP | Small | 8 | 28 min |
| E2A | Coordinator in P&D | Doctorate | 5 months | Ribeirão Preto, SP | Small | 9 | 29 min |
| E3A | CEO | Bachelor's degree | 7 years and 6 months | Belo Horizonte, MG | Medium | 70 | 45 min |
| E4A | CEO | Bachelor's degree | 2 years | Rio Verde, GO | Medium | 14 | 22 min |
| E5A | CEO | Bachelor's degree | 12 years | Goiânia, GO | Medium | 49 | 18 min |
| E6A | CEO | Doctorate | 7 years | Santa Maria, RS | Microenterprise | 2 | 28 min |
| E7A | COO | Bachelor's degree | 3 years | Vinhedo, SP | Medium | 35 | 29 min |
| E8A | Coordinator in marketing | Postgraduate | 20 years | Pelotas, RS | Medium | 30 | 29 min |
| E9A | COO | Bachelor's degree | 4 years | Jundiai, SP | Medium | 45 | 25 min |
| E10A | CEO | High school | 8 years | São Paulo, SP | Small | 20 | 22 min |

**Note.** Developed by the authors.

The interviews conducted with the 10 CEOs of the startups were recorded with the consent of the interviewees. Each interview was then transcribed with the aid of the Transkriptor software and carefully reviewed to ensure accuracy of the interviewee's speech. In total, from 4 hours and 35 minutes of recordings, 10 transcriptions resulted in 95 pages. Each interview generated a document, which was imported and processed using the ATLAS.ti 23 software.

The 10 cases of analyzed agtechs correspond to small and medium-sized companies located in the Southern (2), Southeastern (6), and Central-Western (2) regions of Brazil. Regarding the time in the market, the respondents have an average of approximately 6.7 years of company existence, with educational backgrounds ranging from high school, completed undergraduate degrees, to doctoral degrees. In terms of the number of employees, the average is 28 employees per company.

The analysis categories were previously established as shown in Table 2, based on taxonomies and classifications of sustainable entrepreneurship adhering to previous literature. According to Bardin (2016), a cate-

gory is considered relevant when it belongs to the previously defined theoretical framework.

Data analysis was conducted with the support of the ATLAS.ti 23 software. The use of this software for qualitative data analysis allows for the organization and systematization of various types of documents, such as texts, audio, images, and videos, while also aiding in the management and interpretation of information. As noted by Talanquer (2014), the utilization of different strategies, such as software, contributes to exploratory analyses, as is the case in this research.

The method of analysis employed in the study was content analysis, as recommended by Bardin (2016), which provides a set of techniques for the analysis and systematization of communications, enabling the interpretation and description of message content. The proposed method is divided into three stages: (1) pre-analysis; (2) exploration of the generated material, and (3) treatment of the obtained results in order to collect inferences and their interpretation.

**Table 2.** Pre-established analysis categories.

| Analysis categories | Description | Authors |
|---|---|---|
| Opportunity entrepreneurship | Exploits economic, social, and environmental opportunities. | Cohen and Winn (2007) |
| Necessity entrepreneurship | Motivated by the need to address socio-environmental issues. | Cohen and Winn (2007) |
| Social entrepreneurship | Focus on environmental preservation and improvement. | Shepherd and Patzelt (2011) and Cohen and Winn (2007) |
| Social entrepreneurship | Focus on improving human and social well-being. | Shepherd and Patzelt (2011) and Cohen and Winn (2007) |
| Sustainable entrepreneurship | Seeks to integrate environmental, social, and economic objectives. | Shepherd and Patzelt (2011) and Cohen and Winn (2007) |

**Note.** Developed by the authors.

In the pre-analysis stage, researchers engaged with the documents through a floating reading of the transcripts of the interviews. To explore the material, the messages from the interviewees were coded using citation coding techniques with the assistance of ATLAS.ti 23 software. The selected citations were assigned to their respective categories, resulting in a total of 265 citations from the 10 documents.

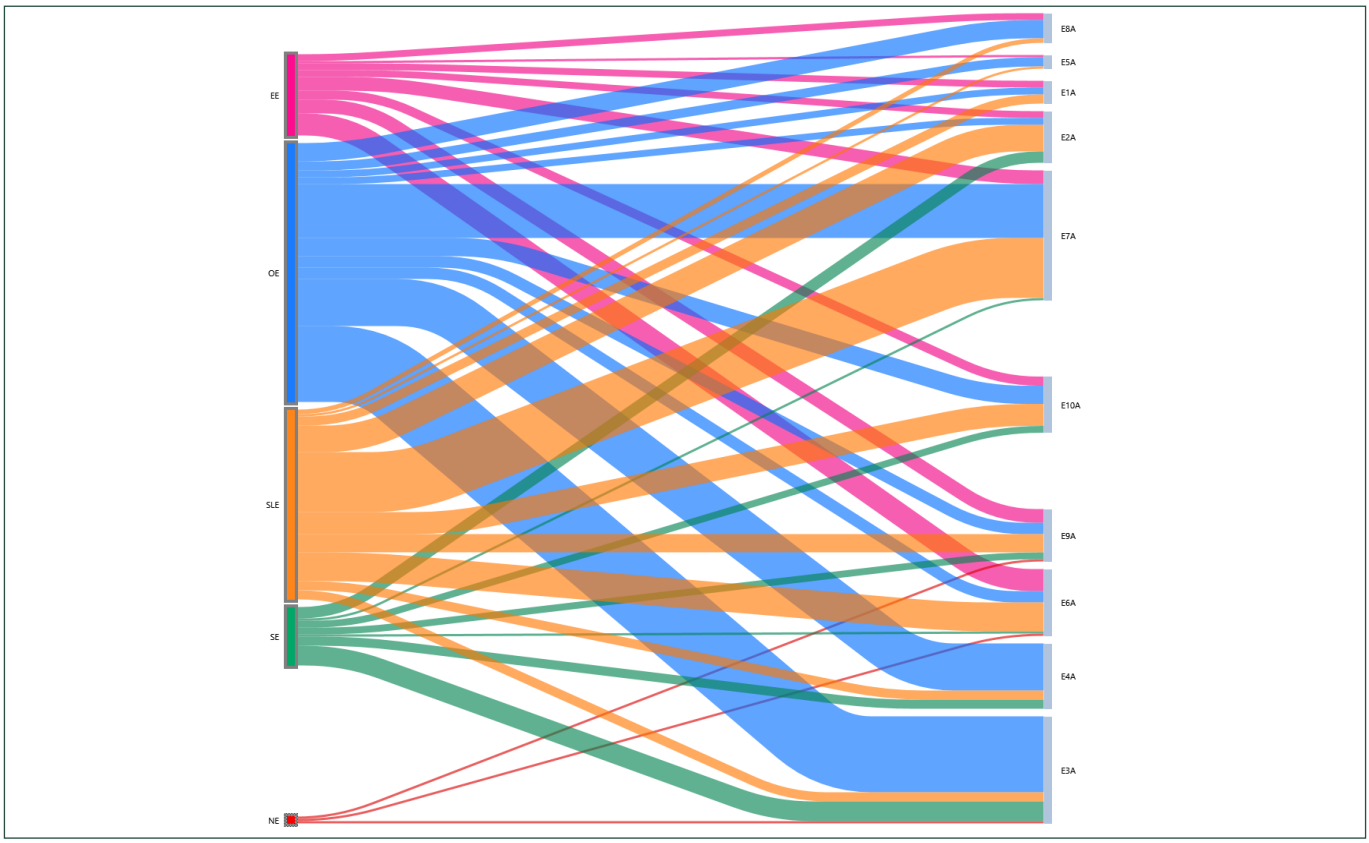
For data presentation, co-occurrence analysis of the categorized citations and mapping of digital technologies were employed. To visualize the interactions between categories, a Sankey diagram was plotted using ATLAS.ti 23, a technique that allows for the association of complex data elements and highlights the magnitude of co-occurrence related to the contributions of each analyzed category (Friese, 2022). Additionally, tables were created containing the number of coded citations per document, associated with the categories and digital technologies mapped for each agtech. Based on the Sankey diagram, descriptive analyses were conducted to understand the main taxonomies and typologies of entrepreneurship, as well as their interactions with the cases. Data analyses were supported by data triangulation, using the previously delimited theory and secondary data collected from the agtechs.

## RESULTS

In this section, we present the analysis of the categories defined a priori and identified from the interviews, involving taxonomies, entrepreneurship typologies, and their relationship with the digital technologies adopted by agtechs for both operational and commercial purposes in meeting specific demands of the agribusiness sector.

The taxonomies were adopted based on the literature, encompassing opportunity-driven entrepreneurship and necessity-driven entrepreneurship. As for typologies, dimensions related to environmental, social, and sustainable entrepreneurship were utilized, considering weak and strong sustainable practices, while incorporating the mapping of digital technologies present in the researched agtechs.

The findings regarding taxonomies and entrepreneurship typologies are demonstrated in the Sankey diagram (Table 2), which, according to Friese (2022), enables visualizing and analyzing the magnitude of the measurements involving the citations through graphical representation in each analyzed case, highlighting the most representative taxonomies and typologies in the codifications. It also allows for visualizing the relationships among the analyzed dimensions.




Source: Developed by the authors using Atlas.ti software. Abbreviations: Environmental entrepreneurship — EE (pink); Necessity-driven entrepreneurship — NE (red); Opportunity-driven entrepreneurship — OP (blue); Social entrepreneurship — SE (green); Sustainable entrepreneurship — SLE (yellow).

**Figure 1.** Identified codifications on taxonomies and entrepreneurship typologies.

The evidence from the citations found in the taxonomies and entrepreneurship typologies presented in the Sankey diagram is supported by the demonstration in Table 3, which shows the co-occurrence of citations from each of the researched documents with each of the predefined categories.

**Table 3.** Co-occurrence of citations from the researched cases.

| | EE | NE | OE | SE | SLE |
|---|---|---|---|---|---|
| E6A | 10 | 1 | 5 | 1 | 13 |
| E3A | | 1 | 34 | 9 | 4 |
| E4A | | | 21 | 4 | 4 |
| E7A | 6 | | 24 | 1 | 27 |
| E1A | 3 | | 3 | | 4 |
| E5A | 1 | | 4 | | 1 |
| E2A | 3 | | 3 | 5 | 12 |
| E8A | 3 | | 8 | | 2 |
| E10A | 4 | | 8 | 3 | 10 |
| E9A | 6 | 1 | 5 | 3 | 8 |
| Totais | 36 | 3 | 115 | 26 | 85 |

Note. Abbreviations: Environmental entrepreneurship — EE; Necessity-driven entrepreneurship — NE; Opportunity-driven entrepreneurship — OP; Social entrepreneurship — SE; Sustainable entrepreneurship — SLE.

Regarding the taxonomies, the research findings reveal that opportunity-driven entrepreneurship is predominant, representing 43% of the analyzed codifications, with a total of 115 citations occurrences. Thus, this category represents the highest occurrence in the agtech startups of the sample, as evidenced by the density of the graph in companies E3A, E4A, and E7A, which have greater significance. On the other hand, necessity-driven entrepreneurship appears only faintly (1%) in the coded responses of the agtechs E3A, E9A, and E6A.

The findings related to typologies allow us to observe that 100% of the agtechs have activities related to sustainable entrepreneurship, with E7A being the most expressive in terms of citations. Environmental entrepreneurship is evident in eight of the agtechs in the sample, representing 14% of the citation occurrences,

while social entrepreneurship represents 10% of the citation occurrences and is present in seven agtechs.

Opportunity-driven entrepreneurship reveals that market demands are for technological innovations (Védula et al., 2022), as is the case with the analyzed agtechs that have the internal capacity and flexibility to absorb market 'pains' and transform them into solutions, as reported by the interviewees:

> "... we took the knowledge that we had, understood the market demands, adapted it to the product, and we closed a contract. That contract was what prevented E3A from going bankrupt at the time" (E3A).

> "... initially, it was a technology that came from abroad, it was a technology embedded in the airplane, and they started validating it here in various agricultural regions, as we know, one of the main agro hubs" (E4A).

> "... he had all the networking in agribusiness, he already knew the problems of agribusiness, and he knew that traceability was one of the problems that needed to be solved" (E7A).

It is understood that market diversification is a strong differential opportunity, and for agtechs such as E3A and E7A, exploring these opportunities expands and mitigates the inherent risks of their businesses. They seek to develop a chain of solutions based on the real problems of their customers by implementing more robust and effective technologies over time.

> "... we provide transparency throughout the supply chain from origin to the end consumer in an auditable process. Because we have a state-of-the-art blockchain platform for end-to-end traceability. We use blockchain technology to have a complete record of the product's history, creating this unique digital identity, but it provides the reliability and necessary trust that those data have not been tampered with" (E7A).

> "And in that, we hit the mark ... we entered the forestry market, which was a more niche market, but no one was willing to solve the problem. So we adapted, took our existing knowledge, understood the market demands, adapted the product, introduced it there, and then it happened" (E3A).

These factors related to opportunities to create market-oriented solutions enable companies to engage with stakeholders and establish a relationship of trust and engagement that sometimes does not occur within the company's environment. This interaction generates trust and a reciprocal relationship to meet future emerging demands. These findings are consistent with the findings of Aliabadia et al. (2022), who identified in their research that strengthening the sustainable entrepreneurial ecosystem enables sustainable development by encouraging entrepreneurs to work toward achieving innovative and profitable activities while keeping economic, environmental, social, and cultural factors aligned with their purposes.

The opportunities associated with knowledge and networking established in different relationships built throughout the entrepreneurs' journey, whether through academic or professional experiences, prove to be crucial in establishing new partnerships and capturing the market, as reported by the respondents.

> "... they graduated in computer engineering to help peach producers assess the health of peach crops, evaluate if there are pests, diseases, and so on. At the time, they saw this possibility of helping them, but it didn't progress much due to the lack of interest from local producers, who were smaller-scale and didn't have many resources to invest in research and knowledge. After some time, an opportunity arose for them to work in the São Francisco Valley, with table grape producers ..." (E8A).

> "... starting to work within this coworking space, being close to these people, knowing that I was working with a startup, starting in this area, in a startup acceleration program, which is Fiemg Lab, an acceleration program for the industry in Minas Gerais, by Fiemg — Federation of Industries of Minas ..., well, I will be able to talk to all the clients there" (E7A).

> "... this technology we use, it comes exactly from the work they developed since their undergraduate studies ... it is a product of Unesp" (E2A).

Based on the interviewees' statements, it is evident that the support of university environments for innovation is a differentiating factor and considered opportune by the majority of agtechs, as the solution validation process receives support from institutions that contribute to the different dimensions that encompass a business. Aliabadia et al. (2022) observe that entrepreneurship ecosystems create an environment that motivates entrepreneurs and encompasses a set of interrelated factors within a specific domain, including universities, research organizations, qualified human resources, formal and informal networks, government,

investors, capital, and professional service providers that drive innovation.

These findings corroborate Rocha et al. (2022), when observing that the involvement of key actors in the knowledge dimension (universities, incubators, and technology parks) in promoting knowledge flows and business exploitation can effectively promote stronger entrepreneurial activity aimed at green initiatives driving sustainability. This feeling is evidenced by interviewee E6A:

> "... we were born within the university, we had university support, we have research grants, we have support from other researchers, from the university itself. So, this made it a little easier for us because we already have a network of contacts within the university, with researchers, with other professors, with other students, so this facilitated access to some resources and support that we needed" (E6A).

> "I always advise people to look for incubators; if I had sought one early on, I wouldn't have made so many mistakes. I only got to know an incubator in 2019. ... I wish I had known about it earlier. We always think that running a business is simple, and then [pause], but it was one of the mistakes we made. Having a Ph.D., I thought it wouldn't be so complex, but I always recommend looking for incubators" (E6A).

This account is corroborated by E3A when they mention that "you start to see that they had a different business vision than what we had," referring to the innovation environment in which they became involved to move forward with the project, which is now a reference in Brazil and Chile, involving fleet management.

These perspectives are aligned with Di Vaio et al. (2022), who highlight that sustainable entrepreneurship advances in understanding how sustainability assessment can be integrated into the life cycle stages of innovative ventures. By introducing and disseminating sustainability innovation, they also play a crucial role in the transition to sustainability through cooperation and collaboration.

The findings also suggest that market demands drive Brazilian companies to offer sustainable solutions through new technologies, expanding the market scope and meeting new demands for products and services with greater technology. These findings corroborate Bertucci Ramos and Pedroso (2021), who consider that the adoption of new technologies, mainly Agriculture 4.0 tools, also called Digital Agriculture, such as drones, sensors, machine-to-machine (M2M) communication linked to the Internet of Things (IoT), agricultural data processing and the creation of applications for managerial decision-making, was decisive for Brazilian agriculture to reach high levels of market share.

Among the technologies developed and utilized, the use of sensors, blockchain, IoT, artificial intelligence, and others were identified (see Table 4). These technologies sometimes also offer opportunities for sustainable business in environmental and social dimensions, as they enable the mitigation of fraud in processes and work with a clean supply chain, such as zero deforestation, avoiding overlap with indigenous areas, complying with environmental regulations, and preventing forced labor and child labor. Additionally, they align with socio-environmental compliance from retail to the end consumer.

> "Brazil, in particular, has been facing global pressure for sustainability. There is a significant demand for it, especially from companies that sell products, particularly those involved in exports. Everyone is buying into it, especially retailers. There are trade agreements that require certain products to originate from areas with no illegal deforestation. Currently, even Europe has a zero-deforestation policy, not just illegal deforestation, but zero deforestation, you know. The products must not come from areas with indigenous land overlap, should not be embargoed by IBAMA (Brazilian Institute of Environment and Renewable Natural Resources), and the owners' CPF (Brazilian tax identification) numbers must not be on the list of forced labor and child labor maintained by the Ministry of Labor. So, there is a socio-environmental compliance throughout the supply chain, starting from retail, selling to end consumers, and not wanting to be involved in socio-environmental issues" (E7A).

> "We align ourselves with sustainability in the sense that the use of technology allows for process optimization, particularly in the day-to-day production of food and agricultural production. It results in cost reduction and optimization of resource usage such as water, soil, and energy. This enables our clients to have a more sustainable agenda. Moreover, we use our algorithms for remotely measuring carbon or predicting how forests can and will regenerate, for example" (E10A).

In the context of social entrepreneurship practices, certain challenges are observed for the analyzed agtechs, as evidenced by the identification of practices in isolated actions. As stated by E4A, "we participated

in a race with underprivileged people here, we sponsored it," which does not adhere to the focus on improving human well-being as advocated by Patzelt and Shepherd (2011). Similarly, another account follows:

> "... we develop social work, and also raise awareness among high school students about the importance of soil. ... there was an event, a fair, the largest coffee fair in Brazil. This technology helped the event neutralize carbon emissions, so this is a very important practice for us in social terms. ... this is how we have been contributing not only to agriculture but also to this social issue" (E2A).

Regarding the typology of environmental entrepreneurship, it is observed that the practices are related to solutions for climate-related issues and their impacts on agricultural production, aiming for the longevity of activities in this space, as reported by E6A, "seeking to reduce the damages caused by droughts," through the implementation of technological models already established in the United States, developed in their academic research, such as an ultrasonic event sensor, improving the results in the face of severe climate changes. These changes have been directly affecting production, and "we thought it would make sense to have a system that assists farmers in decision-making" (E6A).

> "... the weather station, this brings a series of benefits that, by applying it correctly, I reduce damage from pests, reduce the occurrence of diseases, and also reduce the need for new applications ... the monitoring of diseases as well, we converted it to provide an alert for Asian soybean rust" (E6A).

However, when the technology was implemented in Brazil, it faced a lack of expertise to operationalize it, as the 'front end' information hindered technological robustness, as reported by the respondents.

> "... for our systems to accurately simulate the plant, I need the rainfall data from the farm. And so, that was a major difficulty we faced, as sometimes the farmer would forget to record rainfall or would record only one rainfall event even if it rained for 13 days, because that's what was measured by the rain gauge" (E6A).

> "... we focus a lot on gathering this data and minimizing the errors made by the farmers. For example, through the data collected by our sensors, we can understand the history of an area and create management zones within the farmers' fields. However, it's also pointless if the operator doesn't calibrate a machine correctly when it's needed, so all the work goes to waste" (E4A).

The impact of the environment directly affected the simulation, meaning that the developed technology relied on the environmental conditions. In addition to this scenario, the lack of state policies to provide the necessary boost through funding sources, as well as regulations to expedite business procedures, is associated, as pointed out by the participants.

> "... for us, it was the first funding project we obtained resources for. It is extremely bureaucratic, difficult, and time-consuming, so this gap has been a learning experience for us. The selection of scholarship recipients goes through their scrutiny, and we understand that it's challenging to obtain funding ... However, as a startup, we feel constrained by how slow this process is ... The project is supposed to last twenty-four months, and it takes four months just to approve a scholarship recipient" (E7A).

> "We even considered using public means and so on. But ... the cycle is so slow that those who truly innovate don't wait" (E1A).

> "It took a long time for our CNPJ (Company Registration Number) to be issued. Because, as I had a partner abroad, ... my God, it took more than a year, it was very frustrating" (E6A).

These findings corroborate the findings of Zhao et al. (2021), which observe the difficulties that emerging countries face in obtaining incentives, and that these difficulties are also related to the lack of adequate public policies. The accounts testify to the studies of Figueiredo et al. (2022) and Mendes et al. (2022), which discuss how agtechs in emerging countries need to make breakthroughs in the perception of the value of technological products and services, as well as highlight their contribution to necessary changes in daily practices to make activities sustainable, generate fewer environmental impacts, and contribute to socio-environmental inclusion.

Digital transformation proves to be an important pillar for practices related to environmental entrepreneurship. For example, traceability contributes to the evolution and streamlining of processes that were pre-

viously manual and hindered audit processes. The integration of digital technology into agribusiness strengthens the supply chain with increased transparency and addresses the pillars of ESG (environmental, social, and governance).

> "... with this traceability mission, we started adding other technologies to complement the process over time. We began with animal protein, focusing on cattle, then expanded to chicken, and later entered the textile chain. We also ventured into citrus, leather, and other markets with similar demands. Once you have the solution, you establish a clean supply chain and align with the pillars of ESG. ... we were born digital, ... it's in our DNA" (E7A).

Aligned with the concept of technologies, the UN Global Compact, which establishes sustainability pillars through the SDGs, is a relevant discussion in the statement by E7A, "... food traceability, which is one of the pillars we work on, is aligned with five UN SDGs, ... we contribute to these five SDGs of the Global Compact." These SDGs are "Zero Hunger and Sustainable Agriculture," "Decent Work and Economic Growth," "Industry, Innovation and Infrastructure," "Responsible Consumption and Production," and "Partnerships for the Goals."

> "Our traceability is not only declaratory but also documentary, so we provide evidence throughout the process, and it is all digitized in a layer where you have access to the entire chain in just a few clicks. ... This is the biggest difference between us and other players in the market" (E7A).

> "We replace a manual process, which is data collection in the field, with robots and software that capture this information directly in the distributors' and major customers' databases. So we already digitize the collection and processing of data" (E5A).

> "We provide intelligent ways for them to save, how much water they save, how much fertilizer they use, because they don't waste it" (E1A).

> "Almost half of the pesticides are wasted due to application errors or errors in targeting. The farmer applies herbicide and then travels to another farm, and the herbicide ends up killing the entire vineyard or sugarcane plantation" (E6A).

> "I have a problem here, my problem, my equipment, my fleet. I don't know where my trucks are, if they are speeding, who is working ... We realized that a fleet management system, a way to control the equipment, made more sense" (E3A).

> "They started developing a tool to digitize and streamline this process because they had a problem that they needed to apply the solution in a more assertive manner to control pests or diseases at an early stage or even preventively" (E8A).

> "We have a significant impact on the environment, in terms of the amount of CO2 we prevent. Thanks to our system, we are more efficient than a person in a tower" (E9A).

> "We have the opportunity to develop algorithms that detect and predict how a forest will regenerate in the future. Our algorithms are used for logistical purposes within the farms, whether for harvesting or planting, as well as for transporting materials on highways. These algorithms enable you to travel fewer kilometers, consume less fuel, and emit less carbon into the atmosphere" (E10A).

These findings corroborate the perspective of Holzmann and Gregori (2023), who assert that the transformative potential of digital technologies to mitigate and neutralize major environmental and social challenges through entrepreneurial action is increasing. This is supported by the statement of E10A, "through this digital transformation, we transform our clients and data companies. We believe this is the future, much more than just production."

This perspective is further supported by Souza França et al. (2023) and Cavazza et al. (2023), who argue that digital transformation is integrated into the knowledge society and productive processes, assuming greater importance than tangible goods, shaping new paths for growth and innovation. The main digital technologies associated with the researched agtechs have been identified and mapped (Table 4).

Digital transformation requires new understandings and strategies for work relationships, as well as the possibility of (re)structuring and revitalizing agricultural business models (Wolfert et al., 2017). It also proposes different perspectives on what is delivered, to whom it is delivered, and the data that are generated daily (Souza França et al., 2023).

**Table 4.** Mapped digital technologies in the researched agtechs.

| DT Agtechs | TD 01 | TD 02 | TD 03 | TD 04 | TD 05 | TD 06 | TD 07 | TD 08 | TD 09 | TD 10 | TD 11 | TD 12 | TD 13 | TD 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| E1A | v | | | v | v | | | | | | | | | |
| E2A | v | | | v | | v | v | | v | | | | | |
| E3A | v | v | v | v | | v | v | v | v | v | | v | v | v |
| E4A | | | | v | | v | | | | | | | | v |
| E5A | v | v | | | v | v | v | | | | | | | |
| E6A | v | v | | v | v | v | v | | v | v | | | v | |
| E7A | v | v | v | v | v | v | v | v | v | | v | v | | |
| E8A | v | | | | | v | | | v | v | v | v | | |
| E9A | | v | | v | | | v | | v | v | | | v | |
| E10A | v | v | v | v | v | v | v | v | v | | | | v | |

**Note.** TD01 — Applications and software. TD02 — Cloud computing. TD03 — Machine learning. TD04 — Remote and proximal sensors. TD05 — Automation and robotics. TD06 — Digital platforms. TD07 — Information systems. TD08 — Big data. TD09 — Artificial intelligence. TD10 — GPS. TD11 — Blockchain and cryptography. TD12 — Internet of things (IoT). TD13 — Satellites, nanosatellites. TD14 — Telemetry.

The main digital technologies used by agtechs include applications and software, remote and proximal sensors, and digital platforms to streamline work and risk management in agricultural production. These elements demonstrate that digital technologies have been entering various product and service chains (Bolfe et al., 2020). Technological use significantly contributes to improving the performance of the agribusiness sector. This is evidenced by the ubiquity of digital technologies (Table 4) mapped in the researched agtechs. From information systems, artificial intelligence, telemetry, satellites, GPS, to the use of artificial intelligence, all are available for more accurate delivery, aiming to adjust and further improve the elements that guide field operations, increasingly becoming more technological.

It is important to highlight that these technological contributions influence and are related to opportunity-driven entrepreneurship identified in agtechs. They demonstrate elements that systematize the performance, whether technological or entrepreneurial, as the emergence of these opportunities contributes to the entrepreneur's choice, within the context of how the best way to undertake aligns with their opportunity, background, or technical investment for solution development, as E7A states, "... a challenge to deliver a platform that is increasingly better, more suitable, and meets the needs of the farmer."

From this analytical perspective, it is evident that adopting appropriate procedures to promote sustainable entrepreneurship combined with digital technologies in agtechs is opportune. In the contemporary perspective, sustainable development has become one of the main objectives to be achieved to meet current needs, without diminishing the importance of the other objectives listed in the SDGs. However, the challenges and potentialities related to this topic, especially in technology companies and startups, as in the case analyzed, are understood.

## Discussion: Challenges and potential aspects emerging for Brazilian agtechs

In this subsection, we aim to bring together the findings identified in field research, discussions related to sustainable entrepreneurship, the adoption and promotion of technologies, as well as the challenges and potential development aspects for Brazilian agtechs. Gregori et al. (2024) elucidate that digital connectivity is a fundamental aspect of sustainable entrepreneurs' business models. It not only facilitates value creation but also fosters community building around sustainable practices. It is evident that the implementation and adoption of new digital technologies depend on the resources available to the company and rural producers. However, digital transformation is undeniable and beneficial for developing sustainable entrepreneurship, whereas the study by Holzmann and Gregori (2023) suggests that the combination of digital skills and knowledge about sustainability is fundamental for entrepreneurs, highlighting the need for adequate education and training.

It is important to highlight the challenges identified for the growth and acceleration of agtechs, such as the lack of professional management, technological adaptations for product offering and viability, both at the level of consumer farmers, problems with sales scalability, and establishing marketing strategies. As mentioned by interviewees, "We are still struggling in the commercial and marketing area" (E1A), "... sales, product maturity" (E5A), in addition to difficulties in raising funds, and trying "... to make them understand that this work will help farmers improve agricultural practices" (E2A). Gregori et al. (2024) also reiterate the socio-environmental value, that is, the value generated by entrepreneurial practices is not limited to eco-efficiency measures, but manifests itself in the ability to promote collective action and social transformation through digital connectivity.

Based on the findings of this research, it is evident that entrepreneurs are oriented toward sustainabili-

ty and guided by specific principles such as resource allocation, organizational structure configuration, and the creation of management systems that allow them to achieve sustainability goals. These principles help create an organizational environment conducive to innovation, learning, and continuous improvement regarding sustainability. Interviewee E7A emphasizes the importance of "being close to our customers to understand what they need to make the best decision, to achieve greater productivity, our connection to the farmer." The study by Li and Long (2024) shows that the companies analyzed demonstrated that stakeholders should be seen as drivers for the generation of sustainable entrepreneurial opportunities, rather than mere participants in the value co-creation process.

It is also noteworthy that the agtech startup sector, through a growing number of agricultural technology entrepreneurs, is strongly seeking to create a more technological and developed sector in Brazil (Castro & Ramos, 2021). With the support of innovation ecosystems, educational institutions access funding opportunities that foster innovation, having the potential to enhance their managerial expertise and create an organizational design compatible with the needs of the agribusiness market. They have a clearer understanding of existing trends, scenarios, and potentialities in the agribusiness environment to identify niches for action and generate additional income. They deal more clearly with current economic, social, and environmental challenges.

Regarding sustainable positioning for entrepreneurship, this study identified predominantly weak sustainability initiatives, as seen in the literature by Daly (2004) and Amini and Bienstock (2014). Al-Qudah's (2022) study showed that social entrepreneurship initiatives can effectively contribute to sustainable development practices, especially in a context of economic growth. This means there is evidence of adopting practices that align with sustainability premises but are not the core of operations and business. Furthermore, these practices are not interlinked in the production chain in a synergistic and interconnected manner, with the potential to generate transparency and measurement of sustainable production systems that can be certified and legitimized within society. These findings are complementary to those found by Holzmann and Gregori (2023), who investigated the intersection between sustainable entrepreneurship and digitalization, such as the creation of social and environmental value, stakeholder inclusion, enterprise viability, and the role of entrepreneurial individuals. In the study carried out, they found that digital technologies are seen as facilitators that can increase the effectiveness and efficiency of operations, helping to mitigate sustainability challenges.

Thus, it is considered relevant to study sustainable entrepreneurship and agtechs in the Brazilian context, considering the potential positive impacts that such entrepreneurial practices can have on society, the environment, and the economy. Potential aspects are proposed for agtechs to observe in order to enhance sustainable entrepreneurship:

(a) Promotion of environmental sustainability: Sustainable agtechs have the potential to reduce the negative environmental impact of agriculture, such as excessive use of natural resources, soil degradation, water pollution, and loss of biodiversity. By identifying and promoting sustainable practices, agtechs can contribute to greater awareness and adoption of solutions that benefit the environment.

(b) Improvement of food security and product quality: A more sustainable and efficient agricultural sector can contribute to the improvement of food security and the quality of agricultural products. Sustainable agtechs can provide solutions for reducing post-harvest losses, increasing productivity, and improving food quality, benefiting society as a whole.

(c) Job creation and economic development: Sustainable entrepreneurship in the agtech sector can drive the creation of new jobs and foster economic development.

(d) Reduction of social and rural-urban inequality: The adoption of sustainable and innovative practices in Brazilian agtechs can contribute to the reduction of social inequality and disparities between rural and urban areas by providing access to resources, technologies, and knowledge that can improve the quality of life in rural communities.

(e) Awareness and education in sustainability: Increasing awareness and education around sustainable entrepreneurship and sustainable practices in Brazilian agtechs can contribute to the dissemination of research-generated knowledge, positively influencing decision-making and behavior of relevant actors such as farmers, companies, policymakers, and consumers.

(f) Adoption of new technologies: The provision of digital technologies by agtechs, combined with the concept of sustainable entrepreneurship, can con-

tribute to the offering of more technological products and services for the agribusiness sector, driving sustainable and timely growth.

Finally, the study by Li and Long (2024) shows that the adoption of digital platforms allows firms not only to meet the needs of stakeholders but also to acquire resources in return, promoting a cycle of sustainability. The aforementioned study contributes to the literature on sustainable entrepreneurship by developing a research framework that connects the entrepreneurial process to value co-creation on digital platforms.

## PRACTICAL IMPLICATIONS OF THE STUDY FOR STRATEGIC STAKEHOLDERS

The results of this study have practical implications for different stakeholders in the entrepreneurial startup ecosystem, namely:

(a) For startups: Startups can benefit from best practices and insights on sustainable entrepreneurship, helping them develop more effective and sustainable strategies and solutions.

(b) For the innovation ecosystem: Innovation ecosystems can benefit from information on the opportunities and challenges faced by agtechs, which can inform support efforts and policy development.

(c) For the government: The results can help the government identify areas where support is needed to encourage sustainable entrepreneurship and innovation in the agribusiness sector.

(d) For the agribusiness sector: The agribusiness sector can benefit from the innovations and solutions developed by agtechs, contributing to the improvement of sustainability and efficiency in the sector.

(e) For academics and researchers: This study provides a foundation for future research on sustainable entrepreneurship in the context of Brazilian agtechs, encouraging the investigation of new approaches and strategies to promote sustainability in agribusiness.

(f) For municipal and state public managers: Managers can benefit from information on the opportunities and challenges faced by agtechs, which can help them develop more effective policies and programs to support the growth and sustainability of the sector.

In summary, this study contributes to the understanding of practices and strategies of sustainable entrepreneurship in Brazilian agtech startups, highlighting the opportunities and challenges they face. The results have practical, theoretical, and social implications and can inform the efforts of various stakeholders, including startups, innovation ecosystems, government, agribusiness, academics, researchers, and public managers.

## FINAL REMARKS

The findings of this study show that the analyzed companies adopt practices related to the typologies of sustainable entrepreneurship, economic and environmental, while social entrepreneurship receives less attention in their daily activities. While factors that strengthen or weaken business sustainability, the adoption of technologies is considered a very important and critical factor for sustainable development to occur.

Furthermore, it was possible to identify that the study predominantly reveals initiatives related to weak sustainability, meaning that the main objective of the researched companies is market viability, financial feasibility, and market consolidation. Therefore, the results of this study contribute to understanding how Brazilian agtechs adopt sustainable entrepreneurship practices but highlight that the sector faces challenges and opportunities, especially in the adoption and commercialization of technologies. Thus, it is evident that this study contributes to sharing information, and other entrepreneurs, investors, and policymakers can benefit from best practices and insights to support the development of the sector.

In terms of theoretical contribution, this study expands the literature on sustainable entrepreneurship, particularly in the context of Brazilian agtechs. It also provides information on classifications, challenges, and opportunities associated with this type of entrepreneurship, which can be useful for future research. The research has social relevance by highlighting the importance of Brazilian agtechs in promoting sustainable business practices in agribusiness. This can lead to increased awareness of the importance of sustainability and encourage other companies to adopt similar practices.

The implications of the research findings include highlighting the opportunities and challenges faced by agtechs in Brazil, which can inform efforts to support these companies. Additionally, the results can encourage collaboration among startups, innovation ecosystems, government, agribusiness, academics and researchers, and municipal and state public managers to promote sustainability in the sector.

However, the study also has limitations. The limitations of this study include the focus on a limited number of Brazilian agtech startups and the possibility of sample selection bias. Furthermore, the research may not cover all relevant categories and aspects of sustainable entrepreneurship in the context of agtechs. Future research could explore other sectors and regions of Brazil, as well as conduct international comparative studies. Additionally, further research could investigate the relationship between sustainable entrepreneurship and the financial performance of agtech startups, as well as examine the effectiveness of different support policies and programs.

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