Gestão & Regionalidade

Received: 23/07/2022
Accepted: 03/01/2023

Digital transformation in a rural property in the northern region of Rio Grande do Sul: possibilities and limitations

Transformação digital em uma propriedade rural na região norte do Rio Grande do Sul: possibilidades e limitações

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Resumo
O objetivo foi refletir sobre possibilidades e limitações da transformação digital na gestão de uma propriedade rural na região norte do Rio Grande do Sul. Trata-se de uma pesquisa exploratória desenvolvida pela estratégia estudo de caso único, na região norte do Rio Grande do Sul. Os resultados indicam que a transformação digital na propriedade rural decorre do contexto. Manter relações com organizações participantes do ecossistema de inovação no agronegócio facilita o acesso às tecnologias digitais e à capacitação dos trabalhadores rurais para usá-las. As limitações decorrem das competências limitadas dos trabalhadores rurais para operar máquinas inteligentes de forma integrada com os sistemas de gestão da propriedade. Concluiu-se que a tecnologia digital impactou na estrutura da agricultura tradicional, modificando métodos, processos de produção rurais e decisões gerenciais, bem como melhorou o desempenho no processo produtivo. Ao mesmo tempo, a capacitação dos trabalhadores rurais e a infraestrutura de comunicações disponível no Brasil limitam o uso do potencial das máquinas inteligentes.
Palavras-chave: administração rural, propriedade rural, agricultura de precisão, inteligência artificial, modelo de negócios.

Abstract
The objective was to reflect on possibilities and limitations of digital transformation in the management of a rural property in the northern region of Rio Grande do Sul. This is exploratory research developed by the single case study strategy, in the northern region of the state of Rio Grande do Sul. The results indicate that the digital transformation in rural properties stems from the context. Maintaining relationships with other organizations participating in the agribusiness innovation ecosystem facilitates access to digital technologies and the training of rural workers to use them. Limitations stem from the limited skills of rural workers to operate intelligent machines in an integrated manner with property management systems. It was concluded that digital technology had an impact on the structure of traditional agriculture, modifying methods, rural production processes and managerial decisions, as well as improving performance in the production process. At the same time, the training of rural workers and the communications infrastructure available in Brazil limit the use of the potential of intelligent machines.
Keywords: rural management, rural property, precision agriculture, artificial intelligence, business model.

Citation: Grzybovski, D., Mozzato, A. R., & Farias, I. R. F. (2024). Digital transformation in a rural property in the northern region of Rio Grande do Sul: possibilities and limitations. *Gestão & Regionalidade*, v. 40, e20248639. https//doi.org/10.13037/gr.vol40.e20248639

1 Introduction

Different organizations have intensified in the 2020s the use of digital technologies in processes to generate more efficiency (Facin et al., 2022) and reduce waste in a sustainable way (De Clercq, Vats, & Biel, 2018). The technological evolution observed in the post-1990 period generated innovations that amount to a true revolution in different contexts (Sarfati, 2016) and, in particular, in agriculture (Bassoi et al., 2019). The implementation of digital technologies in agriculture shows the evolution of agricultural systems and knowledge management practices (De Paolis et al., 2022) in rural properties, either through the use of information technologies and information systems (ITs/ISs) integrated to agricultural machines and implements, either through the technological system that incorporates artificial intelligence (AI), cloud computing, big data and others in production processes (Pamplona & Silva, 2019; Romani et al., 2020; Silva Neto, Bonacelli, & Pacheco, 2020; Rijswijk et al., 2021; Bentivoglio et al., 2022), which modified the traditional management techniques for precision agriculture (De Clercq, Vats, & Biel, 2018).

In this sense, there is an ongoing digital transformation (Venkatraman, 2017; Lima et al., 2020; Lioutas & Charatsari, 2020; Rijswijk et al., 2021), which began in the 1990s through the **digitization process**, conversion from analogue to digital due to the advancement of information and communication technologies (ICTs) and the configuration of assets (software, music, media and entertainment) (Vial, 2019; Silva Neto, Bonacelli, & Pacheco, 2020). However, in the 2020s, significant transformations are observed in strategic sectors of the economy, including agriculture, in a **digitalization process** to generate insights and process improvements through AI, cloud computing and big data (Silva Neto, Bonacelli, & Pacheco, 2020; Romani et al., 2020; Facin et al., 2022). Thus, processes are changed, economy is generated and business models are subject to revision towards digital transformation (Romani et al., 2020; Lima et al., 2020).

The notion of digital transformation is presented here as an alternative way to the traditional way of executing processes and routines using IS/ITs, as described by Venkatraman (1991; 1994), modifying the concept of “being efficient” and “being fast” to "being smart". Thus, as stated by Souza Filho et al. (2011), ITs/ISs play an important role in crop management and help farmers make more assertive decisions, achieving higher productivity rates, such as those pointed out by Bernardi et al. (2018). However, if, on the one hand, the adoption of digital technologies to boost the production and development of crop generates greater productivity (Souza Filho et al., 2011; Bernardi et al., 2018), on the other hand, social impacts are observed, such as: increased social asymmetries already existing due to digital exclusion (Silva, Freitas, & Pedrozo, 2022), extinction of certain work functions and generation of others (Rijswijk et al., 2021). Therefore, obstacles can not be denied to the adoption of digital technology on all rural properties, precisely because of the lack of specialized labor and high costs of machinery and equipment with digital technology. Soares Filho and Cunha (2015) found limited use of sensors in agriculture and precision irrigation, while Pamplona e Silva (2019) and Puntel et al. (2022) identified low understanding of the importance of producers' harvesting maps, lack of training of machinery and equipment operators with digital technology and lack of qualification of production process managers in agriculture to use digitalized data.

In Brazil, Rio Grande do Sul (RS), especially in the northern region, is featured in the production of agricultural machinery and implements, being responsible for almost half of the national production (Anfavea, 2022), position gained through the improvement of technology used in the mechanization of farming and concentration of industrial and research companies, giving it the title of regional hub in the metal mechanical segment. Also, the region stands out for the concentration of companies specializing in the manufacture of agricultural machinery and implements, equipped with digital technology, and teaching and research institutions (universities, Embrapa, technological centers, incubators) for the technical training and specialization of labor in the segment, configuring a productive agglomeration (Conceição & Feix, 2016). Guided by a state public policy for regional development through the consolidation of regional innovation ecosystems (Inova RS), the northern region of RS intends to be, by 2030, a Latin American reference in innovation through intelligent specialization in technologies associated with agribusiness (SICT, 2022).

The scenario described assumes that rural properties in the region adopt precision agriculture (PA), due to the proximity of industry and teaching and research institutions, and the synergy that such a structural configuration of the space provides. Another assumption is that rural properties adopt digital technologies to extract maximum productivity from farming resources., produce return on technology investments, but still do not have a digital mindset, nor maturity for knowledge management guided by the logic of the digital world that represents a break with legacy models and digital transformation. Study developed by Antonini et al. (2018) indicates that rural producers who use PA are those from small and medium areas of land, with a view to extracting a greater volume of production in a limited area. This suggests that large rural properties, even with a greater volume of resources for investments in digital technology, may have more limitations to break with legacy models and promote digital transformation.

The problem described provoked the following question: what are the possibilities and limitations to the digital transformation in the management of a medium-sized rural property, in the context of the northern region of RS? The **general objective** of the research was to reflect on the possibilities and limitations of digital transformation in the management of a rural property in the northern region of Rio Grande do Sul, investigating: **(a)** the volume of investments made in digital technologies; **(b)** the rural producer's motives for doing so; **(c)** the vision and technical qualifications of the rural worker on the use of these technologies in their work activities and the digital mindset; and **(d)** the way of thinking about strategies, work processes and products based on digital technologies.

The need for more studies on digital transformation in large rural properties, especially those that are increasingly using digital technologies to generate business intelligence, instigated and justifies this research. It is important to emphasize that the rural producer sometimes finds it difficult to apply the ITs/ISs available on the market (Bassoi *et al.,* 2019). A first step to intensify the digital transformation of rural properties is to know the possibilities and limits of PA, which does not dispense with investments in leadership committed to digital logic.

The results of this study are organized into four sections, in addition to this introduction, which contains the research problem, the objective and its justifications. Next, the theoretical and epistemological contours of the central theme are presented, followed by a description of the research design, results, analysis and conclusions.

2 Digital technological innovations in rural administration

Digital technological innovations have contributed to many organizations changing the way they do business, produce and relate in the work environment, as well as starting a process of breaking with the way of acting inherited from traditional business models (Facin *et al.,* 2022). The same digitalization and digital transformation movement is observed in the field, by PA (Inamasu & Bernardi, 2014; De Clercq, Vats, & Biel, 2018; Lima *et al.,* 2020; Romani *et al.,* 2020), but with regional limitations (Lima *et al.,* 2020; Puntel *et al.,* 2022).

PA is a production management technique that considers **spatial variability**, allows the site-specific application of inputs, and **temporal variability**, which allows for a more rational use of inputs, with potential for economic and environmental benefits (Bassoi *et al.,* 2019). It is also a production management system highly dependent on data and information generated in the field, georeferenced, digitalized and high-flow, which provides a structural and conceptual basis for connecting production systems to the digital world (Bassoi *et al.,* 2019), towards the establishment of a new level of technology, digital agriculture (DA) (Bassoi *et al.,* 2019). Both PA and DA contribute to the digital transformation in the management of rural properties.

Digital transformation consists of using IT/ISs and the digital mindset to improve organizational performance and change the way business is done (Facin *et al.,* 2022; Fisher, 2022). The digital mindset is a set of attitudes and behaviors that enable people and organizations to see new possibilities and scenarios from reading data, algorithms and AI, that is, intelligent technologies and intensive use of data (Neeley & Leonardi, 2022). To this end, Rogers (2017) proposes a detailed analysis of the five domains (strategic components) of digital transformation, identified by the acrostic CCVID (customers, competition, data, innovation, value), signaling a management based on new growth strategies, changing old habits and business models built from new ways of working.

Based on the above, it appears that the digital transformation in agriculture is an ongoing process, that digital technologies can create disruptive innovations not only in rural production, but also trigger strategic responses, creating value for the rural product and changing the bases of competition, developing a digital mindset and creating a sustainable business model. In digital transformation, processes are guided by the logic of the digital world (Fisher, 2022), contributing to the structuring of new business models, managing structural changes and overcoming organizational barriers that affect results (Vial, 2019), whose practices have automation and precision agriculture as key elements (Bassoi *et al.,* 2019).

Digital technological innovations, described by the technological advances observed in agricultural machines/equipment with AI and in the development and improvement of genetic material, have become part of agricultural activities (Romani *et al.,* 2020). It is a digital transformation in the field by PA (Inamasu & Bernardi, 2014), which is configured in an agricultural management system based on the spatial and temporal variation of the productive unit characterized by a technological package (Molin, 2002; 2003) and used in the stages of data collection, information management, application of inputs at varying rates, economic and environmental evaluation of the results (Inamasu & Bernardi, 2014; Bernardi *et al.,* 2018; Bassoi *et al.,* 2019).

The practical utility of PA was described by Molin (2002) when defining management units from productivity maps, that is, an image formed by a set of points, which represent:

> a small portion of the field delimited by the width of the harvester platform and by the distance between two readings. [...]Data is collected by sensors installed in appropriate locations on the harvester. [...] These data are transformed into raster-type information in GIS (Geographic Information System) programs after using an interpolator and can then be used for analysis on a single basis and with georeferenced cells (Molin, 2002, p. 3).

The impact of digitization on agriculture, in turn, was expressed by Lioutas and Charatsari (2020) when highlighting improvements in agricultural management through intelligent technologies that save time and resources, increase food quality and reduce environmental impact. Similarly, Lima et al. (2020) state that the "Internet of Things" (IoT) technology, combined with others, enhances the chances of adding value to agricultural production. As Pamplona and Silva (2019) refer, the use of digital technologies in the field promotes a more practical way of working, facilitating the execution of tasks in the daily routine, and also enabling better planning of productive activities and use of production resources by obtaining data that AI provides. One of the examples of field production technologies associated with software is the pre-measurement of temperature, wind speed and other climatic phenomena that are decisive in the decision-making process for planting, maintenance of the crop or harvest (Pamplona & Silva, 2019).

Digital technological innovations in rural properties increasingly use AI and are intended to help rural producers overcome the challenges faced in the production process (Queiroz *et al.,* 2020) due to climate variations, market demands and other contingent factors, adding value to agriculture (Romani *et al.,* 2020). However, not all rural properties have the capacity to manage innovations internally, as pointed out by Bentivoglio et al. (2022). Innovation is the result of a complex interactive process (Schumpeter, 1964) between individuals, organizations and institutions (Bentivoglio *et al.,* 2022) in which communication, learning and social interaction play important roles (Costa & Reis Neto, 2022), both to generate opportunities (Queiroz et al., 2020) as well as social exclusion and poverty (Campanhola, 2005; Wanderley, 2017).

There are variations in the adoption of digital technologies in regional terms (Puntel et al., 2022) and in terms of size of rural properties. Antonini et al. (2018) found that the digital technological innovations present in the PA have been adopted by rural producers in small and medium-sized land areas (less than 50 hectares, according to Federal Law No. 11.428/2006), in search of greater productivity in a limited planting area (Bernardi et al., 2018), showing that the technological resources of PA are not limited only to the application in large rural properties, but actions are needed to improve technology transfer (Campanhola, 2005) with a view to the digital transformation of all rural properties, regardless of size.

Digital technologies are contributing to equip rural producers for digital transformation in the field, due to the possibility of, from digitalized data, generating intelligence and improvement in processes through AI, causing changes in thinking about the inherited business model (Romani *et al.,* 2020; Lima *et al.,* 2020; Facin *et al.,* 2022). The digital transformation includes the main digital technologies, namely: global positioning system (GPS) guidance systems, mapping tools, remote sensing and mobile applications (Puntel *et al.,* 2022). These are used for AI driven harvest monitoring, yield prediction, evaluation of satellite images in search of possible problems both in production activities and in supply, storage and logistics (Bernardi *et al.,* 2018; Silva Neto, Bonacelli, & Pacheco, 2020; Queiroz *et al.,* 2020; Lima *et al.,* 2020), but they can be especially useful to change consumers' experience, add value to Brazilian agriculture, contribute to building a digital mindset and generating insights that enable decision makers to manage digital innovation (Rogers, 2017; Romani et al., 2020; Facin et al., 2022) in rural properties.

Table 1 lists some digital technologies used in rural properties, as well as possibilities and limitations with their implementation.

Most of the digital technology innovations in use on farms have been developed using AI, data science and automation of traditional farm machinery and equipment and the addition of new ones. The images obtained via UAVs, with very high resolution, are surpassing traditional satellite sensing and helping rural producers to make more efficient decisions (Amaral *et al.,* 2020), due to improving the automation of agricultural processes, with specific applications in topographic survey, physiological and biophysical evaluations, monitoring of biological targets, spraying phytosanitary products and application of bioinputs.

Table 1 – Most used digital technological innovations in precision agriculture.

Digital Technology	**Possibilities**	**Limitations**	**References**
Global positioning system (GPS)	Map land boundaries, roads, irrigation systems and problem crop areas (weeds, pests). Localized crop management. Machine location monitoring. Plant/harvest in low visibility conditions. Production management considering the spatial variability of productivity and production factors. Productivity map generation. Production processes are simplified and the producer is more assertive in decision-making.	Accuracy limitations. Some models may have no signal coverage (“shadow areas”). Yield maps require adjustments after data generation in the field.	Molin (2002) Stabile e Balastreire (2006) Garcia *et al.* (2016) Bassoi *et al.* (2019)
Robotics	Digital technology used to automate agricultural machinery and implements, eliminating the need for a human driver. Technique for intensifying production using intelligent machines (robots), which work continuously and consistently with minimal maintenance. Decision errors are less frequent if the machine is well “trained”. Robots control the planting, fertilization, health, root cutting, packaging and weighing process, resulting in products without disease or damage caused by insects.	Energy consumption is a factor that interferes with its range of action. For better use of digital information, robotics requires a modular and multifunctional platform for data acquisition in PA. Most robots are designed for a single application, and the need is typically available at only one season. Automation is not an immediate solution, which generates resistance on the part of rural producers to change crop management practices. It depends on better communication between digital platforms and stable internet for machine programming and operation in production systems. In the social field, robotics is a digital technology that can make people unemployed.	De Sousa, Lopes e Inamasu (2014) Hackenhaar, Hackenhaar e Abreu (2015) Costa *et al.* (2020)
Internet of things (IoT)	Mainly used for data interconnection between machines/tools, increasing the degree of assertiveness in the decision-making process. Increasingly accessible and low-cost technology, which is being associated with mobile location and tracking/monitoring of objects in real time, enabling the emergence of smart farms. Potential to support the sustainability of agricultural systems.	The understanding of the potential of IoT in aggregating an infinite set of devices is still limited, different sets of connectivity devices or network elements with different protocols and different sets of applications. In Brazil, its expansion depends on a still limited rural telecommunications infrastructure.	Bassoi *et al*. (2019) Lima *et al.* (2020) Costa *et al.* (2020)

Unmanned Aerial Vehicle (UAV)/drone	Useful for mapping the planting area and monitoring the agricultural property. With mapping and monitoring, the rural producer is able to visualize areas that suffer from pests or that are insufficiently explored, instrumentalizing managerial decision-making with greater efficiency and enabling the automation of agricultural processes. Applications of phytosanitary products and bioinputs can be optimized.	Technology still depends on a human decision. Although research is evolving towards autonomous decision-making (or with minimal dependence on an expert), technology still depends on a human decision. Computer vision techniques are being proposed to replace human visual assessment. There are few pilots qualified to operate drones in Brazil.	Amaral *et al.* (2020)
Sensors	Electrotechnical devices that respond to a physical/chemical stimulus in a specific way, and that can be transformed into a physical quantity or a signal, for the purposes of measurement and/or monitoring by an instrument. In the field, they provide technical information about the soil (pH, nutrient levels, humidity, temperature, etc.). Technology incorporated into different machines and equipment, including UAVs. They help to measure variables in rural production in real time, helping to qualify the management process according to the requirements and conditions read.	Data generated by sensors needs to be integrated into an automated farm management system that is robust and reliable. Need to improve remote sensing techniques for variable rate applications.	Soares Filho e Cunha (2015) Bossoi *et al.* (2019) Queiroz *et al.* (2020)

Source: The Authors (2022)

In practice, such digital technologies produce economic and financial results favorable to the generation of wealth in the countryside, but also produce environmental and social impacts that sometimes seem to be antagonistic, such as unemployment due to digital illiteracy or the extinction of certain functions in agriculture (Hackenhaar, Hackenhaar, & Abreu, 2015; Silva, Freitas, & Pedrozo, 2022).

Robotics, for example, on the one hand, contributes to achieving higher rates of accuracy in the sowing, weeding and harvesting processes (De Sousa, Lopes, & Inamasu, 2014), on the other hand, reduces the number of rural workers (RIJSWIJK *et al.*, 2021), excludes producers and rural workers with a low level of education to operate intelligent machines (digital exclusion, Silva, Freitas, & Pedrozo, 2022), and contributes to the emergence of a new type of farmer, as described by Hackenhaar, Hackenhaar and Abreu (2015, p. 127-128):

> an academically educated businessman specializing in the mass production of a few agricultural products or just one. He invests a lot of resources in land, facilities and machinery. But it is far from independent. Large food processing companies and supermarket chains dictate the price, variety, size and color of products. Agricultural engineers design production systems for him, and specialist companies supply him with the right types of fertilizer, pesticide and hybrid seed needed for the conditions on his farm. The modern farmer has made a lot of progress compared to his ancestors, but he still faces many challenges and concerns about the possible harmful effects of certain more intense cultivation techniques.

Campanhola (2005) and Wanderley (2017) recognize that there is a "new type of farmer", but he is far from being independent. If, on the one hand, digital technologies facilitate rural work, contribute to soil quality and qualify management decisions, on the other hand, they generate technological dependence and contribute to digital exclusion.

Relying on Souza Filho et al. (2011) and Vial (2019), it is possible to state that the digital technologies implemented in rural properties have a decisive role in the economic-financial performance, in the generation of data to compose the productivity map and in environmental sustainability. However, it is necessary to consider that the development of digital technologies promoted a revolution in society, excluded certain profiles of rural workers, but also generated possibilities to transform basic management models into "intelligent models" (Bassoi *et al.,* 2019). It also introduced the concept of AI in different areas resulting from machine learning, as advocated by Sarfati (2016), Silva Neto, Bonacelli and Pacheco (2020), among others.

AI is a set of algorithms and realizations predefined by the human being, which contributed to the transition from the use of digitization (use of technologies to computerize processes) to digitalization (execution of more complex tasks through the use of digitalized data) (Kelly III, 2015; Silva Neto, Bonacelli, & Pacheco, 2020). Due to its foundation, AI allows decisions to be more assertive, quick and intelligent, leaving it to humans to use their rational capacity to solve problems (Sarfati, 2016), like GPS. In PA, geographic information is a subsidy for knowledge and space management (Molin, 2003), and GPS provides a signal for georeferencing (Molin, 2002), enabling a localized approach to problems on rural properties (Stabile & Balastreire, 2006), in addition to contributing to the performance of rural work even in conditions of low visibility (Garcia *et al.*, 2016).

According to Pereira (2003), with the use of the computer, the implementation of AI became easier, because it reduced the data processing time that, in the past, could be done with pencil and brain, but which would underutilize the organizational resources, generating inefficiency. In this sense, different software started to optimize the worker's time and release their intellectual capacity for the creative process (Kolbjørnsrud; Amico; Thomas, 2016) and to explore the absorptive capacity (De Paolis et al., 2022), producing positive and negative impacts on process management, as pointed out by Rijswijk *et al.* (2021).

With the adoption of AI, in addition to optimizing time, the assertiveness rate is higher than that performed exclusively by the worker's cognitive process and, consequently, errors are reduced. However, before adopting AI, it is necessary to identify the problems you want to solve. According to Sierra (2007), with the advances in technologies, a competitive strategy must be established that becomes vital for the direction of the rural property, being able to leverage the sales of the rural product and the organizational performance.

According to Oleksiewicz and Civelek (2019), machines tend to resemble humans more and more, configuring rural work as an interactive process between human and non-human actors, in an increasingly improved man-machine interface (Fernandes *et al*., 2021). In turn, ethicists and lawyers are urged to deal with issues involving relationships between humans and non-humans. With the expansion of the Internet from the year 2000 onwards and the emergence of numerous solutions and services, it was necessary to adopt new technologies to solve complex, dynamic problems with a certain amount of uncertainty and ambiguity, managing at the same time to handle this exponential mass of data that have emerged as technology advances (Oleksiewicz & Civelek, 2019).

According to Kolbjørnsrud, Amico and Thomas (2016), the increased use of AI contributes to its cheapness, efficiency and potentially more impartiality in its actions than humans. The authors state that such a scenario should not be a cause for concern for workers, as rural work tends to change to focus on things that only humans can do. It can be said that this is how cognitive computing emerges (Kelly III, 2015), which appears to address this new challenge and, behind it, a range of technologies, including AI. However, the cognition mentioned by Kelly III (2015) refers to thinking about cooperation between human and machine, with the part of decoding data and complex problems being the responsibility of machines (robots), and the analysis of processes and managerial decisions remain human, mediated by intelligent machines.

However, countless workers resist new technologies for fear of losing their positions, as new positions and types of work arise due to the evolution and implementation of interactive computer systems for human use through the discipline of human-machine interface (HMI), such as say Fernandes *et al*. (2021). In this logic, Castilho and Campos (2007) state that the process of technologization and use of AI affect human behavior at work, but concern and care for the human minimize resistance and contribute to peaceful coexistence between human and non-human actors in the work environment.

3 Methodology

The research, conceived from the interpretivist perspective as a possibility to break with the dominant view of functionalism (Prolo, Lima, & Silva, 2018) in studies on digital transformation, was developed at the exploratory level using the single case study strategy (Yin, 2001; 2016), with a qualitative approach to the data. To this end, the guidelines of Yin (2016) and Minayo (2016), on theoretical conceptions of the approach articulating with theory, empirical reality and thoughts about reality were followed.

The research universe was defined as the northern region of RS, which stands out in the national scenario in the production of agricultural machinery and equipment (Montoro et al., 2014; Anfavea, 2022), in the production of grains and IT/IS for the agriculture, forming a pre-harvest productive agglomeration (Conceição & Feix, 2016) and an innovation ecosystem guided by a state public policy for regional development (Inova RS) (SICT, 2022).

The research was carried out on a medium-sized rural property ("Gamma Property", fictitious name), which uses ITs/ISs in the production process of grain farming. This case was selected considering the following criteria: size (medium and intensive grain farming), use of digital technology, volume of resources invested in IT/IS, rural workers trained to use digital information, ease of access to data, availability of rural producer in providing the necessary information for the research.

The choice of case is also justified by the interorganizational relationships maintained with other organizations that are part of the innovation ecosystem in agribusiness and agroenergy in the region, as well as by the complementarity of digital assets produced by another company that he maintains with his three children, a family business , which manufactures technologies applied to products for planting and soil fertilization that represent innovations in plantability and generation of high-tech sustainable rural products.

The subjects participating in the research (5) were: the rural producer (owner); two of his daughters (Daughter A; Daughter B) who, together with their father, work in the management of the property and in the family businesses; two rural workers (Worker A; Worker B), responsible for the production process and management of the digitalized data of the crop.

The collection of data from the grain crop and investments made in digital technologies was carried out in the year 2021 and comprised the production and productivity of the period 2017-2020. Data related to digital mindset, organizational culture and business model were collected in the year 2023. The strategy adopted for data collection and analysis was the triangulation of evidence sources (interviews, documents, observations), as proposed by Yin (2001).

In the data collection process, the following instruments were used: **(a)** documentary research: map of the plantation area, reports of what is grown on the property to determine data on productivity, profitability and quality of the crop in the period 2017-2020; **(b)** individual interview guided by three scripts, one for the rural producer, another for rural workers and another for the heir daughters; **(c)** non-participant observation, to learn digitalization practices and the business model. At these moments, field notes related to the technologies used and the way in which they are used by the workers were carried out; the relationship between the worker and technology was verified, as well as the quality of the production process with its use, and the managerial decision process.

The interviews were transcribed and their content subjected to content analysis, as recommended by Bardin (2009). The other data were organized and submitted to source triangulation (Yin, 2001) around three thematic categories defined a priori, namely: (a) investments made in digital technologies; (b) digital mindset; (c) business model.

4 Results and Discussions

4.1 Case Presentation

The rural property under study belongs to a rural producer in the municipality of Passo Fundo and has 140 hectares (ha) of land, with 105ha of cultivation area. He works with crop rotation, namely: soy, corn, wheat and oats. Farming began in the 1970s, in an area of 22.5ha that belonged to the father of the current owner. More land was purchased in the following years and today the property has 140ha.

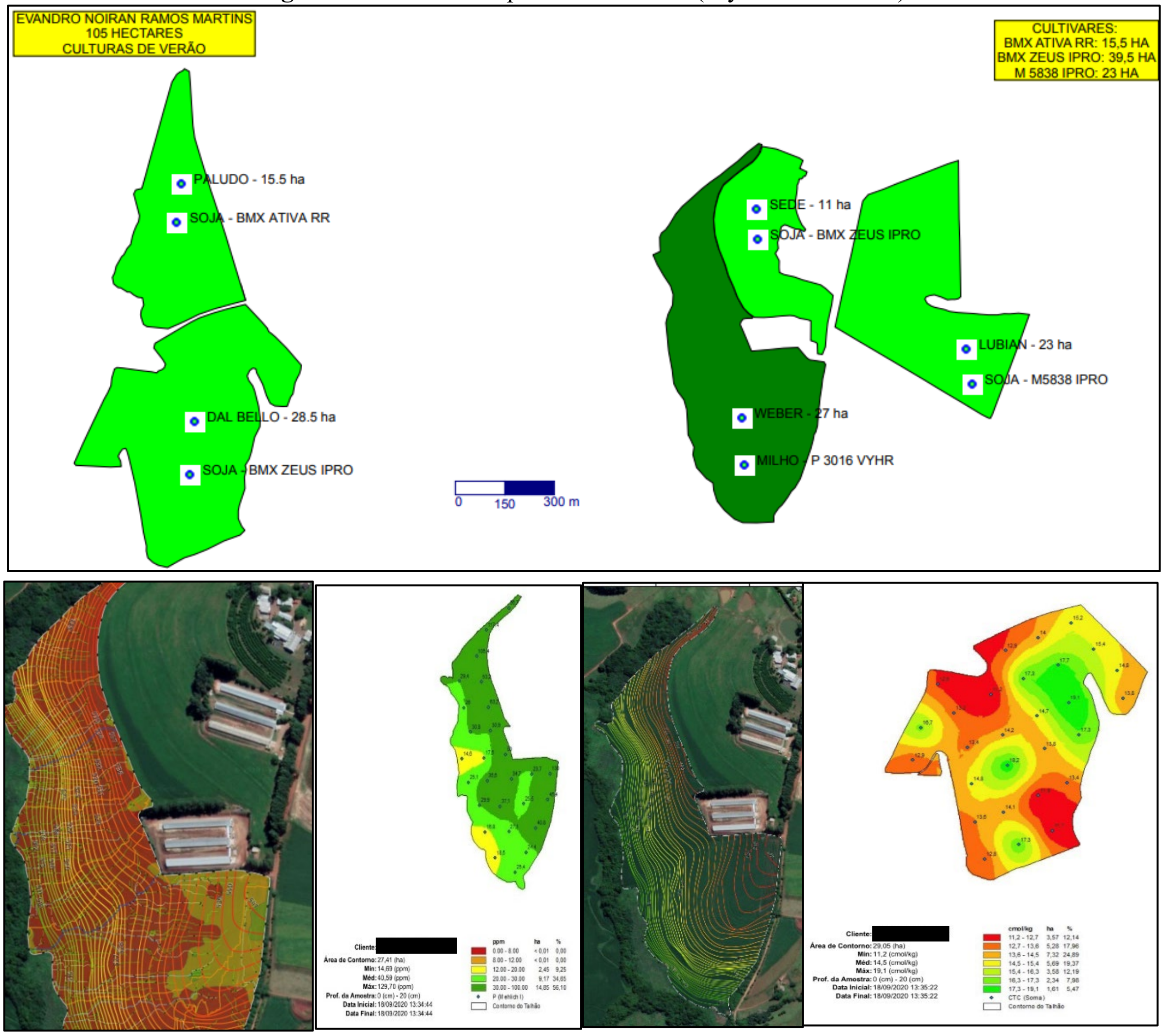
At that time, wheat cultivation began, being the first property in the region to work with mechanization processes (tractors and implements), thus reducing manual work and using technology from the beginning of the company. The rural property was born with a great interest in knowledge and innovation, a purpose that is currently supported by the owner and his children.

In the 1980s, the minimum tillage system was introduced; this type of cultivation seeks to reduce the use of machines in soil preparation and tillage. Tillage is a technique that consists of turning over the land, preparing it for sowing. In addition to the minimum tillage system, the no-till tillage system was introduced (Bertollo & Levien, 2019), which contributes to minimizing soil loss in the crop through minimal soil turning and overlaying the soil with a vegetable layer (Salomão *et al.,* 2020).

In the 1990s, a complete restructuring of the property began, making it a rural company. In 1995, the company's activities were divided, with the inauguration of the consultancy and advisory office in projects and development of agricultural implements, especially with seeders for the no-tillage system. This office began to provide services in the area of product engineering to manufacturers of agricultural implements, through operating manuals, parts catalogs, industrial coding, projects, development, prototypes, field tests and, also, acting with organizational consultancy in the technical, administrative and industrial planning areas. It should be noted that the researched rural property began to serve as an "experimental laboratory" for digital innovations developed by companies that manufacture digital technologies for farming.

The agricultural division of the referred rural property, from the year 2000, was adapted for the execution of prototypes of agricultural implements, with field and bench tests and the development of products and components. Digital technologies started to be used to define the geo-positioned areas with a view to carrying out the planting of the crop, as shown in Figure 1. This technology made it possible to rotate crops and maintain soil quality, contributing to the rural property becoming recognized for its effectiveness by different organizations, through the awards: Entrepreneurial Talents, Top Talent Vip, "Soil Conservationist Farmer and Water Producer". The rural producer considers the award for "conservationist farmer", through the program Conserve To Produce Better, as the main recognition of the Government of the State of RS for his work.

Figure 1 – Summer crop cultivation area (soybeans and corn)



Source: Property documents (2020).

The rural producer interviewed stated that the quality of planting on the property has been improving continuously, and that the reason for this is to have technical information about the soil and adopt conservationist procedures, sustainable practices that directly interfere with the formation of organic matter, water infiltration in the plantations carried out in contour and terracing systems with hydrological mapping of the areas. It also highlights that PH, nutrient levels, humidity and temperature are generated by systems and sensors coupled to agricultural machinery. The interviewee states that, "for a crop to maximize its profit, it is important to take care of the soil. Our main focus is to maintain its integrity." Even with the scarcity of rain, the crops of the grain crop were not lost, obtaining results well above the average in the region and with lower costs, a fact justified by the use of conservationist techniques in soil management with the use of digital technologies, such as: GPS in the machines, autonomous systems for dosing seeds and fertilizers activated by agricultural servo motors, engine control unit (ECU) and control screens, sensors to detect and activate the mechanisms, interface with fertility and yield maps, row seeding, offsets in sowing curves, use of drones, among others.

At that moment, with one focus on productivity and the other on sustainability, Gama Property begins a process of building a digital mindset in all activities. All crop data began to be integrated into a management system, enabling the generation of data, information and business intelligence, even recognizing a limitation for not having managerial accounting.

Daughter B, graduated in Administration and studying Agronomy, who is being prepared to be her father's successor in the management of the rural property, described the knowledge management practices generated by the digitalized data as follows:

> Everything is digitalized and interconnected. We need to professionalize management, have more controls, especially processes. In real time, both the workers and the owner and his daughters analyze the data and make decisions based on them, making visible the lower use of fertilizers and the increase in production. What is still not done is managerial accounting.

The interviewees show that the digital transformation contributes to soil quality due to sustainable practices, while the integration of activities from poultry to farming, due to the power of chicken manure to fertilize the soil, reduces costs with chemical fertilizers. The production of fertile eggs, another productive activity carried out on the property, generates a monthly income, which is added to the income obtained from the sale of grains, and reduces the costs of soil fertilization.

The rural property under study is one of the owner's enterprises, who is an entrepreneur in several areas and activities in the context of agribusiness. A large part of the profits from the businesses he maintains are invested in grain farming. Thus, he manages to invest in new technologies and improve rural property management.

In 2023, the businesses were integrated into a group with three companies. Three generations work on the rural property, with Daughter B taking over management this year along with her father. The businessman's father continues to work on the property, but has no decision-making power. The daughter takes over with the main purpose of professionalizing the rural property, demonstrating commitment to the qualification of management processes. It was evident that the family works with the same purposes and values, demonstrating strategic alignment and harmony between the members of the two generations (father and daughters). However, they do not deny that relationships (family and company) are often mixed up, which they perceive as an obstacle in managerial decisions, on the one hand, and as a driver, on the other hand, to professionalize family management in all companies belonging to the family.

4.2 Presentation and discussion of results

4.2.1 Investments made in digital technologies

The periods of planting and harvesting were analyzed, in which technologies were used to facilitate work and streamline processes on the rural property. As shown in Table 1, in the period 2015-2020, investments were systematically made in the acquisition of agricultural machinery and equipment with digital technologies, which contributed to protect the soil, act in the integrated control of erosion and invasive plants, improve the infiltration of rainwater, retaining moisture and preserving soil nutrients. Likewise, sensors were acquired that feed the monitoring systems for solid fertilizers and fine seeds with digitalized data, in order to be accurate in monitoring the flow of inputs.

Chart 1 – Investments made in the acquisition of agricultural machinery and equipment, in the period 2015-2020.

Description of the good	Year of acquisition	Purchased quantity	Original acquisition value (BRL)
Self-propelled harvester model MF Massey Ferguson 32gkc	2015	1	290.000,00
6.10m flexible cutter bar platform - Caracol	2015	1	60.000,00
Model 7370 tractor, Massey Ferguson brand	2015	1	150.000,00
Knife roller model 6000	2015	1	60.000,00
Grain trailer model 8015 Fankhauser brand	2016	1	33.100,00
Montana self-propelled sprayer	2016	1	350.000,00
Tractor model LS 62hp	2019	1	123.500,00
Seeder Select 2219/21 Serie un028, Kuhn brand	2019	1	70.000,00
AT 200 model monitor	2020	1	2.318,37
Sensor Fert Sensor	2020	21	9.466,59
Distributor of seeds and fertilizers	2020	1	17.500,00
Total		**31**	**1.165.884,96**

Source: Research data (2020).

Investments made in digital technologies contributed to improving the processes of soil preparation, planting and harvesting, especially to digitalize data and generate intelligence in rural business. The self-propelled harvester model MF 32gkc, for example, operates mediated by robotics technology, delivering yield maps to rural producers, which contribute to managerial decisions taken based on intelligent systems in real time (Costa *et al.,* 2020; Hackenhaar, Hackenhaar, & Abreu, 2020). The GPS built into the harvester contributed to improving the systemic approach to the decision, showing images of the specific situation of the plantation, which would not be visible to the human eye, as stated by Molin (2002; 2003).

The tractors, in turn, are equipped with automatic pilot and electro-electronic control systems with sensing, sold by the owner's company, to help with contour planting, showing the producer when and where the areas are or are not leveled. These sensors and digitalized systems are important for full crop monitoring and for more assertive decision-making. Therefore, the evidence points to the use of autonomous machines due to the use of AI.

Together, digital technologies incorporated into agricultural machines contribute to rural property management (De Sousa, Lopes, & Inamasu, 2014), facilitating the assessment of the machine's productivity capacity and supporting the decision on whether or not to spray the crop.

4.2.2 Digital Mindset

Between 2015 and 2020, machines with mechanical technology gave way to machines with electronic and digital technology. Machines were purchased to carry out planting, harvesting, sowing and spraying, and the digitalized data in these processes began to be used to control production and productivity, as well as to manage stocks and transport of grains.

In this logic of the use of technologies, according to the interviewees, from the year 2015 onwards, there was a significant advance in favor of PA in the rural property under analysis. Strategic decisions were taken considering the benefits generated by digitalized data, resulting from the increase in digital technologies implemented in the production process, aiming to improve the planting of crops. According to the rural producer:

> With the implementation of digital technologies we have visible gains. Every time we implement a new technology, we see an improvement in planting and a noticeable increase in productivity and a gradual reduction in costs. Everyone wins, me as a producer, the workers who are involved and the soil itself, which is conserved and becomes more sustainable.

The interviewees, when asked about the effects produced by the use of agricultural machinery and equipment with AI, reported having observed greater capacity for autonomy in planting, better quality in the production process and greater assertiveness in decisions with the digitalization of systems. They also described that the technology implemented on the property contributed to improving control over the planting areas, respecting and improving the chemical, physical and biological conditions of the soil with regard to the application of inputs, for example, qualifying both the plantation and the harvesting and reducing operating costs. The rural producer reaffirms his thesis:

> The progress was fantastic, the use of field metrics brought greater accuracy, contributing to soil sustainability. As a result of automation, I can say that there was a reduction of 14% to 20% in the application of fertilizers and an increase in productivity of 18 to 25% over the compatible years, after the adoption of the technologies, making joint investments highly viable with soil conservation practices, with infiltration of rainwater.

Parallel to the implementation of digital technologies in the production process, the technical capacity of rural workers was also improved, enabling them to operate machines, equipment and systems with AI. Such a practice is important for the work team to incorporate digitalization into their routine activities, while changing the way they relate to work, as explained by Inamasu and Bernardi (2014) and Pamplona and Silva (2019). However, the rural producer and his daughters admit that not all rural workers have the skills to leverage their operations through digital technologies, even though the purchase of technology is linked to the training and assistance of workers. According to them, “we cannot deny that there is still resistance regarding technologies”.

When questioned about this, the rural producer's daughters claim that acceptance of the technology ends up being quick due to the training and follow-up offered by the digital technology supplier. When the same question was asked to the Rural Producer, he stated:

> We hired an employee who was a truck driver, who soon accepted and quickly assimilated the technology and, although he had never worked with the equipment, he soon adapted very well to the integrated system and the digitalized data, presenting very assertive results in the field. In general, we have no difficulty with the workers, they learn quickly and work well with the systems and intelligent data generation after training.

Complementarily, daughter B comments:

> I believe that the fact of having training and follow-up in the introduction of new technologies is essential. Thus, everyone, regardless of schooling or way of working, assimilates quickly, not least because such technologies are not difficult to handle, they are accessible to everyone in this sense.

Still, the interviewees were asked about the impacts of the implemented technologies observed on the behavior of rural workers. They observed “alignment between worker and technology” (Rural Producer), as the work “began to be carried out with agility” (Worker A). As the rural producer observes: “in their routine activities today, they [workers] demonstrate technical knowledge in handling agricultural machinery and equipment”, in which digital technologies are coupled (AI, sensors, others). Daughter A claims not to perceive major difficulties in handling the technology by the workers, due to the fact that all support is provided to them, both by the company that supplies the technology and by the rural producer himself.

It is undeniable that, in addition to the insertion of digital technologies, the rural property works with level planting, which is a technique also known as "contour planting" (Worker B). In the words of the Rural Producer, this planting technique represents a sustainable practice, because: "planting on a level is respecting the soil, using lines that have different heights depending on the terrain. Thus, we avoid erosion [in the planting land] caused by the accumulation of water in an uneven plantation and without respecting the areas".

Respect for the soil and concern for sustainability is present in the speech of the rural producer and his daughters, showing that it is part of the culture of their companies. In this logic, the owner also reports that row seeding should be used to avoid overlapping planting lines, planting with compensation in curves in the deposition of seeds in units per linear meter, in addition to the variable rates in the sowing lines in the process carried out with the planter and the seeder. Thus, there is a reduction of between 9% and 14% in the use of seeds and fertilizers and an increase in productivity of 5% to 12%. Mapping is also carried out with the collection of georeferenced soil samples, for application at variable rates, using outsourced equipment. The equipment enters the soil at pre-defined points to collect, generating a fertility map to show where the most balanced land is found, qualifying the decision on fertilizer application, both in terms of costs and effectiveness in the process. As De Sousa, Lopes and Inamasu (2014) point out, this technology reduces and even extinguishes the use of fertilizers, reduces the amount of seeds in the planting process and, therefore, reduces production costs. Hackenhaar, Hackenhaar and Abreu (2015) also demonstrate such gains, which are observed in the rural property in question, also due to the concern of the rural producer in relation to sustainable practices, both those related to the sustainability of the enterprise, as pointed out by Souza Filho et al. (2011) and Vial (2019), and for environmental sustainability, which can be confirmed when the rural producer won the aforementioned award from the State of RS.

In addition, to generate aerial image maps of the property with greater proximity, drones are being used. According to Amaral et al. (2020), the use of this technology is effective in controlling pests and preserving the crop. The digital images generated by the drones are analyzed, with the help of specific software, with a view to detecting pests and designing an intervention plan. Added to these digital technologies in crop production are the technologies applied in grain storage. Storage can generate extra income for the rural producer (ROCHA et al., 2019). Aware of such benefits arising from storage with digitalization of the variables that interfere with the quality of the grain, the rural producer invested approximately BRL 950,000.00 (base value: September/2020), in the construction of grain silos with aeration systems and inputs. Subjected to the appropriate aeration process, the temperature and water content of the grains interfere with the quality, which may influence the occurrence of insects and microorganisms (Nascimento & Queiroz, 2011).

The workers' acceptance of the new technological resources in agriculture was fundamental to align the interests of the different actors and, at the same time, generate a sense of belonging and engagement, as pointed out by Bezerra and Mozzato (2021). In this sense, daughter A has developed a work with the workers in all her father's businesses, with precepts of work psychology. Both the owner and the workers on the property claim that the professional training offered by the suppliers of digital technologies was fundamental. Here are reports that reinforce the above: "I didn't know anything, I just used my cell phone, but with all the explanations and follow-up from the salespeople, we were getting the hang of it" (Worker B); "I'm glad they taught us, I even thought I wasn't going to learn, but then it was and is very interesting" (Worker B). As the rural producer and his daughters say, "you just need to know how to use a cell phone". In this logic, the rural producer reinforces: "the company that produces the technology teaches and tests it *in loco* and, afterwards, is available to solve any doubt or problem". Daughter B adds: "the company producing the technology is always available, which reassures users, not least because the technologies, despite being complex, are easy to understand for their use".

In this sense, the interviewees understand that investment in digital technologies facilitates the work of rural workers, making it possible to produce more and with better quality in less time compared to traditional production systems. When there is planting, harvesting or spraying, the machines that are integrated with autopilot are used to achieve higher assertiveness rates (De Sousa, Lopes, & Inamasu, 2014). However, intelligent machines need the "supervision" of the worker. For this, the rural worker needs to be qualified and, thus, his cognitive process turns to the most humanized part of the work, leaving the most complex situations to the intelligent machines (Kelly III, 2015). In the context of digital transformation, it must be considered that humans and non-humans coexist in harmony in the work environment (Castilho & Campos, 2007), and this is what was observed in the rural property studied.

4.2.3 Category "business model"

Digital technological innovations in use in production and management processes on rural properties raise debates in different fields of knowledge, with emphasis on rural sociology, rural economy, environment and rural administration. The technological package chosen by the rural producer determines the results obtained in the production process, which are mediated by the financial availability of each rural property to make investments.

The digital technologies implemented in the property studied have changed the way of planting, harvesting and preparing production reports, as well as making decisions. The explanation lies in the importance of digital technology in generating reports at the exact moment of soil handling, enabling assertive decisions to be made on the spot. Such technologies impact on the structure of traditional agriculture, modifying rural production methods and processes, managerial decisions on production and harvesting and analysis of organizational performance.

Thus, with the technological improvement in the planting processes of crops, the productive capacity in the same planted area increased, due to the resources available to carry out controls (pests and water requirement, for example) and reduce production costs to the waste of inputs. Such results were recognized by the Government of the State of RS by granting the owner the prize "Soil Conservationist Farmer and Water Producer". One of the criteria for granting the aforementioned award was the commitment assumed with sustainability practices, aligning production practices with the Sustainable Development Goals of the United Nations Organizations (SDG/UN) through the technologies implemented in the management of water and soil and equally sustainable economic and financial management.

AI in the rural property analyzed has been gaining ground and directly interfering with productivity, planting quality and profitability and, indirectly, with the profile of the rural worker required to operate the new technologies in the field. Increasingly, there is a transition from work, until then manual, to machines, thus empowering workers to exercise their knowledge acquired over time with the entire planting/harvesting system. In this sense, the understanding of Lioutas and Charatsari (2020) on the impact of digitalization in agriculture is resumed. If, on the one hand, it improves agricultural management, increases the quality of food and reduces the environmental impact, on the other hand, it produces exclusions and imposes limits on its use, either by the territorial extension of the property, or by the qualification and education level of the rural workers.

In this sense, the initial assumption that the investigated rural property adopts digital technologies due to the proximity of the industry that produces these technologies and the teaching and research institutions that train professionals specialized in technologies for PA, was confirmed. The Gama Property is an integral part of the innovation ecosystem in agribusiness in the northern region of RS and the synergy that this structural configuration of the space provides contributes to the adoption of digital technologies in the management of rural properties.

Another initial assumption was confirmed, that the Gama Property adopts digital technologies to extract the maximum productivity from the crop's resources and produce a return on technological investments. Therefore, the digital mindset and rupture with the traditional inherited model were verified. However, the owner and the daughters admit that they need to improve on certain managerial controls, above all, related to managerial accounting.

Thus, it can be said that there is evidence that indicates the potential of the Gama Property in creating a new business model. Its practices are being guided by the perspective of sustainability and continuous innovation to add value to the rural product, by the digital mindset in all activities and digitalization of all processes for the rural property to be increasingly intelligent and efficient, in the sense put by De Clercq, Vats and Biel (2018), when conceptualizing PA for the first time. Of such digital practices and technologies implemented in the Gama Property, new ways of producing more and better, with less, have emerged, which as a whole represent ruptures in the way of doing things. This is a disruptive innovation, but there are opportunities to improve management controls and advance in some knowledge management practices, obeying the logic of the digital world.

The analyzed case teaches that there are limitations for the effective occurrence of the digital transformation. Among others described in this section, we highlight the following: (i) low level of qualification of rural workers to deal with digital technology; (ii) precarious communication infrastructure in rural areas, to enable the use of the potential available in intelligent machines; (iii) accuracy limitations in productivity maps, which require qualified professionals in digital data processing in rural property management; (iv) limited amount of pilots on the market, qualified to operate drones; (v) overcoming thinking about the traditional model of rural property management, developing a digital mindset, which requires time; (vi) recognize that the construction of a digital mindset is associated with the integration of crop data into a management system and the reports generated by management accounting.

5 Conclusions

Coming to the end of this research, it is understood that it was possible to reflect on the limitations and possibilities of digital transformation in the management of rural properties, an objective initially outlined. Among the reflections, it is feasible to state that the digital transformation in the rural scenario is ongoing and bringing many possibilities and perspectives to rural properties, even more so when working from the perspective of interorganizational relationships with other organizations participating in the innovation ecosystem in agribusiness in the northern region of RS: digital technology companies focused on innovation in the field, companies specialized in the manufacture of agricultural machinery and implements and teaching and research institutions (universities, Embrapa, technology centers and incubators). However, the existing limitations are not denied, such as the necessary development of the digital mindset that leads to a break with inherited models, so that the digital transformation actually occurs.

The digital transformation in the field has the potential to change processes, generate savings in the different stages of the crop production process and, at the same time, subject the business model to revision. With the emergence of digital technologies, organizational skills were also subject to revision, as digitized data began to generate AI, insights and process improvements. The changes, however, were not limited to processes. Digital technologies also provoked rural producers, their family members and rural workers to use digital logic, demanding a new organizational culture. The rural workers who work on the studied rural property demonstrate acceptance and engagement with technological innovations, aware that the machine needs their cognitive capacity and knowledge to produce effective results in resource management, whether in terms of productivity, profitability or quality. At the same time, such workers are dependent on an ongoing process of professional training in order to know how to understand the complexity of the system inherent to PA.

The evidence in the Gama Property case suggests potentialities, but also limitations for the occurrence of digital transformation in rural properties. As it is a medium-sized rural property and maintains interorganizational relationships with other organizations participating in the agribusiness innovation ecosystem in the northern region of RS, it has easy access to different digital technologies, financial resources to make investments and teaching and research institutions to train its rural workers. At the same time, rural workers do not have the skills to operate agricultural machinery and equipment in an integrated manner with property management systems, because their training is still more oriented towards "knowing how to do", limiting the use of the potential of intelligent machines to use digital technology in its various stages, including to develop action plans and improve the experience of stakeholders.

This case study made both academic and managerial contributions. **Academic contributions** are related to results that contribute to research on the subject, more specifically those related to investments in digital technologies in rural properties, and also studies that combine technologies with the potential of PA, in a harmonious relationship between intelligent machines and rural workers. In turn, **managerial contributions** are directed at rural producers who are considering implementing digital technologies on their properties, who need to be clear about what digital transformation is. Furthermore, business models will remain economically viable. Specifically, for this case studied, the contribution of the study to the analyzes related to the technological investments made is highlighted, allowing greater clarity regarding the consolidated digital transformation in the rural property, and also the one that is still necessary. In turn, as **limitations** of this research, the fact that a study and numerical monitoring was not carried out regarding the gains and losses in the rural property, with the digital transformation.

Given the need for more research on the topic in question, **suggestions for future research** are presented: a new technological revolution is underway in the field through digital engineering, whose technologies develop blockchain and other digital solutions for global food supply chains, which need to be considered in studies on digital transformation in large rural properties. Such technologies demand increasingly qualified rural workers. Thus, conducting research in the field of rural administration through actor-network theory in order to explore the limits of the machine (non-human actor) combined with the individual capabilities of human actors (worker). Another suggestion is to conduct quantitative research that measures the economic gains in large rural properties arising from the digital transformation.

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