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DIGITAL TECHNOLOGIES FOR KNOWLEDGE, TECHNOLOGY APPROPRIATION AND A SOURCE OF COMPETITIVE ADVANTAGE IN FAMILY-BUSINESS RURAL PROPERTIES

ADOÇÃO DE TECNOLOGIAS DIGITAIS PARA A APROPRIAÇÃO DE CONHECIMENTO, TECNOLOGIA E FONTE DE VANTAGEM COMPETITIVA EM PROPRIEDADES RURAIS DE GESTÃO FAMILIAR

TECNOLOGÍAS DIGITALES PARA LA APROPIACIÓN DE CONOCIMIENTO, TECNOLOGÍA Y FUENTE DE VENTAJA COMPETITIVA EN PROPIEDADES RURALES DE EMPRESAS FAMILIARES

Ivanete SCHNEIDER [1]
ivanete@uniarp.edu.br
Maria Eduarda dos Santos PEREIRA [2]
edumaria.pereira08@gmail.com
Leandro HAHN [3]
leandrohahn@epagri.sc.gov.br
Alceu Salles CAMARGO JÚNIOR [4]
alceu@usp.br

[1] University of São Paulo (USP) and Alto Vale do Rio do Peixe University (Uniarp), São Paulo – São Paulo (SP) – Brazil. Postdoctoral Fellowship at School of Economics, Business, Accounting and Actuary/USP (FEAUSP) and Professor at Development and Society Graduate Department at Uniarp

[2] Alto Vale do Rio do Peixe University (Uniarp), Caçador, Santa Catarina (SC) – Brazil. Bachelor of Business Administration.

[3] Company of Agricultural Research and Rural Extension of Santa Catarina (EPAGRI), Caçador, Santa Catarina (SC) – Brazil. Researcher at Experimental Station of Caçador (EECD).

[4] University of São Paulo (USP), São Paulo – São Paulo (SP) – Brazil. Associate Professor at School of Economics, Business, Accounting and Actuary/USP (FEAUSP).

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ABSTRACT: This study addresses a gap in the existing literature concerning adopting digital technologies and knowledge appropriation in family-business rural properties in less-developed regions. The research analyzed how digital technologies can contribute to knowledge and technology appropriation in these properties and its impact on the resources that confer competitive advantage. A survey was conducted on 125 rural family-business owners. The findings reveal a high usage of communication tools, but a low adoption of advanced agricultural technologies, such as management software and automation systems. The analysis further identified that suppliers strongly mediate knowledge appropriation, while the relationships with universities and research centers remain limited. The study concludes that, although there is good development of resources, these properties face challenges in effectively employing advanced technologies. This limitation significantly constrains the international competitiveness of the Brazilian agribusiness sector.

KEYWORDS: Digital technologies. Knowledge appropriation. Rural properties. Technological innovation.

RESUMO: *Existe uma lacuna na literatura sobre a adoção de tecnologias digitais e a apropriação de conhecimento em propriedades rurais de gestão familiar em regiões menos desenvolvidas. A pesquisa analisou como as tecnologias digitais podem contribuir para a apropriação de conhecimento e tecnologias nessas propriedades e seu impacto nos recursos que conferem vantagem competitiva. Um levantamento foi realizado com 125 proprietários de negócios familiares rurais. Os resultados revelam um alto uso de ferramentas de comunicação, mas uma baixa adoção de tecnologias agrícolas avançadas, como softwares de gestão e sistemas de automação. A análise também identificou que os fornecedores desempenham um papel relevante na mediação da apropriação de conhecimento, enquanto as relações com universidades e centros de pesquisa permanecem limitadas. O estudo conclui que, embora haja um bom desenvolvimento de recursos, essas propriedades enfrentam desafios para empregar efetivamente tecnologias avançadas, uma limitação que restringe significativamente a competitividade internacional do agronegócio brasileiro.*

PALAVRAS-CHAVE: *Tecnologias digitais. Apropriação de conhecimento. Propriedades rurais. Inovação tecnológica..*

RESUMEN: *Existe una brecha en la literatura sobre la adopción de tecnologías digitales y la apropiación del conocimiento en propiedades rurales gestionadas por familias, particularmente en regiones menos desarrolladas. La investigación analizó cómo las tecnologías digitales pueden contribuir a la apropiación de conocimientos y tecnologías en estas propiedades y su impacto en los recursos que confieren una ventaja competitiva. Se realizó una encuesta con 125 propietarios de negocios familiares rurales. Los resultados revelan un alto uso de herramientas de comunicación, pero una baja adopción de tecnologías agrícolas avanzadas, como software de gestión y sistemas de automatización. El análisis también identificó que los proveedores desempeñan un papel relevante en la mediación de la apropiación del conocimiento, mientras que las relaciones con universidades y centros de investigación siguen siendo limitadas. El estudio concluye que, aunque existe un buen desarrollo de recursos, estas propiedades enfrentan desafíos para emplear eficazmente tecnologías avanzadas, una limitación que restringe significativamente la competitividad internacional del sector agroindustrial brasileño.*

PALABRAS CLAVE: *Tecnologías digitales. Apropiación del conocimiento. Propiedades rurales. Innovación tecnológica.*

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INTRODUCTION

Digital technology plays a crucial role in contemporary economic development, and its contribution to economic and social progress is widely evidenced in two main domains: first, digital technology optimizes resource allocation, enhances productive efficiency, and stimulates output growth; second, it influences production patterns and the lifestyles of microeconomic agents, driving improvements in their well-being (Yang et al., 2023). The incorporation of technologies into rural properties is an area of research that has been gaining increasing attention in the scientific field (Abdul-Majid et al., 2024; Gabriel & Gandorfer, 2023; Li et al., 2023; Romera et al., 2024).

Essentially, the adoption of technologies has shown significant potential to substantially enhance the productive efficiency of agricultural operations through the implementation of advanced crop management systems, environmental condition monitoring, and optimized resource utilization. This increase in efficiency leads to more robust and sustainable agricultural production, capable of meeting the growing food demands of the global population (Chunfang et al., 2024). Furthermore, the adoption of technologies in rural properties has been associated with significant reductions in production costs. Through process automation, precision agriculture practices, and optimized input use, farmers can achieve more efficient financial resource management, contributing to the competitiveness and economic sustainability of agricultural activities (Li et al., 2023). These technologies also have the potential to improve decision-making processes, enabling more effective management of risks and volatilities, to maximize yields and drive the economic system (Abdul-Majid et al., 2024).

The adoption of technologies in rural properties is also linked to supporting climate change adaptation and environmental sustainability (Chunfang et al., 2024; Oduro et al., 2023), particularly through the implementation of efficient irrigation systems, the selection of crop varieties resistant to extreme climatic conditions, and the adoption of adaptive agricultural practices (Chunfang et al., 2024). Moreover, technology can aid in integrated pest management, soil conservation, and the use of renewable energy, thereby preserving natural resources and ecosystems (Chunfang et al., 2024; Oduro et al., 2023). Lastly, technology adoption can also foster digital inclusion and rural development by providing farmers in remote regions access to information, financial services, and markets. This access can significantly contribute to the socioeconomic development of rural communities, reducing disparities between urban and rural areas, and promoting more equitable and sustainable development (Gabriel; Gandorfer, 2023).

Although the adoption of digital technologies has been widely associated with significant gains in efficiency, competitiveness, and sustainability in the agricultural sector (Abdul-Majid et al., 2024; Chunfang et al., 2024; Gabriel & Gandorfer, 2023; Li et al., 2023; Oduro, et al., 2023), the process of appropriating these technologies in family-business rural properties, especially in

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less-developed regions, remains a considerable challenge.

This is because, on one hand, the utilization of digital technologies is directly dependent on the resources available to the property, including human capital, infrastructure, and access to information. Rural properties located in less-developed regions may face structural limitations that hinder the adoption and effective use of digital technologies, such as internet connectivity, access to technical support services, and farmer training (Trendov et al., 2019). On the other hand, these resources also affect the capacity for knowledge and technology appropriation, as adoption is not limited to the introduction of new tools but requires the development of internal capabilities to use them effectively (Teece & Pisano, 2003). Furthermore, there is an intrinsic relationship between the use of digital technologies and the appropriation of knowledge and technologies, as access to and utilization of these tools can facilitate information exchange, learning, and innovation within these family businesses. However, it remains uncertain to what extent family-business rural properties can transform the adoption of digital technologies into a continuous process of knowledge appropriation that enhances their competitiveness.

Considering this context, this research aims to address the following central question: How does the utilization of digital technologies in family-business rural properties located in a less-developed region of an emerging country affect the appropriation of knowledge and technologies and generate competitive advantage? The overall objective of this study is to analyze how the adoption of digital technologies can contribute to overcoming the challenges of knowledge and technology appropriation in family-business rural properties, and how it impacts their competitive advantage.

Literature Review

Knowledge and Technology Appropriation in Rural Properties

Innovations and digital technologies play a crucial role as viable solutions to contemporary challenges. The so-called Fourth Industrial Revolution (Industry 4.0) is witnessing a rapid transformation across various sectors, driven by the adoption of disruptive digital technologies such as blockchain, the Internet of Things (IoT), data analysis algorithms, artificial intelligence, and immersive reality. In the agricultural and food sectors, the spread of mobile technologies, remote sensing services, and distributed computing is contributing to optimizing small producers' access to information, inputs, markets, financing, and training. These digital technologies are creating new opportunities for the integration of smallholders into a digitally driven agri-food system (Trendov et al., 2019).

The appropriation of knowledge and technologies can be defined as the process throu-

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gh which individuals, organizations, or communities acquire, adapt, and utilize knowledge and technologies developed by others, adjusting them to their specific context to generate value (Ko et al., 2021). This process is central to socioeconomic development, as it enables agents to absorb innovations, technical knowledge, and management practices to apply them to their local environments (Romero-Rodríguez et al., 2020). Knowledge appropriation is a concept defined as a firm's ability to extract benefits from its resources and capabilities, resulting in profit through innovation. The effectiveness of this strategy is strongly influenced by the strength of protection, the magnitude of which is associated with the depth of appropriability. In other words, the more robust and exclusive the mechanisms that protect a firm's knowledge and innovations, the greater its ability to generate sustainable value from that knowledge (Cuéllar et al., 2024).

Appropriation is not merely the passive adoption of new technologies; rather, it involves an active cycle of learning, experimentation, and adaptation, in which knowledge and technology are shaped according to local needs and resources (Ko et al., 2021). According to the theory of innovation diffusion, proposed by Rogers and expanded in the study by Outcault et al. (2022), appropriation occurs in different stages: awareness, interest, evaluation, experimentation, and adoption. These stages are influenced by factors such as interpersonal communication, the relative advantage of innovation, its compatibility with existing practices, perceived complexity, and cultural context. The effectiveness of this process depends on the adopters' ability to modify and integrate knowledge and technology into their operations and local realities.

The adoption of digital technologies in rural properties brings several advantages, such as increased productive efficiency, optimized use of natural resources, and reduced operational costs (Chunfang et al., 2024). Through digital tools, farmers can make more accurate and comprehensive decisions based on precise and real-time data, improving risk management and resilience in the face of climate variability (Abdul-Majid et al., 2024). Moreover, the appropriation of these technologies facilitates the integration of smallholders into global value chains, increasing their access to markets and technical information (Gabriel & Gandorfer, 2023).

An essential aspect of digital transformation is the digital competence of farmers. According to Leddin et al. (2023), digital literacy and technological skills are crucial factors influencing the adoption of digital innovations. Internet access plays a central role, as it not only facilitates the use of digital technologies but also opens a wide range of opportunities for learning, communication, and access to resources that are essential for socioeconomic progress in rural areas (Trendov et al., 2019).

Moreover, the digital economy enables farmers to access innovative financial services, such as online payments, credit, and investment. This is especially important in the context of rising agricultural input costs. Digital financing reduces transaction costs and expands farmers' access to financial resources, mitigating financial constraints on the adoption of

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emerging technologies in the agricultural sector (Chunfang et al., 2024). These technologies form the foundation of the Agriculture 4.0 concept, marking the fourth agricultural revolution, characterized by automation, data analytics, and the use of digital technologies to optimize agricultural production and minimize environmental impacts (Leddin et al., 2023). Beyond the economic impact, digital transformation has broader effects on farmers' well-being, improving their living conditions and reducing the impact of economic and environmental risks (Abdul-Majid et al., 2024).

Previous studies have demonstrated that the appropriation of knowledge and technologies in rural properties primarily occurs through the adoption of digital technologies, such as the IoT, drones, sensors, and geospatial information systems, which assist in agricultural decision-making and process optimization (Li et al., 2023). The dissemination of mobile devices, remote sensors, and other digital tools has enabled smallholders to access critical information, such as weather conditions, crop status, and market trends, while also facilitating the adoption of more sustainable agricultural practices (Trendov et al., 2019). This provides farmers with a deeper understanding of their land conditions, empowering them to make more informed and strategic decisions (Abdul-Majid et al., 2024). These findings support the central hypothesis of this study:

H1 – The greater the use of digital technologies, the greater the appropriation of knowledge and technologies in rural properties.

In the context of emerging countries, such as rural regions of Latin America, the appropriation of technologies is often hindered by structural barriers, including limited internet access, low technical qualifications, and lack of financial resources. However, initiatives that provide technical support, training, and access to financing have shown potential to overcome these barriers, integrating farmers into broader digital ecosystems and fostering open innovation (Oduro et al., 2023). The success of this process depends on enabling conditions such as access to digital infrastructure, digital literacy, and institutional support.

Nevertheless, there are disadvantages, particularly for small farmers in less-developed regions. The adoption of technologies can be financially prohibitive, requiring significant investments in infrastructure and training. The complexity of new technologies may lead to resistance or difficulty in usage, especially among populations with lower education levels or limited familiarity with digital tools (Cuéllar et al., 2024; Khan et al., 2022). Another challenge is the inequality in access to these technologies, which can exacerbate disparities between large and small producers, increasing digital exclusion and limiting the potential for sustainable rural development (Trendov et al., 2019).

Romera et al. (2024) further highlight that the proliferation of technologies targeting the agricultural sector has increased the complexity of operations, resulting in information

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overload for farmers and emphasizing the lack of interoperability between different technological tools. Moreover, the main barriers to the adoption of digital technologies in agriculture are more sociotechnical than purely technical, as they reflect the inherent complexities of agricultural digitalization and the diversity of roles within agricultural systems. Technological solutions, no matter how advanced, must meet the specific needs of farmers to be successfully adopted (Romera et al.,2024).

In conclusion, the adoption of digital technologies in rural properties, despite limitations, facilitates the implementation of strategies to increase productivity, optimize natural resource use, and reduce environmental impacts. This will occur primarily through the integration of geospatial information systems, IoT devices, and advanced data analysis techniques, enabling the enhancement of productivity and more comprehensive capture of the clients' preferences and needs. These technologies will allow the efficient collection, processing, and interpretation of large volumes of agricultural data. Additionally, digital platforms and mobile applications can simplify access to relevant technical and scientific information, promoting the dissemination of knowledge and sustainable practices among networks of producers and suppliers. Thus, the adoption of digital technologies will provide significant support in overcoming the challenges associated with knowledge and technology appropriation in rural areas(Gabriel & Gandorfer, 2023).

Digital technologies and competitive advantage in rural properties

The concept of competitive advantage within the Resource-Based Theory (RBT) (also known as the Resource-Based View) approach understands strategy from an alternative perspective to traditional economics, which primarily focuses on product and market analysis. RBT posits that the production, development, and accumulation of resources with specific attributes within a company result in the achievement of sustainable competitive advantage (Barney, 1991; Barney et al., 2011, 2021). The resources Barney (1991) refers to include all assets, capabilities, organizational processes, firm attributes, information, and knowledge, among others—if the firm can control these assets and implement strategies that enhance the company's efficiency and effectiveness.

Resources are defined as any strength or weakness of a given company, or as assets (both tangible and intangible) that are (semi)permanently tied to the firm (Wernerfelt, 1984). Based on this definition, Barney (1991) categorized resources in the literature into three distinct groups. The first category includes physical resources, such as a company's physical technology, plants and equipment, geographical location, and access to raw materials. The second category covers human resources, including training, experience, critical thinking, intelligence, relationships, and the individual beliefs of managers and employees. The third category com-

prises organizational resources, which refer to the formal structure of the company, formal and informal planning, control, and coordination systems, and informal relationships within groups in the company and between companies operating in the same environment.

The RBT of the firm has existed for more than two decades and has emerged as a dominant management theory for explaining performance differences among firms (Barney, 1991; Barney et al., 2011, 2021; Mugera, 2012). The theory posits that the internal resources a company controls have the potential to be a source of sustainable competitive advantage if those resources are valuable, rare, inimitable, and nonsubstitutable. While RBV serves as a critical theoretical foundation in management literature, it has yet to be widely studied in the context of rural properties (Mugera, 2012).

Even so, previous studies have shown that the utilization of digital technologies can optimize business resources by facilitating access to detailed information on resources such as soil, plants, and animals, addressing the specific needs of rural properties, such as better production control, improved optimization, and more effective planning. On the other hand, technology is also driven by external factors, such as market demands for increased competitiveness. This can be supported by precision agriculture, which focuses on the reduced use of fertilizers, and other digital means like blockchain, which aids in food and timber traceability. Organizational factors, such as the existence of cooperatives, can also play an essential role in sharing the costs of technological change for small producers. Additionally, technological mediators can facilitate access to new digital solutions (Ferrari et al., 2022).

Furthermore, the literature highlights that the strategic resources of rural properties are predominantly intangible, particularly within organizational and human resources, confirming some of the necessary premises for configuring strategic resources that are valuable, rare, and nonsubstitutable. These resources can enable better utilization of other resources (such as physical, technological, financial, and reputational), promoting synergy and greater organizational gains (Carvalho et al., 2014).

This theoretical foundation supports the second central hypothesis of this study:

H2 – Quanto maior a utilização de tecnologias digitais, maior a presença de recursos que conferem vantagem competitiva sustentável nas propriedades rurais.

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METHODOLOGY

Research Context

Despite significant advances in expanding access to information and communication technologies (ICT) and digital networks observed in recent years, particularly in developed countries that have nearly achieved universal access, significant challenges persist, especially in less developed nations or regions. In these contexts, many people are unable to utilize e--services due to a lack of access to ICT, low income, limited user capabilities, and inadequate infrastructure (Trendov et al. 2019).

To understand and study this context, we selected, for convenience and accessibility, the Midwest region of Santa Catarina, which includes eight municipalities and represents the poorest region of the state.

The selection of the mid-west region of Santa Catarina for this study is based on socioeconomic indicators that highlight its relative vulnerability within the state. According to data from the Government of Santa Catarina (2020), this region, comprising eight municipalities, exhibits one of the lowest Gross Domestic Product per capita values in the state, falling below the state average. Additionally, the Human Development Index of these municipalities is at levels comparable to less developed regions of Brazil, facing significant challenges in education, health, and income. Furthermore, data from the FIESC Observatory (cited in Hahn & Baldissarelli, 2024) support this disparity, emphasizing that the region experiences lower levels of industrialization and limited access to basic services, reflecting characteristics that position it among the most deprived areas in the state and comparable to peripheral regions in other Brazilian states.

This area shares characteristics with other underdeveloped regions in Brazil. Rural properties in this region exhibit a variety of factors, reflecting the area's agricultural and livestock diversity. In general, these rural properties vary in size and predominant agricultural activities, including grain cultivation, fruit production, cattle ranching, dairy farming, and the presence of environmental preservation areas and forest reserves. Additionally, family farming plays a significant role in the local economy, contributing to the subsistence and sustainable development of rural communities in the Midwest of Santa Catarina.

Data Collection and Sample

This research is classified as descriptive and was executed following the premises of the cross-sectional survey method, aiming to collect data from a representative sample of rural properties (Fowler Jr., 2009; Hair *et al.*, 2011). The data collection technique utilized struc-

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tured questionnaires administered through electronic forms and self-administered in-person surveys to a single representative from each rural property in the region.

Thus, for this research, participants were Brazilian, over 18 years old, and rural producers from the Midwest region of Santa Catarina, who voluntarily agreed to respond to the questionnaire. This study's sample comprised completed and returned questionnaires, totaling 125 respondents. Table 1 presents the main characteristics of the sample.

Table 1. Sample Characteristics

	Variable	Frequency
Labor Force of the Property	Family labor	75,2%
	Temporary wage workers (during planting/harvest season)	41,6%
	Permanent wage workers	16,8%
Activities of the Properties	Grain cultivation	64,0%
	Cattle farming (beef/dairy)	56,0%
	Poultry and/ or swine farming	5,6%
	Horticulture	54,4%
	Fruit farming	24,0%
	Reforestation	8,8%
	Other	8,0%
Production property uses	Own land only	53,6%
	Leased land only	7,2%
	Both (own land and leased land)	39,2%
Education Level of the Main Manager	Elementary Education	24,8
	High School	42,4%
	Higher Education (undergraduate)	24,8%
	Postgraduate Education (graduate)	8,0%

Source: research data (2024).

According to the data presented, most of the properties are primarily characterized by family labor (75.2%), although there is additional support from temporary wage workers (41.6%) and permanent wage workers (16.8%). The predominant activities are grain cultivation (64%) and cattle farming, either for beef or dairy (56%), followed by horticulture (54.4%) and fruit farming (24%). Additionally, most properties use only their land for production (53.6%), while 39.2% combine both owned and leased land. Regarding the education level of the main managers, 42.4% have completed high school, and 28.8% have higher education. On average, five people work on each property, with variations ranging from 1 to 70 workers.

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Measures

The Knowledge and Technology Appropriation Questionnaire was developed based on the research by Sprakel and Machado (2021). The remaining sections of the questionnaire were created following the guidelines provided by Hahn and Hahn (2024).

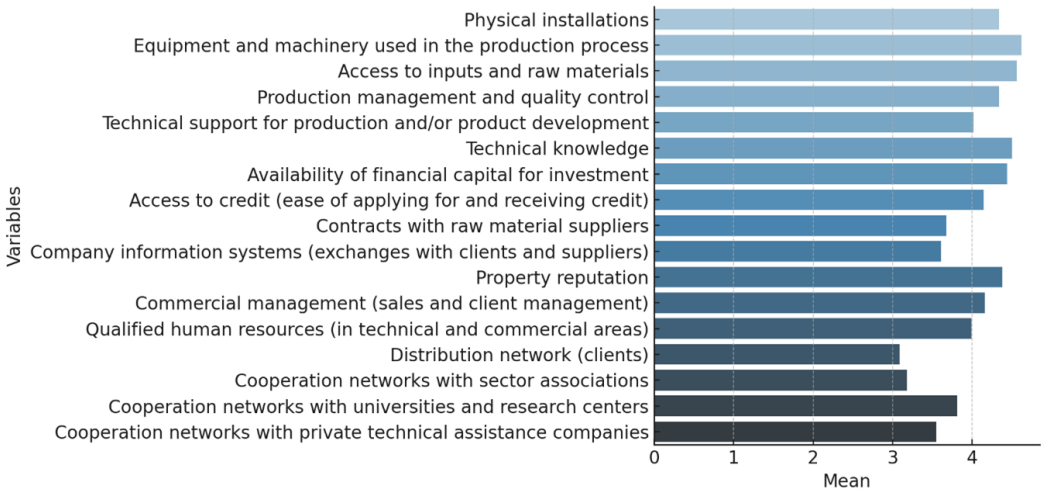
Data Analysis

The data were analyzed using IBM SPSS Statistics 20 software, employing descriptive statistical analyses (frequency distribution, univariate measures such as mean and standard deviation) and bivariate analyses, such as correlation and linear regression (Cohen, 1988; Hair *et al.*, 2011).

Results

Figure 1 presents an analysis of the resources in rural properties in terms of averages (a), as well as a heatmap (b) showing the frequency of intensity levels for each type of resource. The color intensity in the heatmap reflects the magnitude of the responses. The data reveal that respondents highlight the main resources of their properties as physical installations (average 4.34), the use of equipment and machinery in the production process (average 4.62), access to inputs and raw materials (average 4.56), and production management and quality control (4.34). Additionally, the availability of financial capital for investments (4.44) and the property's reputation (4.38) are also considered crucial for development and innovation in the sector.

Figura 1. Mean perceptions of each resource in the properties; Heatmap of property resources.



Fonte: Dados da pesquisa (2024).

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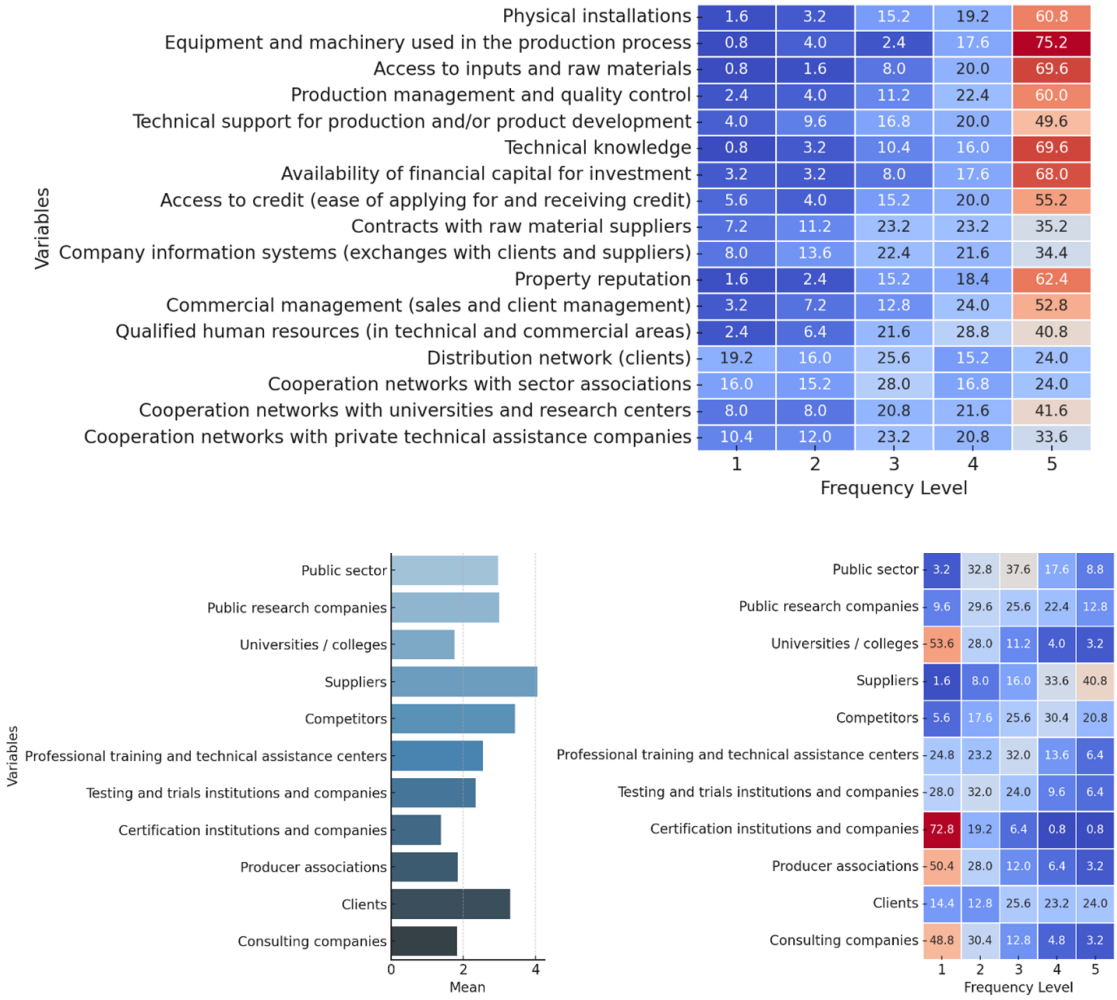
Figure 2. Mean frequency of relationships with external actors for knowledge appropriation; and heatmap of knowledge appropriation.



Source: Research data (2024).
Note: In the heatmap, each cell represents the frequency for each resource type, with the color intensity reflecting the magnitude.

Regarding the use of digital technologies (Figure 3), communication tools, including WhatsApp, Telegram, and Facebook, showed the highest levels of adoption (average 4.24). Weather forecasting software and applications also had wide usage within the sample (average 3.98), as did banking operation software and apps (average 3.55). In contrast, lower averages were associated with technologies such as agricultural management software (average 2.66), GPS and automation systems (average 2.38), software and apps for purchasing inputs (average 2.09), drones and satellite remote sensing (average 1.66), and automated irrigation systems (average 1.71).

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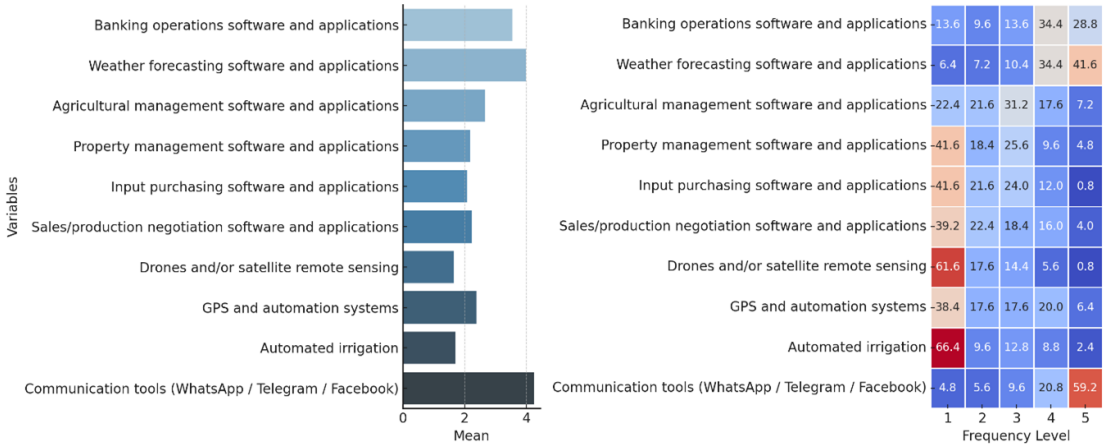
Figure 3. Mean usage of digital technologies; heatmap of digital technology usage in the Properties



Source: Research data (2024).
Note: In the heatmap, each cell represents the frequency for each resource type, with the color intensity reflecting the magnitude.

Next, Table 2 presents the correlation results between the dimensions under analysis, where a linear correlation is a fundamental premise for using linear regression. For this purpose, Pearson's correlation was used (ranging from –1 to 1), which measures the strength and direction of the relationship, with positive values indicating a direct correlation (when one variable increases, the other tends to increase as well) (Cohen, 1988; Hair *et al.*, 2011).

The results show that the correlation between "Knowledge and technology appropriation" and "Property resources" is positive and significant ($r = 0.297$, $p < 0.01$), indicating a moderate and important relationship between these variables. Similarly, there is a positive and significant correlation between "Knowledge and technology appropriation" and "Use of digital technologies" ($r = 0.291$, $p < 0.01$). The strongest relationship is observed between "Property resources" and "Use of digital technologies" ($r = 0.419$, $p < 0.01$), suggesting that the availability of resources is more strongly associated with the use of digital technologies.

Table 2. Correlation Results Between Variables

	Knowledge and technology appropriation	Property resources	Use of digital technologies
Knowledge and technology appropriation	1		
Property resources	0,297**	1	1
Use of digital technologies	0,291**	0,419**	0,419**

Source: Research data (2024).
**Significant correlations at $p < 0.01$.

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Table 3. Result of the hypothesis test

	b	t Statistic	R^2	R^2-ajus	F Statistic	F Sig.	Hypotheses
H1. Use of digital technologies → Knowledge and technology appropriation	0,258	3,371	0,085	0,077	11,366	0,001	Supported
H2. Use of digital technologies → Property resources	0,440	5,124	0,176	0,169	26,253	0,000	Supported

Source: Research data (2024).

Table 3 presents the results of the hypothesis testing based on linear regression analysis, where two hypotheses are evaluated, exploring the relationship between the use of digital technologies and two dependent variables: knowledge and technology appropriation (H1) and property resources (H2). For each hypothesis, the R^2 and adjusted R^2 coefficients indicate the proportion of the variability in the dependent variable explained by the independent variable (use of digital technologies).

In the case of H1, the R^2 value of 0.085 and the adjusted R^2 of 0.077 suggest that approximately 7.7% of the variability in knowledge and technology appropriation can be explained by the use of digital technologies. The F-test (11.366) and the significance value of $p = 0.001$ indicate that the model is statistically significant, and thus, hypothesis H1 is supported.

For H2, the R^2 value of 0.176 and the adjusted R^2 of 0.169 shows that around 16.9% of the variability in property resources can be attributed to the use of digital technologies. The F-test (26.253) and the significance value of $p < 0.001$ indicate that the model is highly significant, supporting hypothesis H2. In both cases, the t-values for the regression and b coefficients confirm the statistical significance of the tested relationships, validating the associations proposed by the hypotheses.

Discussion and Conclusions

The results of this research reveal important aspects of the dynamics of knowledge and technology appropriation in family-managed rural properties in a less-developed region. The first significant observation is the strong reliance of rural producers on suppliers and competitors as their primary sources of knowledge and technology—findings that align with previous research conducted in regions with less-developed innovation ecosystems (Hahn & Hahn, 2024). This dependence on suppliers, in particular, can be attributed to the limited interaction with educational and research institutions, such as universities, certification companies, and producer associations. The low engagement with these entities highlights a scenario where

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rural producers, by not accessing specialized and innovative knowledge from universities and research centers, remain dependent on what suppliers introduce to the market. This dependence on suppliers was first identified by Pavitt (1984) and continues to be relevant and applicable in more recent studies (Bogliacino & Pianta, 2016).

It is important to note that, on the one hand, reliance on suppliers facilitates access to new technologies, as supplier companies, generally possessing greater capacity for innovation and technological development, can provide rural properties with modern implements, equipment, and inputs. However, this relationship also creates a scenario of technological dependence in which producers may not have full autonomy to select the innovations that best meet their needs, remaining constrained by the commercial offerings of supplier companies.

Another crucial point discussed in this study is the evidence that, although the rural properties in the sample possess considerable resources in terms of physical facilities, equipment, and inputs, most of the use of digital technologies is concentrated in communication tools such as WhatsApp, Telegram, and Facebook. More advanced technologies, such as agricultural management software, GPS systems, automation, and drones, still have little penetration in these properties, with significantly lower averages. This suggests that, while rural producers have invested in communication infrastructure and technology, the adoption of innovations that could directly impact the production process and generate sustainable competitive advantages remains limited.

Thus, the technological adoption capacity of these producers is an important discussion point. The existence of resources such as modern machinery and quality control systems indicates that, even as family-run properties in a less-developed region, there is a significant level of available infrastructure. However, the question remains as to how strategically these resources are being used to generate competitive advantage. In practical terms, this means that properties may be acquiring technology but still face challenges in its appropriation and efficient use. This finding is consistent with the observation that the correlation between property resources and knowledge and technology appropriation is positive but only moderate ($r = 0.297$, $p < 0.01$).

Theoretically, this study supports the literature on absorptive capacity (Cohen & Levinthal, 1990 and further authors), which suggests that the mere acquisition of technology (or the resource itself) is not sufficient to generate a competitive advantage. The rural properties studied seem to exhibit a limited capacity to absorb and integrate more advanced technologies into their processes, as evidenced by the predominance of communication tools rather than advanced agricultural technologies. This phenomenon can be understood as a reflection of the lack of technical knowledge and training on the part of the producers (as discussed in Cuéllar et al., 2024; Khan et al., 2022; Trendov et al., 2019). In addition to their limited interaction with

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research entities, producers may not be fully equipped to take full advantage of the resources they acquire.

From a practical standpoint, the results highlight the need for interventions that promote technical training (as previously proposed by Khan et al., 2022; Leddin et al., 2023) and expand partnerships with universities and research centers. Strengthening cooperation networks between rural properties and educational institutions could be an effective strategy for improving access to specialized knowledge and innovation. Additionally, incentive policies aimed at increasing the inclusion of rural producers in technical training programs could help reduce their dependence on suppliers as their sole source of innovation.

Finally, while rural properties demonstrate a solid resource structure, greater efforts are needed to ensure that these properties not only acquire technology but also use it as a source of sustainable competitive advantage. This study suggests a gap between the availability of resources and the effective appropriation of technology, which warrants further exploration in future research.

Limitations and Recommendations for Future Research

Despite the significant results and the achievement of the central objective of this research, certain limitations need to be acknowledged, particularly regarding potential biases inherent to the context and sample analyzed. One of the primary limitations is the regional dependence of the data, as the study was conducted in a single less-developed region. While these factors are crucial for understanding the local dynamics of technological appropriation, they also limit the generalizability of the findings to other, more industrialized regions or areas with a higher presence of large agricultural properties and more robust innovation ecosystems. The socioeconomic heterogeneity between regions may influence the dynamics of technology adoption and knowledge appropriation in ways that were not fully addressed in this study.

Another relevant bias relates to the respondents' self-reported nature of the data. The collection of information regarding the use of resources and technologies was based on the perceptions of the rural producers themselves, which may introduce response biases such as exaggerated optimism or underestimation of the use of specific technologies. Additionally, the limited technical knowledge of rural producers could affect how they report their use of technologies.

Based on the discussions raised, several directions for future research emerge, focusing on a deeper exploration of the dynamics of knowledge and innovation appropriation in rural properties, particularly in less-developed regions. First, it would be essential to explore more thoroughly the role of suppliers as mediators of innovation in rural properties. While the results of this research indicate a significant dependence on suppliers, little is known about how

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and to what extent these suppliers influence the selection, acquisition, and implementation of technologies in the properties. Investigating the commercial incentives that drive suppliers' technological offerings could shed light on whether this relationship fosters or limits genuine innovation in the sector.

Another relevant topic is the absorptive capacity of rural producers, aiming to better understand the factors that limit the effective appropriation of advanced technologies. Future research could investigate which technical training mechanisms are most effective in maximizing the productive use of advanced technologies, especially in regions where human capital is scarce. Additionally, research could examine the extent of knowledge intermediation carried out by universities and research institutions and how collaboration between these actors and rural properties could be enhanced.

Other topic that deserves attention is the role of public policies and institutional support networks in fostering agricultural innovation. Given the low interaction between producers and universities or producer associations, future studies could explore how institutional structures can be more effective in promoting an environment that facilitates the flow of knowledge and innovation to rural properties. The development of rural innovation ecosystems, where universities, associations, and producers actively collaborate, could be a fertile area for research, with a focus on identifying the incentives and barriers that hinder the development of these networks.

Lastly, there is a vast field of exploration in organizational innovation within rural properties, particularly regarding the strategic use of digital technologies. Future studies could examine how the adoption of communication technologies (such as WhatsApp and Telegram) can be leveraged to increase organizational efficiency and collective learning and how these technologies can be integrated with more advanced tools, such as agricultural management systems, to maximize the benefits of innovation and competitiveness.

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