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Drivers and Barriers to Digital Agriculture Adoption: A Mixed-Methods Analysis of Challenges and Opportunities in Latin American

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Abstract: This study aims to identify and analyze the adoption of digital agriculture in Latin America, focusing on Brazil, by examining barriers and drivers across diverse biomes. It identifies key factors influencing technology integration using a mixed-methods approach, including a literature review and empirical data from selected Brazilian municipalities. The central barriers include limited digital literacy, financial constraints, labor shortages, service provider accessibility, and infrastructure inadequacies. Drivers encompass productivity gains, cost reduction, improved management, infrastructure availability, and producer education. This research highlights the need for strategic policy interventions to address these barriers, enhancing digital literacy, infrastructure, and connectivity. Overcoming these challenges is crucial for realizing the transformative potential of digital agriculture and promoting productivity, sustainability, and economic development in the region.

Keywords: climate-smart practices; smart agriculture; AI in agriculture; digital technologies; sustainable agriculture

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1. Introduction

Information and communication technologies in agriculture have become increasingly frequent, driving the shift from traditional to digital agriculture. Digital agriculture, also known as smart agriculture, refers to the use of digital technologies that enhance sustainability, productivity and optimization, encompassing everything from pre-production to post-production, transforming traditional agriculture into a more efficient and environmentally friendly sector [1,2].

The central pillar of digital agriculture refers to the availability of connectivity linked to the use of digital technologies (such as big data, artificial intelligence, machine learning, remote sensing, and internet of things), which provide rural producers with access to data that allows them to make computerized decisions, as well as the possibility of optimizing their production practices [1,3–5]. However, incorporating these digital technologies is a complex process permeated by a series of challenges and opportunities, including the transformation of the traditional paradigms of the sector. (The traditional paradigms refer to the practices and beliefs established in agriculture prior to the introduction of digital agriculture. These paradigms include decisions based primarily on personal experience and local knowledge, manual land management, limited access to information and connectivity, reliance on manual labor, and linear supply chains with little transparency. Digital agriculture challenges these paradigms by introducing data-driven decisions, automated

management, robust connectivity, new technological skills, and more efficient and transparent supply chains [6]). Among the main challenges are issues related to privacy and data security [4], the adaptation and development of technological capabilities [6], and economic, financial, and infrastructure issues linked to their adoption [7].

Against this backdrop, this paper aims to identify and analyze the main drivers of and barriers to adopting digital agriculture, considering the context of Latin American countries. Furthermore, an effort will be made to compare the findings from the literature with the barriers identified in adopting digital agriculture technologies within the Agro-Technological Districts (DATs) of the Center of Science for Development in Digital Agriculture (Semear Digital Center/Brazil). In other words, it will seek to answer the following questions: RQ1: "Based on the specific scientific literature on the Latin American context, what are the main drivers and barriers to the adoption of Digital Agriculture?" and RQ2: "Which of the barriers identified in the literature are present within the operational context of the Semear Digital Center?".

Although there have been previous studies on the subject, there is a gap in the literature about identifying the main barriers and factors in the adoption of digital agriculture, specifically considering the context being addressed. From a methodological point of view, the study adopts an exploratory approach and was conducted using a bibliometric review, documentary research, and the specific analysis of the Semear Digital Center. The structure of the paper comprises three parts, in addition to this introduction and conclusions. The first part presents the theoretical framework used to conduct the research, presenting the main concepts and their characteristics. The second part deals with the methodological approach adopted in this study. The third part presents the results and discussions obtained through bibliometric analysis and compares the results with identifying barriers within the Semear Digital Center.

As an initial contextualization, the Semear Digital Center (The Semear Digital Center, through a multi-institutional collaboration combining cutting-edge research, applied agri-digital expertise, telecommunications innovation, and academic rigor, aims to drive equitable digital transformation in Latin American agriculture. Focusing on scalable solutions for smallholder farmers, the center addresses technical and social barriers, such as connectivity, tool accessibility, digital literacy, and policy gaps. With a 5-year horizon, the Center aims to achieve systemic impact through interoperable technologies, supportive policies, and human capital development, ensuring that innovations are technologically robust, economically viable, and culturally adapted to Latin America's diverse agricultural contexts.) is funded by the São Paulo Research Foundation (FAPESP) and involves seven Brazilian institutions: Embrapa digital agriculture (host institution), University of São Paulo/Luiz de Queiroz College of Agriculture (USP/Esalq, Piracicaba, Brazil), CPQD, National Telecommunication Institute (Inatel, Santa Rita do Sapucaí, Brazil), Agricultural Economics Institute (IEA, São Paulo, Brazil), Agronomy Institute (IAC/Apta, Campinas, Brazil), and Federal University of Lavras (UFLA, Lavras, Brazil). The Center's 5-year operation began in November 2022 and aims to overcome inequalities in agriculture through research, development, and innovation in Information and Communication Technology to increase the production and productivity of small and medium farmers.

2. Theoretical Background

Agriculture is one of the sectors most significantly affected by the growing adoption of Information and Communication Technologies [1,8]. This phenomenon involves the use of digital technologies and the optimization of agricultural processes, considering the use of several tools, such as artificial intelligence, sensors, and drones, to improve production efficiency, reduce costs, and provide more sustainable practices for the sector [9].

Digital agriculture has, therefore, emerged as a "guiding thread for the demands of consumer markets attentive to the sustainability of production in the countryside" [1] (p. 61). Its implementation allows, for instance, farmers to monitor their crops in real time, analyze climate data, automate agricultural tasks, and optimize the use of inputs. Producers can make computerized decisions by collecting and analyzing data, resulting in greater profitability and, consequently, healthier and more sustainable harvests [10].

In other words, digital agriculture represents a revolution in the agricultural sector and can be defined as "the use of detailed digital information to guide decisions along the agricultural value chain" [11] (p. 5084). The potential benefits of digital transformation in agricultural production chains are highlighted by Bolfe and Massruhá [12]: (i) at the level of input manufacturers, optimization of resources, greater production efficiency, development of disruptive solutions, new products and markets, greater safety and quality; (ii) at the level of rural producers, greater efficiency in agricultural productivity, rural sustainability, possibilities for new job opportunities, optimization of decision-making, and greater possibilities for rural succession; (iii) at the level of processors, planning and management actions, adding value, reducing losses, food and drink quality, greater safety, and certifications; (iv) at the level of distributors, product diversity, new market niches, use of different marketing platforms, efficient deliveries, and traceability; (v) at the level of end consumers, urban–rural connectivity, digital protagonism, cultural appreciation, transparency and engagement, and new businesses.

Its implementation, however, requires the availability of infrastructure and connectivity on the rural properties, and depending on the technology, technical knowledge, and digital literacy for its operationalization, as well as specificities concerning the type of soil and climate. The high initial investment, maintenance, and management costs also appear to challenge producers to overcome [13]. Another issue is related to the possibility of widening economic and social inequalities, especially in the case of small and medium-sized properties (as well as isolated properties), given their low access to connectivity and infrastructure [14]. In this regard, state action is required to implement public policies capable of supporting this transformation, and creating a favorable environment for the adoption of these digital technologies. The type of organization (e.g., cooperatives) in which producers participate is also seen as a driver for the adoption of these technologies in the field, enabling collaboration, the exchange of knowledge and experiences, as well as the shared use of technologies [2,3,15–17].

As mentioned above, some studies have sought to identify such barriers and drivers of adoption [2,3,13,15], among others, but few have explicitly focused on the Latin American context, mainly conducting a bibliometric and empirical analysis.

Regarding the scope of this paper-Latin American countries-it can be seen that there has been an increase in internet access in recent years, but this has not yet reached 100% of rural properties. Given the region investigated, this data exemplifies just one of the challenges that permeate digital transformation in agriculture. Considering this context, it is essential to identify and analyze the obstacles hindering this adoption, as well as the drivers that motivate rural producers to implement these technologies, considering the region's specific characteristics.

3. Materials and Methods

This paper employs a mixed-methods approach, integrating bibliometric research, document analysis, and empirical research, to thoroughly understand the barriers and drivers of digital agriculture in the specific context of Latin American countries. In this regard, the study was developed through four stages: 1. data collection and processing,

2. data eligibility, 3. bibliometric analysis, and 4. comparison between the identified barriers.

To conduct the bibliometric research (steps 1 to 3), the Scopus, Web of Science, Dimensions, and Scielo databases were used, with the results filtered and standardized using the VOSviewer 1.6.19 software. Data were collected in February 2024, using a combination of keywords in English, Portuguese, and Spanish (Query equation (English, Portuguese, and Spanish): ("Latin America" OR "Argentina" OR "Bolivia" OR "Brazil" OR "Chile" OR "Colombia" OR "Costa Rica" OR "Cuba" OR "Ecuador" OR "El Salvador" OR "Guatemala" OR "Haiti" OR "Honduras" OR "Mexico" OR "Nicaragua" OR "Panama" OR "Paraguay" OR "Peru" OR "Dominican Republic" OR "Uruguay" OR "Venezuela") AND ("digital agriculture" OR "smart farming" OR " smart agriculture" OR "agriculture 4.0" OR "agriculture 5.0") AND ("constraints" OR "driver" OR "adoption" OR "barrier" OR "use" OR "application" OR "willingness" OR "intention")). After compiling the results (n = 140), the publications were screened based on the reading of titles and abstracts (n = 104), keeping those that dealt exclusively with the adoption of digital technologies by the agricultural sector, considering both studies on experiences of use and studies on barriers and adoption factors in the context above.

The data were parameterized using the VOSviewer software to analyze the co-occurrence of authors' keywords, generating a visualization (Network Visualization) that represents the frequency of occurrence of keywords. The proximity of the terms indicates their association in the same cluster based on the frequency of co-occurrence [18,19]. The software parameter was set to a minimum threshold of 2 occurrences per keyword, yielding 7 clusters and identifying 39 keywords.

Subsequently, considering the publications screened, we categorized the barriers and adoption factors identified, presenting an overview of the main determinants and obstacles to implementing digital agriculture in Latin American countries. The final step compares the barriers identified through bibliometric analysis with those identified in the Semear Digital Center's implementation context. Figure 1 details the methodological design of the research, presenting the processes carried out to obtain the results.

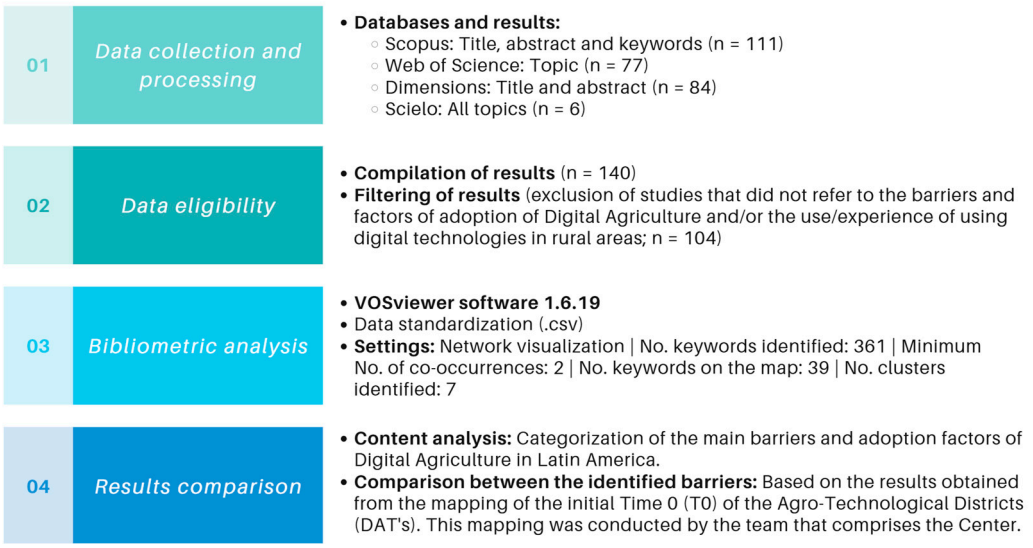

Figure 1. Methodological design of the research. Author's elaboration.

The integrated mixed-methods approach adopted in this paper provides a more robust and nuanced understanding of digital agriculture adoption in Latin America than any single method could achieve alone. This methodology bridges the gap between theoretical discourse and practical implementation challenges by triangulating quantitative

bibliometric patterns with qualitative document analysis and on-the-ground insights from the Semear Digital Center. The systematic comparison between literature-derived barriers and empirical findings exposes critical gaps in the regional innovation ecosystem, while the multilingual, multi-database approach ensures comprehensive coverage of Latin American scholarship.

This triangulation addresses a critical gap in Latin American literature by: (1) validating theoretical barriers (e.g., infrastructure) with empirical data from DATs, revealing understudied challenges like land tenure insecurity (e.g., DAT Jacupiranga); (2) identifying divergences (e.g., climate adaptation prominent in bibliometric clusters but less visible in DATs); and (3) enabling context-specific policy design, such as prioritizing connectivity investments in mountainous regions (e.g., DAT Caconde).

4. Results and Discussion

The results obtained are presented in two parts. The first is the bibliometric analysis. The second part presents a compilation of the main results regarding the barriers and adoption factors of digital agriculture in the Latin American context, with a special emphasis on the Brazilian case.

4.1. Bibliometric Analysis

Figure 2 shows the analysis of the co-occurrence of keywords used by the authors identified in the bibliometric research carried out, with a view to the topic of this study. In addition to the barriers and adoption factors of digital agriculture, the bibliographic productions identified also deal with experiences of using and implementing these digital technologies in the field. The data from this research generated this network graph, which comprises seven interconnected clusters, highlighted in different colors.

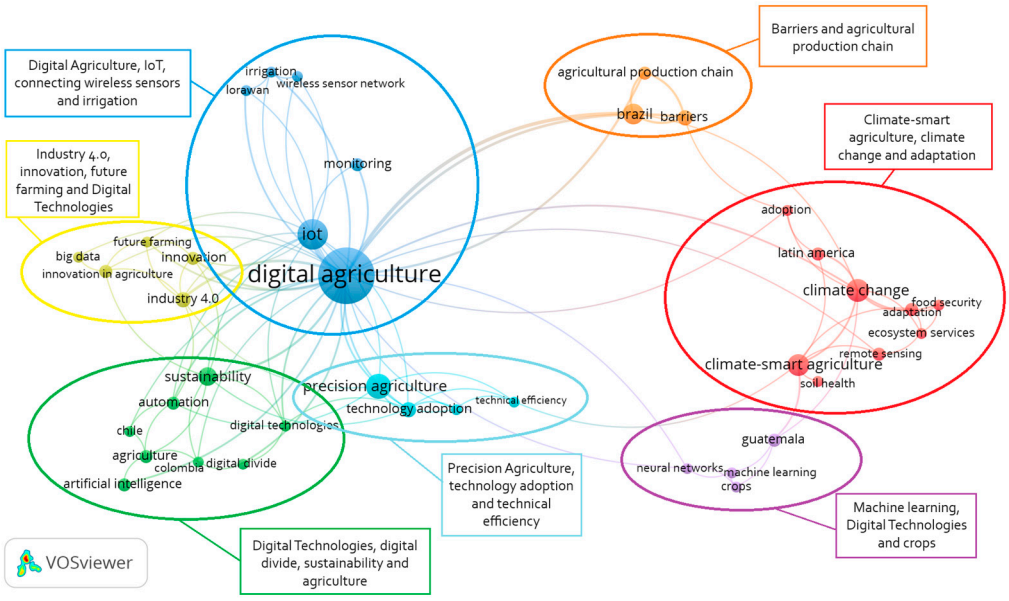

Figure 2. Network visualization of bibliometric research. Author's elaboration.

The red cluster, composed of nine keywords, shows the relationship between the concept of 'climate-smart agriculture', climate change, and the need to adapt traditional agriculture to more sustainable agriculture. Although this concept is not explored in this article, this cluster presents a series of research studies that can be highlighted, such as Acosta et al. [20] and Mosso et al. [21], which deal with the issue of gender inequality in the agricultural sector and its relationship with the adoption of sustainable practices in

Latin American communities. In this particular cluster, the dimension of sustainability and global climate change is emphasized, given the activities linked to the agricultural sector.

The green cluster, comprising eight keywords, deals with the use of digital technologies in the countryside, the relationship between digital exclusion in different contexts in Latin American countries, and sustainability. Publications by Engås et al. [22] and Florez et al. [23] are examples of studies that explore the difficulty of access to digital technologies in developing countries and their potential consequences concerning this inequality.

The blue cluster, made up of six keywords, addresses the relationship between digital agriculture, the implementation of IoT technologies, the connection of wireless sensors, the use of these technologies for irrigation, as well as the monitoring of these different types of use. Among the central studies identified, Chacho et al. [24] deal with experiences of using digital technologies in monitoring and controlling production applied to traditional properties in Ecuador. Collado et al. [25] provide an insight into the potential and challenges of implementing digital agriculture in Panama, and Ahmed et al. [26] explore the use of sensors and IoT technologies in Chile, paying special attention to their benefits, such as improving the decision-making process and validating advanced forecasting algorithms.

The yellow cluster, made up of five keywords, highlights the interconnection between Industry 4.0, technological development, innovative processes, and the prospect of future agriculture. In this regard, the relationships between the use and development of these technologies for the field, the challenges inherent in the contexts of Latin American countries (such as the lack of resources, infrastructure, and digital literacy), and the need to foster innovation in the 4.0 segment are explored [27–29].

The purple cluster, made up of four keywords, deals with the relationship between machine learning technologies and their use in different types of crops. Among the prominent studies, De Macedo [30] specifies that the use of remote sensing, in conjunction with machine learning algorithms, makes it possible to deal with agricultural operations data more quickly and at a lower cost. Smith et al. [31] explore the use of these technologies as tools capable of generating soil and crop data, which can make it possible to draw up specific recommendations for certain contexts, guaranteeing profitable production for small and medium-sized farmers.

The ciano cluster, comprising four keywords, shows the relationship between the adoption of digital technologies in the field, such as precision agriculture technologies, and their technical efficiency. An example of this relationship is the study by Carrer et al. [32], which suggests that adopting Precision Agriculture Technologies can enhance farmers' decision-making, increasing the efficiency of the resources used in the production process, and economic and environmental sustainability. However, among the obstacles to this adoption are aspects related to the farmer's education level, the property size, and the availability of specialized technical assistance.

Finally, the orange cluster, made up of three keywords, specifically addresses the relationship between the barriers to adopting these digital technologies in agricultural production, with more studies on the Brazilian case. These specific studies are explored in the next section of this article.

Although the clusters are differentiated by color, the analysis shows a direct interconnection between them. This interconnection reveals the direct relationship between terms encompassing both the concept of 'digital agriculture' and the concept of 'climate-smart agriculture'. Focusing more on 'digital agriculture', makes it clear that it correlates with the adoption of different digital technologies, and their potential, challenges, and experiences linked to each use and cluster identified.

Based on the studies identified, several barriers and factors affect the adoption of digital agriculture technologies in the Latin American context. Specifically, regarding adoption

barriers, firstly, the owner's lack of digital literacy and technological knowledge stands out, especially regarding digital and technological platforms [9,12,13,33]. Secondly, the economic and financial conditions are associated with the high costs of installations, skilled labor, operating components, sustainable energy sources, and management/maintenance of the technologies incorporated [2,13,17,29]. Thirdly, a lack of qualified labor and a limited number of companies providing services [12,13,33–35]. Fourthly, there is a lack of trust and uncertainty about the usefulness and benefits of technology, as well as cultural issues linked to family traditions [22,34]. Fifthly, matters related to the available technological infrastructure [2,17,36].

Other barriers are also mentioned by the publications identified, such as environmental, ethical, and social issues, age of the producer, educational background, interruption of work in progress [2,17,36], lack of state support, regional issues and lack of local economic development [34] political challenges and/or lack of procedures and agreements on data use [2,17,36], need to foster R&D and innovative business models and insufficient interactions between the actors of the technological innovation system [2,17,34,36], necessity of tests and an action plan for technology implementation [2,17,36], and negative opinions from relatives, neighbors, and friends [29].

On the other hand, the perceived usefulness (such as increased productivity, reduced costs, faster work, and reduced workload) and the expectations of the producer are considered to be the main factors in the adoption of digital agriculture [13,29]. In second place is the need to improve farm management and organization, followed by the availability of technological infrastructure [29,37], education background [9,37,38], property size [9,37,39], economic and financial conditions [9], age of the producer [38], facilitating conditions [38], facilitating conditions (ease of use and testing) [40], personal and formal source of information (training courses/seminars, consultants, farmers' associations) [38], propensity to take risks and innovate [38,39], experience of the producer [9], and type of organization to which the producers are linked (whether cooperative or individual) [38,39].

These adoption factors are in line with the study conducted by Schroeder et al. [14], which highlights elements linked to the producer's profile (age, education, gender, willingness to take risks), property characteristics (property size, type of property, level of debt, resource endowment), social relations (local cultures, social environment, attitudes), support institutions, the legal environment (laws and regulations); economic factors (cost of investment, return on investment and profitability), dimensions related to technological infrastructure (ease of use, perceived usefulness, availability of technical support, complexity of the system, compatibility with other technologies), information on technological availability (exhibitions, fairs, seminars and demonstrations), and decision support systems (ease of data processing, support for decision-making).

Figure 3 summarizes the main barriers and adoption factors for digital agriculture in the context discussed, considering the highest frequencies presented for each element. It is interesting to note that, in both cases, some elements (in bold) can act as barriers to adoption and adoption factors, such as the producer's economic and financial conditions, the technological infrastructure available, and the producer's educational level.

The aspects addressed by these studies are interconnected, making it possible to outline a multifaceted scenario of various elements that play essential roles in adopting digital technologies in the countryside. However, two relevant aspects should be highlighted: 1. Membership of cooperative networks tends to favor the adoption of digital technologies by rural producers [2,17,36,38,39]; 2. The need for these digital technologies to be adapted to the needs of producers [2,17,36].

Cooperative networks are recognized as environments that facilitate the incorporation of these technologies without necessarily relying on government funding. In this context,

it is argued that the dynamics of these networks can help to mitigate some of the barriers previously identified, such as limited economic and financial resources, as well as limitations related to producers' technological knowledge, as can be seen in some Brazilian case studies [17,36,38,40].

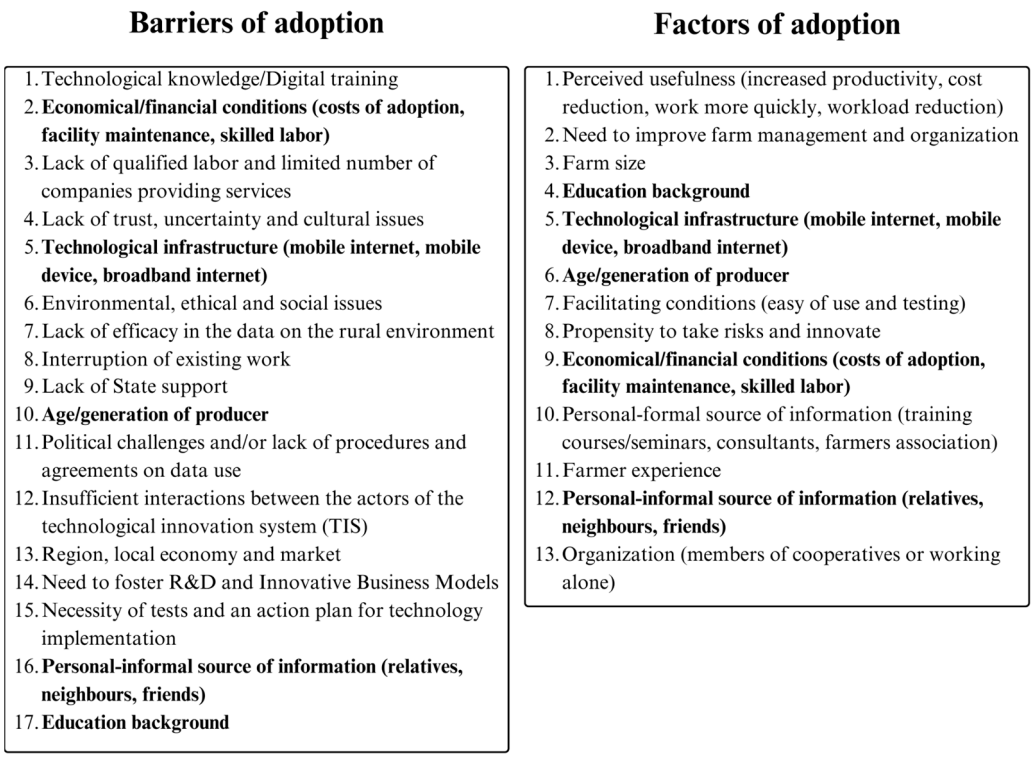

Figure 3. Main barriers and adoption factors for digital agriculture in Latin American countries, derived from bibliometric analysis. Author's elaboration.

For the second point, it is crucial to consider that a solution to any issue is not defined by its sophistication, but rather by its effectiveness in meeting the specific needs of the producer and his community. Therefore, when a given technological solution is not suited to the context and needs of the producer, it creates obstacles to the implementation of other technologies, becoming new barriers to adoption.

Generally speaking, although these findings are relevant for formulating public policies for the sector, it is important to recognize that the sources of information in the studies identified focus on the perspective of the rural producers interviewed and may be subject to a specific bias. In this sense, it is argued that there is a need to use data that is secondary to the methodology adopted by the studies analyzed, such as the development of digital agriculture adoption indicators and the use of official government data.

4.2. Barriers to the Adoption of Digital Technologies in the Context of the Semear Digital Center

As previously indicated, this section will specifically address the barriers to the adoption of digital technologies within the context of the Semear Digital Center. Among the Center's primary objectives are as follows:

- To map and select production chains that require digital solutions in various areas;
- To develop digital solutions through partnerships;
- To identify connectivity bottlenecks and propose communication solutions;
- To research, develop, and validate enabling technologies for digital solutions;
- To train farmers, agricultural technicians, and consultants on digital technologies through farmer associations, cooperatives, and public and private extension offices.

To achieve these goals, 10 Agro-Technological Districts (DATs) were selected to host the Center, distributed throughout all regions of Brazil. A DAT is a system integrating hardware, software, and connectivity, established in a specific region (generally limited to a single municipality) to address the real needs of farmers. It serves as a model or showcase for technologies and digital services focused on solving farm problems that can be easily adopted and integrated into production processes.

In this context, using a set of indicators related to the available infrastructure, technical assistance, socioeconomic and educational data, 10 DATs were selected, as shown in Figure 4.

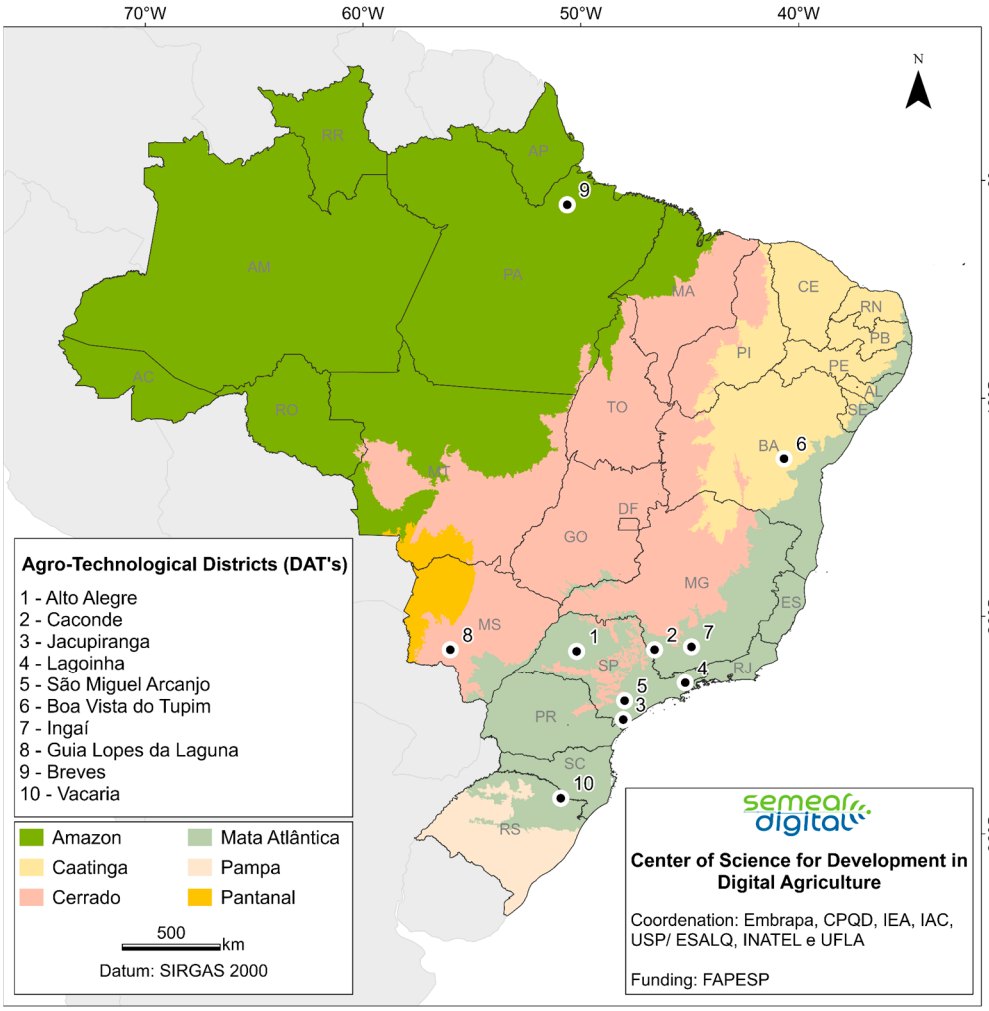

Figure 4. Location of the DATs of the Semear Digital Center in Brazil. Author's elaboration.

Concerning the barriers identified in the baseline Time Zero (T0) assessment (the moment T0 refers to one of the preliminary stages of the project, which aims to identify the rural properties that will be part of the project, as well as to collect data on socioeconomic aspects in the municipality, identify the main productive crops, the profile of the producers, the analysis of value added, the analysis of agricultural income, local governance, the use of digital technologies in the field, and the assessment of rural producers' demands), data are available from nine DATs already visited by the Center's team (Excluding DAT Breves-PA, which has not yet been mapped due to logistical issues.). These barriers are depicted in Appendix A, including the characterization of them.

The comparison of the results reveals that the barriers identified in the bibliometric analysis align with most of those found in the context of the DATs of the Semear Digital

Center. The lack of technological infrastructure, particularly the absence of rural connectivity, stands out as a major obstacle to the adoption of digital technologies. The high costs associated with implementation and maintenance, as well as the shortage of technical training, skilled labor, digital literacy, and collaboration with other stakeholders in the innovation system (such as the lack of industrial investment) are additional challenges.

Age and generation also hinder the adoption of digital agriculture, along with the lack of government support. Specific issues include the absence of public policies, excessive bureaucracy, and limited rural credit for digital transformation. Other barriers were also identified, differing from those in the bibliometric analysis, including the following:

- Land management issues that hinder the implementation of computerized systems, along with a lack of standardized production processes;
- A lack of organization and collaboration among producers, who could share information and technologies;
- An absence of technologies specifically tailored to the needs of rural producers;
- The region's topography, which may hinder the adoption of certain digital technologies;
- Limited access to information, particularly regarding the existence of such technologies;
- Secure land tenure, essential for accessing rural credit and agricultural development projects; and,
- Diversity in production systems and/or a focus on a single crop, as some crops benefit more from digital technologies than others, making it difficult to adapt these technologies to other crops.

Figure 5 summarizes the comparison of barriers identified in both contexts.

More specifically, Figure 6 presents the comparison between the clusters identified in the bibliometric analysis and the results obtained from the empirical analysis of the DATs.

Although not all barriers linked to the bibliometric analysis were identified in the field, other important barriers were added to the analyzed context. In any case, the main barriers to the adoption of digital agriculture refer to those presented in both analyses, addressing technological, economic, political, and social dimensions involved in the adoption of these technologies.

It is worth noting that although the role of the State is important for providing rural credit and implementing public policies capable of encouraging the adoption of these technologies in the countryside, the organization among rural producers also proves to be an important tool for such digital transformation [3].

Besides from that, these mixed-methods approach directly address our research questions:

RQ1: The green and orange clusters (digital divide/localized barriers) map to pervasive adoption challenges (e.g., connectivity), while blue (IoT) highlights drivers like irrigation efficiency (aligned with Chile's LoRa successes [26]).

RQ2: Divergences—such as land tenure (absent in clusters but critical in DATs)—underscore how bibliometric trends may overlook contextual realities, necessitating empirical validation.

BARRIERS OF ADOPTION	BIBLIOMETRIC ANALYSIS	EMPIRICAL RESEARCH
SOCIOECONOMIC BARRIERS		
ECONOMICAL/FINANCIAL CONDITIONS (COSTS OF ADOPTION, FACILITY MAINTENANCE, SKILLED LABOR)	✓	✓
TECHNOLOGICAL KNOWLEDGE/DIGITAL TRAINING/DIGITAL LITERACY	✓	✓
AGE/GENERATION OF PRODUCER	✓	✓
LAND TENURE		✓
EDUCATION BACKGROUND	✓	
REGION, LOCAL ECONOMY AND MARKET	✓	
TECHNICAL BARRIERS		
TECHNOLOGICAL INFRASTRUCTURE (MOBILE INTERNET, MOBILE DEVICE, BROADBAND INTERNET)	✓	✓
LACK OF QUALIFIED LABOR AND LIMITED NUMBER OF COMPANIES PROVIDING SERVICES	✓	✓
INFORMATION ACCESS		✓
TOPOGRAPHIC CHALLENGES		✓
LACK OF TAILORED SOLUTIONS AND STANDARDIZATION	✓	
LACK OF EFFICACY IN THE DATA ON THE RURAL ENVIRONMENT	✓	
NEED TO FOSTER R&D AND INNOVATIVE BUSINESS MODELS	✓	
NECESSITY OF TESTS AND AN ACTION PLAN FOR TECHNOLOGY IMPLEMENTATION	✓	
CULTURAL AND SOCIAL BARRIERS		
LACK OF COLLABORATION AND PRODUCER ORGANIZATIONS		✓
LACK OF TRUST, UNCERTAINTY AND CULTURAL ISSUES	✓	
ENVIRONMENTAL, ETHICAL AND SOCIAL ISSUES	✓	
PERSONAL-INFORMAL SOURCE OF INFORMATION (RELATIVES, NEIGHBORS, FRIENDS)	✓	
MANAGEMENT AND POLICY BARRIERS		
LACK OF STATE SUPPORT	✓	✓
POLITICAL CHALLENGES AND/OR LACK OF PROCEDURES AND AGREEMENTS ON DATA USE	✓	✓
INSUFFICIENT INTERACTIONS BETWEEN THE ACTORS OF THE TECHNOLOGICAL INNOVATION SYSTEM (TIS)	✓	✓
DIVERSE PRODUCTION SYSTEMS AND/OR FOCUS ON A SINGLE CROP		✓
MANAGEMENT CHALLENGES		✓
INTERRUPTION OF EXISTING WORK	✓	

Figure 5. Comparison of barriers to the adoption of digital technologies in agriculture, identified in a bibliometric analysis and the context of DATs at the Semear Digital Center. Author's elaboration.

Cluster	Bibliometric Focus	Barriers (DATs)	Overlap
Red	Climate adaptation, gender inequality in sustainable practices	Low digital literacy (e.g., Ingaí, Jacupiranga) and lack of tailored solutions for diverse crops (e.g., Vacaria's apple-focused adoption)	Gender and generational gaps (e.g., Ingaí's aging farmers) mirror literature gaps in equitable technology access
Green	Rural digital divide	Connectivity deficits (all DATs), high costs (e.g., Lagoinha), and lack of collaboration (e.g., Alto Alegre)	Confirms bibliometric findings on infrastructure as a universal barrier
Blue	IoT for irrigation/monitoring	Topography limits tech adoption (e.g., Jacupiranga), lack of skilled labor (e.g., Caconde)	Field data validates IoT's potential but highlights contextual hurdles (e.g., Chile's LoRa success vs. Brazil's terrain challenges)
Yellow	Tech development vs. resource scarcity	Credit constraints (e.g., Ingaí, São Miguel Arcanjo) and bureaucratic hurdles (e.g., São Miguel Arcanjo)	Reinforces the need for policy innovation to support R&D
Purple	Crop-specific algorithms	Lack of standardized data (e.g., Jacupiranga), single-crop focus (e.g., Vacaria)	ML potential is underutilized due to fragmented production systems
Ciano	Economic/environmental benefits	High costs (all DATs), land tenure insecurity (Jacupiranga)	Efficiency gains are offset by financial and structural barriers
Orange	Localized adoption challenges	Policy gaps (São Miguel Arcanjo), lack of extension services (Guia Lopes da Laguna)	Confirms Brazil's unique mix of infrastructural and governance hurdles
Other details: Validation and Divergence			
Validation: Empirical data from DATs (e.g., connectivity, literacy) aligns with bibliometric clusters (especially green and orange).			
Divergence: • **Bibliometric Gaps:** Land tenure and topography (e.g., Jacupiranga) were underrepresented in literature but critical in fieldwork. • **Empirical Gaps:** Climate topics (red cluster) were less visible in DAT barriers.			

Figure 6. Alignment of bibliometric clusters with empirical barriers (DATs/Semear Digital Center). Author's elaboration.

5. Conclusions

This study analyzed the adoption of digital agricultural technologies in Latin America, focusing on Brazil. The research combined bibliometric analysis of the existing literature with empirical data from Brazil's Semear Digital Center to identify both barriers and drivers of technology adoption in the region. In general, the literature indicated that several challenges and opportunities characterize the transition to digital agriculture. Among the main barriers identified in this study were the lack of technological knowledge and digital literacy on the part of producers, their economic and financial conditions (considering the high costs of installation, maintenance, and hiring skilled labor and management), the lack of qualified labor to operate these technologies, as well as the limited number of companies providing services in this area. In addition to these factors, the lack of reliability, the presence of uncertainties and cultural issues related to the preservation of family traditions, and the lack of technological infrastructure and connectivity, are also highlighted among the main factors hindering the adoption of digital agriculture in Latin American countries, especially in the case of Brazil.

As for the drivers, the most significant emphasis was placed on the perceived usefulness and expectations of the producer when it comes to implementing these digital technologies (especially when it comes to increasing productivity, reducing costs and the workload), as well as the need to improve the management and organization of the property, the technological infrastructure and connectivity available, the size of the property and the educational background of the producer. In both cases, some factors act both as barriers to implementation and as adoption factors, such as economic and financial conditions and the technological infrastructure available.

The barriers identified in the bibliometric analysis are very similar to those observed in the DATs of the Semear Digital Center, especially regarding the technological infrastructure available, the economic factors (high implementation and maintenance costs), the social factors (technical training and digital literacy), and the policy-related factors (lack of public policies, excessive bureaucracy, and limited government support). Major challenges include land management, producer-related factors (lack of organization, collaboration, and access to appropriate technologies), geographic factors (topographical constraints), secure land tenure, and production diversity (related to the challenges in adapting digital technologies to diverse crops).

Four actionable recommendations emerge:

- Digital literacy programs: Partner with cooperatives to deliver localized training, addressing age-related barriers.
- Rural connectivity PPPs: Leverage public–private partnerships to expand connectivity.
- Tailored financial instruments: Develop microloans for smallholders, informed by credit constraints.
- Land tenure formalization: Integrate tenure security with digital adoption policies to unlock credit access.

In light of the findings, in terms of practical recommendations, Latin American policymakers should prioritize investments in rural connectivity, digital literacy training programs, financial support mechanisms, and context-specific technology solutions.

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Appendix A

Table A1. Barriers to adopting digital technologies in DATs (Semear Digital Center). Author's elaboration.

DAT	N. Agricultural Establishments	Production Chains	Biome	Barriers to Adopting Digital Technologies
Alto Alegre (São Paulo)	468	Sugarcane, peanut, banana, corn, watermelon, rubber, and coffee	Atlantic Forest	Connectivity and infrastructure constraints: Limited rural connectivity, and inadequate infrastructure, including electricity and mobile internet. Digital literacy: Low digital literacy among producers. Cost barriers: High equipment and software costs, along with internet connection fees. Lack of collaboration and producer organizations: A demand exists for platforms to share information, negotiate collectively, and access technologies. Management challenges: Producers face difficulties in tracking production costs and income.
Boa Vista do Tupim (Bahia)	2.536	Cassava, tomato, watermelon, corn, beans, and goats	Caatinga	Connectivity and infrastructure constraints: Limited rural connectivity, and inadequate infrastructure, including electricity and cellular networks. Digital literacy: Digital literacy is a critical need for farmers. Lack of collaboration and producer organizations: Producers seek platforms for knowledge sharing, collective bargaining, and technology access.
Caconde (São Paulo)	1.262	Coffee and fish farming (tilapia)	Atlantic Forest	Connectivity and infrastructure constraints: Despite high digital technology adoption for weather forecasting and planning, limited rural connectivity hinders the full potential of digital agriculture. Digital literacy: Farmers require more training in production, management, and marketing to effectively use digital tools. Cost barriers: High costs and complexity limit farmers' access to advanced technologies. Industry investment: Insufficient industry investment in digital agriculture solutions.

Table A1. *Cont.*

DAT	N. Agricultural Establishments	Production Chains	Biome	Barriers to Adopting Digital Technologies
Guia Lopes da Laguna (Mato Grosso do Sul)	672	Soybean, corn, crop-livestock-forest integration, cassava, sugarcane, coconut, tomato, banana, watermelon, sweet potato, and beekeeping	Cerrado	Connectivity and infrastructure constraints: Limited fiber optic infrastructure in rural areas restricts access to high-quality internet. Cost barriers: High deployment costs limit internet service providers' investments in rural areas. Digital literacy: Low digital literacy among small-scale producers. Information access: Limited internet access restricts access to digital resources and tools for farm management. Lack of tailored solutions and standardization: Existing digital solutions often do not meet the specific needs of small-scale farmers.
Ingaí (Minas Gerais)	236	Dairy cattle farming, corn, and soybean	Atlantic Forest	Digital literacy: Low digital literacy among producers. Age and generational gap: The age of producers is a significant challenge to digital agriculture adoption. Skills gap/lack of skilled labor: Producers require specific training to use digital tools and there is a demand for skilled labor. Credit constraints: Limited access to credit hinders technology investments.
Jacupiranga (São Paulo)	505	Banana, heart of palm, cassava, corn, rubber, passion fruit, rice, coconut, sugarcane, guava, and buffalo	Atlantic Forest	Connectivity and infrastructure constraints: While internet coverage is adequate, digital adoption is primarily focused on drone-based spraying, with untapped potential in other areas. Limited roads and electricity restrict technology adoption. Digital literacy: Low digital literacy, especially for invoicing and app usage. Skills gap/lack of skilled labor: Producers require training in crop management, drone operations, and management software. Management challenges: Lack of a centralized database hinders data-driven decision-making. Land tenure: Secure land tenure is essential for accessing credit and development projects. Cost barriers: High production costs and limited credit hinder technology investments. Topographic challenges: Rugged terrain limits technology adoption in certain areas.

Table A1. *Cont.*

DAT	N. Agricultural Establishments	Production Chains	Biome	Barriers to Adopting Digital Technologies
Lagoinha (São Paulo)	257	Corn, dairy cattle farming, cassava, tangerine, tomato, beans, pigs, and laying hens	Atlantic Forest	Connectivity and infrastructure constraints: Uneven fiber optic coverage creates a digital divide. Limited data infrastructure hinders the implementation of advanced digital solutions. Cost barriers: High equipment costs and internet fees limit technology adoption. Digital literacy: Low digital literacy among producers, especially older ones. Skills gap/lack of skilled labor: Producers require training in various areas to effectively use digital tools. Credit constraints: Limited access to credit hinders technology investments. Diverse production systems: The diversity of agricultural activities requires tailored technological solutions. Lack of tailored solutions and standardization: Varied production practices and products hinder large-scale technology implementation.
São Miguel Arcanjo (São Paulo)	1.916	Fruit and vegetable cultivation	Atlantic Forest	Connectivity and infrastructure constraints: Uneven internet coverage limits digital access. Lack of infrastructure limits agricultural development and technology use. Digital literacy: Low digital literacy among producers is a major barrier. Cost barriers: High costs of technology hinder adoption. Bureaucratic hurdles and policy gaps: Complex regulations hinder production and marketing. Insufficient government support discourages technology adoption. Lack of collaboration and producer organizations: Individualism limits negotiation and resource access. Credit constraints: Limited access to credit hinders investments.
Vacaria (Rio Grande do Sul)	1.039	Apple, grape, blackberry, blueberry, soybean, corn, wheat, potato, oats, barley, beans, onion, tomato, pear, peach, orange, tangerine, cassava, persimmon, and sweet potato	Atlantic Forest	Connectivity and infrastructure constraints: Limited connectivity hinders digital tool access and data collection. Focus on a single crop: The apple chain is a leading adopter of digital technologies, but other crops lag. Digital literacy: Low digital literacy among small-scale producers. Skills gap/lack of skilled labor: Producers require training in various areas to effectively use digital tools. Cost barriers: High equipment costs and internet fees limit technology adoption.

References

1. Massruhá, S.M.F.S.; Leite, M.A.A.; Luchiari, A., Jr.; Evangelista, S.R.M. Digital transformation in the field towards sustainable and smart agriculture. In *Digital Agriculture: Research, Development and Innovation in Production Chains*; Massruhá, S.M.F.S., Leite, M.A.A., Oliveira, S.R.M., Meira, C.A.A., Luchiari, A., Jr., Bolfe, E.L., Eds.; Embrapa: Brasília, Brazil, 2023; pp. 17–35.
2. Da Silveira, F.D.; Silva, S.L.C.D.; Machado, F.M.; Barbedo, J.G.A.; Amaral, F.G. Agriculture 4.0 and its Barriers in the Agricultural Production Chain Development in Southern Brazil. *SSRN* **2022**, 4229367. [CrossRef]

3. Dibbern, T.; Romani, L.A.S.; Massruhá, S.M.F.S. Main drivers and barriers to the adoption of Digital Agriculture technologies. *Smart Agric. Technol.* **2024**, *8*, 100459. [CrossRef]
4. Pauschinger, D.; Klauser, F.R. The introduction of digital technologies into agriculture: Space, materiality and the public–private interacting forms of authority and expertise. *J. Rural. Stud.* **2022**, *91*, 217–227. [CrossRef]
5. Gebresenbet, G.; Bosona, T.; Patterson, D.; Persson, H.; Fischer, B.; Mandaluniz, N.; Chirici, G.; Zacepins, A.; Komasilovs, V.; Pitulac, T.; et al. A concept for application of integrated digital technologies to enhance future smart agricultural systems. *Smart Agric. Technol.* **2023**, *5*, 100255. [CrossRef]
6. Soma, T.; Nuckchady, B. Communicating the benefits and risks of digital agriculture technologies: Perspectives on the future of digital agricultural education and training. *Front. Commun.* **2021**, *6*, 762201. [CrossRef]
7. ITU; FAO. *Status of Digital Agriculture in 18 Countries of Europe and Central Asia*; ITU: Geneva, Switzerland, 2020.
8. Lasi, H.; Fettke, P.; Kemper, H.G.; Feld, T.; Hoffmann, M. Industry 4.0. *Bus. Inf. Syst. Eng.* **2014**, *6*, 239–242. [CrossRef]
9. De Souza, K.X.S.; Oliveira, S.R.M.; Macário, C.G.N.; Esquerdo, J.C.D.M.; Moura, M.F.; Leite, M.A.A.; de Lima, H.P.; de Castro, A.; Ternes, S.; Yano, I.H.; et al. Digital agriculture: Definitions and technologies. In *Digital Agriculture: Research, Development and Innovation in Production Chains*; Massruhá, S.M.F.S., Leite, M.A.A., Oliveira, S.R.M., Meira, C.A.A., Luchiari, A., Jr., Bolfe, E.L., Eds.; Embrapa: Brasília, Brazil, 2023; pp. 37–50.
10. Massruhá, S.M.F.S.; Leite, M.A.A. Agricultura digital. *Rev. Eletrônica Competências Digit. Agric. Fam.* **2016**, *2*, 72–88.
11. Shepherd, M.; Turner, J.A.; Small, B.; Wheeler, D. Priorities for science to overcome hurdles thwarting the full promise of the 'digital agriculture' revolution. *J. Sci. Food Agric.* **2020**, *100*, 5083–5092. [CrossRef]
12. Bolfe, E.L.; Massruhá, S.M.F.S. A transformação digital e a sustentabilidade agrícola. *Agroanalysis* **2020**, *40*, 32–34.
13. Bolfe, E.L.; Jorge, L.A.D.C.; Sanches, I.D.A.; Luchiari, A., Jr.; da Costa, C.C.; Victoria, D.D.C.; Inamasu, R.Y.; Grego, C.R.; Ferreira, V.R.; Ramirez, A.R. Precision and digital agriculture: Adoption of technologies and perception of Brazilian farmers. *Agriculture* **2020**, *10*, 653. [CrossRef]
14. Schroeder, K.; Lampietti, J.; Elabed, G. *What's Cooking: Digital Transformation of the Agrifood System*; Agriculture and Food Series; World Bank: Washington, DC, USA, 2021. [CrossRef]
15. Caffaro, F.; Cavallo, E. Perceived Barriers to the Adoption of Smart Farming Technologies in Piedmont Region, Northwestern Italy: The Role of User and Farm Variables. In *Innovative Biosystems Engineering for Sustainable Agriculture, Forestry and Food Production: International Mid-Term Conference 2019 of the Italian Association of Agricultural Engineering (AIIA)*; Springer International Publishing: Berlin/Heidelberg, Germany, 2020; pp. 681–689.
16. Caffaro, F.; Cremasco, M.M.; Roccato, M.; Cavallo, E. Drivers of farmers' intention to adopt technological innovations in Italy: The role of information sources, perceived usefulness, and perceived ease of use. *J. Rural. Stud.* **2020**, *76*, 264–271. [CrossRef]
17. Da Silveira, F.; Barbedo, J.G.A.; da Silva, S.L.C.; Amaral, F.G. Proposal for a framework to manage the barriers that hinder the development of agriculture 4.0 in the agricultural production chain. *Comput. Electron. Agric.* **2023**, *214*, 108281. [CrossRef]
18. Van Eck, N.J.; Waltman, L. Visualizing bibliometric networks. In *Measuring Scholarly Impact: Methods and Practice*; Ding, Y., Rousseau, R., Wolfram, D., Eds.; Springer International Publishing: New York, NY, USA, 2014; pp. 285–320. [CrossRef]
19. Waltman, L.; Van Eck, N.J.; Noyons, E.C. A unified approach to mapping and clustering of bibliometric networks. *J. Informetr.* **2010**, *4*, 629–635. [CrossRef]
20. Acosta, M.; Riley, S.; Bonilla-Findji, O.; Martínez-Barón, D.; Howland, F.; Huyer, S.; Castellanos, A.; Martínez, J.; Chanana, N. Exploring women's differentiated access to climate-smart agricultural interventions in selected climate-smart villages of Latin America. *Sustainability* **2021**, *13*, 10951. [CrossRef]
21. Mosso, C.; Pons, D.; Beza-Beza, C. A Long Way toward Climate Smart Agriculture: The Importance of Addressing Gender Inequity in the Agricultural Sector of Guatemala. *Land* **2022**, *11*, 1268. [CrossRef]
22. Engås, K.G.; Raja, J.Z.; Neufang, I.F. Decoding technological frames: An exploratory study of access to and meaningful engagement with digital technologies in agriculture. *Technol. Forecast. Soc. Chang.* **2023**, *190*, 122405. [CrossRef]
23. Florez, M.; Melo, J.; Bourdon, I.; Piot-Lepetit, I.; Gauche, K. Digital Divide between Colombian and French Agriculture. In Proceedings of the 27th Americas Conference on Information Systems (AMCIS 2021), Online Conference, 9–13 August 2021.
24. Chacho, P.; Maza, J.; Icaza, D.; Arias, P.; Diaz, J.; Amón, X.; Sumba, N.; Pallmay, C.; Coyago, C.; Rivera, P. Wireless system for the control and real time monitoring of agricultural areas of Arenillas canton in Ecuador. In Proceedings of the 2019 IEEE CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON), Valparaiso, Chile, 13–27 November 2019; IEEE: Piscataway, NJ, USA, 2019; pp. 1–8.
25. Collado, E.; Fossatti, A.; Saez, Y. Smart farming: A potential solution towards a modern and sustainable agriculture in Panama. *AIMS Agric. Food* **2018**, *4*, 266–284. [CrossRef]
26. Ahmed, M.A.; Gallardo, J.L.; Zuniga, M.D.; Pedraza, M.A.; Carvajal, G.; Jara, N.; Carvajal, R. LoRa based IoT platform for remote monitoring of large-scale agriculture farms in Chile. *Sensors* **2022**, *22*, 2824. [CrossRef]
27. Ramírez, E.A.C.; Albarrán, J.C.; Mora, L.E.M.; Hernández, M.Y. Agro 4.0:¿ Una posibilidad de mejora en el campo venezolano o una solución para la agricultura en Venezuela? *Rev. Agroaliment.* **2022**, *28*, 213–229. [CrossRef]

28. Fernandes, A.D.N.M.; Barros, M.A.D.C.; Hamatsu, N.K. Trend of Technologies 4.0 in Brazil-what does the demand about the Public Selection MCTI/FINEP/FNDCT Grant to Innovation 04/2020 tell us? *Rev. Cienc. Agron.* **2021**, *51*, 1–12. [CrossRef]
29. Pivoto, D.; Barham, B.; Waquil, P.D.; Foguesatto, C.R.; Corte, V.F.D.; Zhang, D.; Talamini, E. Factors influencing the adoption of smart farming by Brazilian grain farmers. *Int. Food Agribus. Manag. Rev.* **2019**, *22*, 571–588. [CrossRef]
30. De Macedo, M.M.G.; Mattos, A.B.; Oliveira, D.A.B. Generalization of convolutional LSTM models for crop area estimation. *IEEE J. Sel. Top. Appl. Earth Obs. Remote Sens.* **2020**, *13*, 1134–1142. [CrossRef]
31. Smith, H.W.; Ashworth, A.J.; Nalley, L.L.; Schmidt, A.; Turmel, M.S.; Bucaro, A.; Owens, P.R. Boundary line analysis and machine learning models to identify critical soil values for major crops in Guatemala. *Agron. J.* **2023**, *116*, 1071–1087. [CrossRef]
32. Carrer, M.J.; de Souza Filho, H.M.; Vinholis, M.D.M.B.; Mozambani, C.I. Precision agriculture adoption and technical efficiency: An analysis of sugarcane farms in Brazil. *Technol. Forecast. Soc. Chang.* **2022**, *177*, 121510. [CrossRef]
33. Puntel, L.A.; Bolfe, E.L.; Melchiori, R.J.M.; Ortega, R.; Tiscornia, G.; Roel, A.; Scaramuzza, F.; Best, S.; Berger, A.G.; Hansel, D.S.S.; et al. How digital is agriculture in a subset of countries from South America? Adoption and limitations. *Crop. Pasture Sci.* **2022**, *74*, 555–572. [CrossRef]
34. Boisier, G.; Hahn, K.; Geldes, C.; Klerkx, L. Unpacking the Precision Technologies for Adaptation of the Chilean Dairy Sector. A Structural-functional Innovation System Analysis. *J. Technol. Manag. Innov.* **2021**, *16*, 56–66. [CrossRef]
35. Kolling, C.E.; Rampim, L. Agricultura de precisão e digital: Perspectivas e desafios dos produtores rurais do estado do paraná. *Uningá Rev.* **2021**, *36*, eUJR3981. [CrossRef]
36. Da Silveira, F.; da Silva, S.L.C.; Machado, F.M.; Barbedo, J.G.A.; Amaral, F.G. Farmers' perception of barriers that difficult the implementation of agriculture 4.0. *Agric. Syst.* **2023**, *208*, 103656. [CrossRef]
37. Flores, J.A.E.; Montes-Rivera, F.Y.; Valdivia-Alcalá, R.; Cruz-Betanzos, A. Agriculture 4.0: Is Mexico Ready? *Agro Prod.* **2023**, *4*, 91–106. [CrossRef]
38. Mendes, V.; Viola, E. Green Digitalization? Agriculture 4.0 and the Challenges of Environmental Governance in Brazil. In *Sustainability Challenges of Brazilian Agriculture: Governance, Inclusion, and Innovation*; Springer International Publishing: Cham, Switzerland, 2023; pp. 207–226.
39. De Souza Filho, H.M.; Buainain, A.M.; da Silveira, J.M.F.J.; Vinholis, M.D.M.B. Condicionantes da adoção de inovações tecnológicas na agricultura. *Cad. Ciênc. Tecnol.* **2011**, *28*, 223–255.
40. Strong, R.; Wynn, J.T.; Lindner, J.R.; Palmer, K. Evaluating Brazilian agriculturalists' IoT smart agriculture adoption barriers: Understanding stakeholder salience prior to launching an innovation. *Sensors* **2022**, *22*, 6833. [CrossRef] [PubMed]